Ministry for Primary Industries
Manatū Ahu Matua

Aquatic Environment and Biodiversity Annual Review 2014

A summary of environmental interactions between the seafood sector and the aquatic environment

Growing and Protecting New Zealand

MINISTRY FOR PRIMARY INDUSTRIES

AQUATIC ENVIRONMENT AND BIODIVERSITY ANNUAL REVIEW

(2014)

FISHERIES MANAGEMENT SCIENCE TEAM

ACKNOWLEDGEMENTS

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DISCLAIMER

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PREFACE

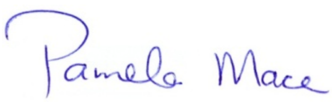
This, the 2014 edition of the Aquatic Environment and Biodiversity Annual Review, expands and updates previous editions. It summarises information on a range of issues related to the environmental effects of fishing and aspects of marine biodiversity and productivity relevant to fish and fisheries. This review is a conceptual analogue of the Ministry's annual reports from the Fisheries Assessment Plenary. It summarises the most recent data and analyses on particular aquatic environment issues and, where appropriate, assesses current status against any specified targets or limits. Whereas the reports from the Fisheries Assessment Plenary are organised by fishstock, the Aquatic Environment and Biodiversity Annual Review is organised by issue (e.g. protected species bycatch, benthic impacts), and almost all issues involve more than one fishstock or fishery.

Several Fisheries Assessment Working Groups (FAWGs) contribute to the Fisheries Assessment Plenary, but only two generally contribute to the Aquatic Environment and Biodiversity Annual Review. These are the Aquatic Environment Working Group (AEWG) and the Biodiversity Research Advisory Group (BRAG). A wide variety of research is summarised in the Aquatic Environment and Biodiversity Annual Review, and some of this is peer-reviewed through processes other than the Ministry's science working groups. In particular, the Department of Conservation funds and reviews research on protected species, and the Ministry of Business, Innovation and Employment funds a wide variety of research, some of which is relevant to fisheries. Where such research is relevant to fisheries it will be considered for inclusion in the review.

Continual future expansion and improvement of this review is anticipated and additional chapters will be developed to provide increasingly comprehensive coverage of the issues. A new chapter is included this year for trophic interactions relevant to fisheries, and the appendix summarising aquatic environment and marine biodiversity research since 1998 has been updated. Data acquisition, modelling, and assessment techniques will also progressively improve, and it is expected that reference points to guide fisheries management decisions will be developed. Both will lead to changes to the current chapters. We hope the condensation in this review of the information from previously scattered reports will assist fisheries managers, stakeholders and other interested parties to understand the issues, locate relevant documents, track research progress and make informed decisions.

This revision has been led by the Science Group within the Directorate of Fisheries Management of the Ministry for Primary Industries (primarily Martin Cryer, Rohan Currey, Adele Dutilloy, Rich Ford, Mary Livingston, and Nathan Walker) but has relied critically on the input of members of the AEWG and BRAG, as well as the Department of Conservation's Conservation Services Technical Working Group. I would especially like to recognise and thank the large number of research providers and scientists from research organisations, academia, the seafood industry, environmental NGOs, Māori customary, DOC and MPI, along with all other technical and non-technical participants in present and past AEWG and BRAG meetings for their substantial contributions to this review. My sincere thanks to each and all who have contributed.

I am pleased to endorse this document as representing the best available scientific information relevant to those aspects of the environmental effects of fishing and marine biodiversity covered, as at December 2014.



Pamela Mace
Principal Advisor Fisheries Science
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1 INTRODUCTION

1.1 CONTEXT AND PURPOSE

This document contains a summary of information and research on aquatic environment issues relevant to the management of New Zealand fisheries. It is designed to complement the Ministry's annual Reports from Fisheries Assessment Plenaries (e.g., the November Plenary, MPI 2014b, and the May plenary, MPI 2014a) and emulate those documents' dual role in providing an authoritative summary of current understanding and an assessment of status relative to any overall targets and limits. However, whereas the Reports from Fisheries Assessment Plenaries have a focus on individual fishstocks, this report has a focus on aquatic environment fisheries management issues and biodiversity responsibilities that often cut across many fishstocks, fisheries, or activities, and sometimes across the responsibilities of multiple agencies.

This update has been developed by the Science Team within the Fisheries Management Directorate of the Regulation and Assurance branch, Ministry for Primary Industries (MPI). It does not cover all issues but, as anticipated, includes more chapters than previous editions. As with the Reports from Fisheries Assessment Plenaries, it is expected to change and grow as new information becomes available, more issues are considered, and as feedback and ideas are received. This synopsis has a broad, national focus on each issue and the general approach has been to avoid too much detail at a local, fishery, or fishstock level. For instance, the benthic (seabed) effects of mobile bottom-fishing methods are dealt with at the level of all bottom trawl and dredge fisheries combined rather than at the level of a target fishery that, although it might be locally important, might contribute only a small proportion of the total impact. The details of benthic impacts by individual fisheries will be documented in the respective chapters in the May or November Report from the Fisheries Assessment Plenary, and linked there to the fine detail and analysis in Aquatic Environment and Biodiversity Reports (AEBRs), Fisheries Assessment Reports (FARs), and Final Research Reports (FRRs). Such sections have already been developed for several species in the Fishery Assessment Plenary Reports, and others will follow.

The first part of this document describes the legislative and broad policy context for aquatic environment and biodiversity research commissioned by MPI, and the science processes used to generate and review that research. The second, and main, part of the document contains chapters focused on various aquatic environment issues for fisheries management. Those chapters are divided into five broad themes: protected species; non-QMS (mostly fish) bycatch; benthic effects; ecosystem issues (including New Zealand's oceanic setting); and marine biodiversity. A third part of the review includes a number of appendices for reference. This review is not yet comprehensive in its coverage of all issues or of all research within each issue, but attempts to summarise the best available information on the issues covered. Each chapter has been considered by the appropriate working group at least once.

1.2 LEGISLATION

The primary legislation for the management of fisheries, including effects on the aquatic environment, is the Fisheries Act 1996. The main sections setting out the obligation to avoid, remedy, or mitigate any adverse effect of fishing on the aquatic environment are sections 8, 9, and 15, although sections 10, 11, and 13 are also relevant to decision-making under this Act (Table 1.1). The Ministry also administers the residual parts of the Fisheries Act 1983, the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992, the Fisheries (Quota Operations Validation) Act 1997, the Maori Fisheries Act 2004, the Maori Commercial Aquaculture Claims Settlement Act 2004, the Aquaculture Reform (Repeals and Transitional Provisions) Act 2004, the Driftnet Prohibition Act 1991, and the Antarctic Marine Living Resources Act 1981. Other Acts are relevant in specific circumstances: the Wildlife Act 1953 and the Marine Mammals Protection Act 1978 for protected species; the Marine Reserves Act 1971 for "no take" marine reserves; the Conservation Act 1987; the Hauraki Gulf Marine Park Act 2000; the Resource Management Act 1991 for issues in coastal marine areas that could affect fisheries interests or be the subject of sustainability measures under section 11 of the Fisheries Act; and the

Table 1.1: Sections of the Fisheries Act 1996 relevant to the management of the effects of fishing on the aquatic environment.

Fisheries Act 1996
s8 Purpose – (1) The purpose of this Act is to provide for the utilisation of fisheries resources while ensuring sustainability, where (2) "Ensuring sustainability" means – (a) Maintaining the potential of fisheries resources to meet the reasonably foreseeable needs of future generations: and (b) Avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment: "Utilisation" means conserving, using, enhancing, and developing fisheries resources to enable people to provide for their social, economic, and cultural well-being. s9 Environmental Principles. associated or dependent species should be maintained above a level that ensures their long-term viability; biological diversity of the aquatic environment should be maintained: habitat of particular significance for fisheries management should be protected. **s11 Sustainability Measures.** The Minister may take into account, in setting any sustainability measure, (a) any effects of fishing on any stock and the aquatic environment; **s15 Fishing-related mortality of marine mammals or other wildlife.** A range of management considerations are set out in the Fisheries Act 1996, which empower the Minister to take measures to avoid, remedy or mitigate any adverse effects of fishing on associated or dependent species and any effect of fishing-related mortality on any protected species. These measures include the setting of catch limits or the prohibition of fishing methods or all fishing in an area, to ensure that such catch limits are not exceeded.

Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 for issues outside the Territorial Sea. These Acts are administered by other agencies and this leads to a requirement for the Ministry for Primary Industries to work with other government departments (especially the Department of Conservation and through the Natural Resource Sector[1]) and with various territorial authorities (especially Regional Councils) to a greater extent than is required for most fisheries stock assessment issues.

Under the primary legislation lie various layers of Regulations and Orders in Council (see http://www.legislation.govt.nz/). It is beyond the scope of this document to summarise these.

[1] The Natural Resources Sector is a network of government agencies established to enhance collaboration. Its main purpose is to ensure a strategic, integrated and aligned approach is taken to natural resources development and management across government agencies. The network is chaired by MfE's Chief Executive. The Sector aims to provide high-quality advice to government and provide effective implementation and execution of major government policies through coordination and integration across agencies, management of relationships, and alignment of the policies and practices of individual agencies.

In addition to its domestic legislation, the New Zealand government is a signatory to a wide variety of International Instruments and Agreements that bring with them various International Obligations (Table 1.2). Section 5 of the Fisheries Act requires that the Act be interpreted in a manner that is consistent with international obligations and with the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992.

1.3 POLICY SETTING

1.3.1 OUR STRATEGY 2030 AND MPI'S STATEMENT OF INTENT 2014/19

The Ministry for Primary Industries is the principal adviser to the Government on agriculture, horticulture, aquaculture, fisheries, forestry, and food industries, animal welfare, and the protection of New Zealand's primary industries from biological risk. MPI's Statement of Intent, SOI, is an important guiding document for the short to medium term. That for 2014–19 is available on the Ministry's website at:

http://www.mpi.govt.nz/document-vault/3342

Table 1.2: International agreements and regional agreements to which New Zealand is a signatory, that are relevant to the management of the effects of fishing on the aquatic environment.

International Instruments	Regional Fisheries Agreements
• **Convention on the Conservation of Migratory Species of Wild Animals (CMS).** Aims to conserve terrestrial, marine and avian migratory species throughout their range. • **Agreement on the Conservation of Albatrosses and Petrels (ACAP).** Aims to introduce a number of conservation measures to reduce the threat of extinction to the Albatross and Petrel species. • **Convention on Biological Diversity (CBD)** Provides for conservation of biological diversity and sustainable use of components. States accorded the right to exploit resources pursuant to environmental policies. • **United Nations Convention on the Law of the Sea (UNCLOS)** Acknowledges the right to explore and exploit, conserve and manage natural resources in the State's EEZ…with regard to the protection and preservation of the marine environment including associated and dependent species, pursuant to the State's environmental policies. • **Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES).** Aims to ensure that international trade in wild animals and plants does not threaten their survival. • **United Nations Fishstocks Agreements.** Aims to lay down a comprehensive regime for the conservation and management of straddling and highly migratory fish stocks. • **International Whaling Commission (IWC)** Aims to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry. • **Wellington Convention** Aims to prohibit drift net fishing activity in the convention area. • **Food and Agriculture Organisation – International Plan of Action for Seabirds (FAO-IPOA Seabirds)** Voluntary framework for reducing the incidental catch of seabirds in longline fisheries. • **Food and Agriculture Organisation – International Plan of Action for Sharks (FAO –IPOA Sharks)** Voluntary framework for the conservation and management of sharks. • **Noumea Convention.** Promotes protection and management of natural resources. Parties to regulate or prohibit activity likely to have adverse effects on species, ecosystems and biological processes. • **Food and Agriculture Organisation - Code of Conduct for Responsible Fisheries** Provides principles and standards applicable to the conservation, management and development of all fisheries, to be interpreted and applied to conform to the rights, jurisdiction and duties of Sates contained in UNCLOS.	• **Convention for the Conservation of Southern Bluefin Tuna (CCSBT)** Aims to ensure, through appropriate management, the conservation and optimum utilisation of the global Southern Bluefin Tuna fishery. The Convention specifically provides for the exchange of data on ecologically related species to aid in the conservation of these species when fishing for southern bluefin tuna. • **Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).** Aims to conserve, including rational use of Antarctic marine living resources. This includes supporting research to understand the effects of CCAMLR fishing on associated and dependent species, and monitoring levels of incidental take of these species on New Zealand vessels fishing in CCAMLR waters. • **Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (WCPFC).** The objective is to ensure, through effective management, the long-term conservation and sustainable use of highly migratory fish stocks in accordance with UNCLOS. • **South Tasman Rise Orange Roughy Arrangement.** The arrangement puts in place the requirement for New Zealand and Australian fishers to have approval from the appropriate authorities to trawl or carry out other demersal fishing for any species in the STR area • **Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean** (a Regional Fisheries Management Organisation, colloquially **SPRFMO**) has recently been negotiated to facilitate management of non-highly migratory species in the South Pacific.

The SOI sets out the Ministry's strategic direction for the coming 5 years, primarily through implementation of *Our Strategy 2030* (Appendix 16.7). This strategy was agreed by Cabinet in August 2011 and sets out MPI's vision of "growing and protecting New Zealand" and defines the focus and overall approach of the organisation. The strategy includes four focus areas and outcomes: maximising export opportunities; improving sector productivity; increasing sustainable resource use; and protecting from biological risk. MPI is conducting a review of its strategic intentions and priorities at present. The overarching vision the four outcomes which support this will not change, but a more specific set of organisational priorities is being developed and will be included in the next 4-year Plan and the 2015–20 SOI.

Aspects of the role specific to fisheries in the SOI include supporting the understanding of sustainable limits to natural resource use as part of Medium-Term Objective 5 *The primary sector, including Māori, maximises the use and productivity of natural resources within environmentally sustainable limits and is resilient to adverse climatic and biosecurity events*. The SOI notes that the primary industries are reliant on natural resources to provide significant economic benefits to New Zealand. How we all use and manage these natural resources affects New Zealand's future prosperity and the natural capital that underpins New Zealand's production systems. Increases in economic performance need to be consistent with sustaining natural capital over the long term, to achieve lasting economic prosperity. To maintain productivity over time, New Zealand's primary industries must also be resilient to change, including to a changing climate and biosecurity events.

Another important role is supporting third-party certification of fisheries by, for example, the Marine Stewardship Council as part of Medium-Term Objective 1 *Export success is enhanced by the integrity of primary sector products and increasing the use of New Zealand's unique culture and brand*. The SOI notes that New Zealand's export sectors derive significant benefits (including lower market access costs) and competitive advantage from New Zealand's reputation for safe and suitable food, favourable animal and plant health status and market assurances. To leverage these advantages, MPI needs new ways of assisting New Zealand exporters to access and succeed in international markets and gain additional export value from the New Zealand brand, including its Māori dimension.

To provide relevant information to fulfil these roles, MPI contracts the following types of research (relevant to this document):

- aquatic environment research to assess the effects of fishing on marine habitats, protected species, trophic linkages, and to understand habitats of special significance for fisheries;
- marine biodiversity and productivity research to increase our understanding of the systems that support resilient ecosystems and productive fisheries.

1.3.2 FISHERIES 2030

New Zealand's Quota Management System (QMS) forms the overall framework for management of domestic fisheries (see http://www.fish.govt.nz/en-nz/Commercial/Quota+Management+System/default.htm). Within that framework, Fisheries 2030 provides a long-term goal for the New Zealand fisheries sector. After endorsement by Cabinet, it was released by the Minister of Fisheries in September 2009. It can be found on the MPI website at:

http://www.fish.govt.nz/en-nz/Fisheries+2030/default.htm?wbc_purpose=bas

(*noting that the Ministry of Fisheries merged with the Ministry of Agriculture and Forestry on 1 July 2011 and became the Ministry for Primary Industries on 30 April 2012. This URL and other links in this document have been checked for this edition, but will eventually change as MPI's systems are progressively developed*).

Fisheries 2030 sets out a goal to have *New Zealanders maximising benefits from the use of fisheries within environmental limits*. To support this goal, major outcomes for Use (of fisheries) and Environment are specified. The Environment outcome is the main driver for aquatic environment research: *The capacity and integrity of the aquatic environment, habitats and species are sustained at levels that provide for current and future use*. Fisheries 2030 states that this means:

- Biodiversity and the function of ecological systems, including trophic linkages, are conserved
- Habitats of special significance to fisheries are protected
- Adverse effects on protected species are reduced or avoided
- Impacts, including cumulative impacts, of activities on land, air or water on aquatic ecosystems are addressed.

1.3.3 FISHERIES PLANS

Fisheries planning processes for deepwater, highly migratory species, inshore finfish, inshore shellfish and freshwater fisheries use objective-based management to drive the delivery of services, as described in Fisheries 2030 and affirmed in the SOI and Our Strategy 2030. The planning processes are guided by five National Fisheries Plans, which recognise the distinctive characteristics of these fisheries. Plans for Deepwater and Highly Migratory species were approved by the Minister in September 2010 and a suite of three plans for inshore species was released in prototype form in July 2011. These plans establish management objectives for each fishery, including those related to the environmental effects of fishing. All are available on the Ministry's websites.

Deepwater and middle depth fisheries:
http://www.fish.govt.nz/en-nz/Consultations/Archive/2010/National+Fisheries+Plan+for+Deepwater+and+Middle-Depth+Fisheries/default.htm

Highly migratory species (HMS) fisheries:
http://www.fish.govt.nz/en-nz/Consultations/Archive/2010/National+Fisheries+Plan+for+Highly+Migratory+Species/default.htm

Inshore fisheries (comprising finfish, shellfish, and freshwater fisheries):
http://www.fish.govt.nz/en-nz/Fisheries+Planning/default.htm

These pages are being progressively updated and consolidated and some more recent documents have been made available at MPI's publications page at:
http://www.mpi.govt.nz/news-and-resources/publications/.

Certain research areas (aquatic environment, marine amateur fisheries, and marine biodiversity and productivity) are not covered by fisheries plans or span multiple fisheries and plans. Antarctic and other international fisheries research is also excluded from fish plans as it is beyond their spatial scope. These areas are administered by the science team and subject to the general drivers in Table 1.1, Table 1.2 and Fisheries 2030, or by more specific objectives in, for example, National Plans of Action (NPOAs, for seabirds and sharks) or Threat Management Plans (TPMs, for sea lions and Māui/Hector's dolphins).

1.3.4 OTHER STRATEGIC DOCUMENTS

A number of strategies or reviews have been published that potentially affect fisheries values and research. These include: the New Zealand Biodiversity Strategy (2000, currently being refreshed and updated by DOC); the Biosecurity Strategy (2003, followed by its science strategy 2007); the MPA Policy and Implementation Plan (2005); MfE's discussion paper on Management of Activities in the EEZ (2007, now translated to the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012); MRST's Roadmap for Environment Research (2007); the Revised Coastal Policy Statement (2010); the National Plan of Action to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries (2004, revised and updated by MPI in 2013); and the New Zealand National Plan of Action for the Conservation and Management of Sharks (2008, a revision is currently under consultation). Links to these documents are provided in Appendix 16.8 because they provide some of the broad policy setting for aquatic environment issues and research across multiple organisations and agencies.

In 2012, the Natural Resource Sector cluster formed a Marine Director's Group to improve data sharing and information exchange across key agencies with marine environmental responsibilities, particularly MPI, DOC, MfE, EPA, LINZ, MBIE. The Marine Director's Group is chaired by MPI and DOC and a substantial amount of cross-agency work has been initiated to: summarise relevant marine information held by different agencies and current marine research investment; identify knowledge and funding gaps; and to develop a long-term Marine Research Strategy for New Zealand (this document is in an advanced stage of drafting).

1.4 SCIENCE PROCESSES

1.4.1 RESEARCH PLANNING

Until 2010 the Ministry of Fisheries ran an iterative planning process to determine, in conjunction with stakeholders and subject to government policy, the future directions and priorities for fisheries research. Subsequently, the Ministry has adopted an overall approach of specifying objectives for fisheries in Fisheries Plans and using these plans to develop associated implementation strategies and required services, including research. These services are identified in Annual Operational Plans that are updated each year.

For deepwater fisheries and highly migratory stocks (HMS), the transition to the new research planning approach is well advanced because fisheries plans for these areas have been approved by the Minister. Research for these fisheries are already being developed using Fisheries Plan and Annual Operating Plan processes as primary drivers, and, as necessary, Research Advisory Groups (RAGs) to develop the technical detail of particular projects. The Ministry's website contains more information on this approach, developed during the Research Services Strategy Review, at: http://www.fish.govt.nz/NR/rdonlyres/04D579E5-6DCC-42A6-BF68-9CAB800D6392/0/Research_Services_Strategy_Review_Report.pdf (see Section 5.2, pages 14 to 21) and in summary at:http://www.fish.govt.nz/NR/rdonlyres/432EA3A0-AEA7-41DD-8E5C-D0DCA9A3B96B/0/RSS_letter.pdf. Generic terms of reference for Research Advisory Groups are in Appendix 16.5. For inshore fisheries, the three Fisheries Plans (inshore finfish, shellfish, and freshwater) are still under development, so a transitional research planning process was established for 2010 and developed slightly in 2011. This included the following steps:

- Identification of the main management information needs using:
  - Fisheries Plans or Fisheries Operational Plans where available
  - Any relevant Medium Term Research Plan
  - Fishery managers' understanding of decisions likely to require research information in the next 1–3 years.
- Technical discussions as required (i.e., tailored to the needs of the different research areas) to consider:
  - The feasibility and utility of each project
  - The likely cost of each project
  - Any synergies or overlaps with work being conducted by other providers (including industry, CRIs, MBIE, Universities, etc.)
- Stakeholder meetings as required to discuss relative priorities for particular projects

The process for aquatic environment research (other than aspects driven by the specific needs of fishery managers, including services specified in fisheries planning documents) followed essentially these same steps, working particularly closely with the Department of Conservation (DOC) on protected species issues.

The Ministry runs a separate planning group to design and prioritise its research programme on marine biodiversity. Given its much broader and more strategic focus, the Biodiversity Research Advisory Group (BRAG) has both peer review and planning roles and therefore differs slightly in constitution from the Ministry's other working and planning groups.

1.4.2 CONTRIBUTING WORKING GROUPS

The main contributing working groups for this document are the Ministry's Aquatic Environment Working Group (AEWG) and Biodiversity Research Advisory Group (BRAG). The Department of Conservation's Conservation Services Programme and National Plan of Action Seabirds Technical Working Group (CSP/NPOA-TWG, see http://www.doc.govt.nz/conservation/marine-and-coastal/commercial-fishing/marine-conservation-services/meetings-and-project-updates/) also considers a wide range of DOC-funded projects related to protected species, sometimes in joint meetings with the AEWG. The Ministry's Fishery Assessment Working Groups occasionally consider research relevant to this synopsis. Terms of reference for AEWG and BRAG are periodically revised and updated (see Appendix 16.1 and 16.3 for the 2013 Terms of Reference for AEWG and BRAG, respectively).

AEWG is convened for the Ministry's peer review purposes with an overall purpose of assessing, based on scientific information, the effects of fishing, aquaculture, and enhancement on the aquatic environment for all New Zealand fisheries. The purview of AEWG includes: bycatch and unobserved mortality of protected species, fish, and other marine life; effects of bottom fisheries on benthic biodiversity, species, and habitat; effects of fishing on biodiversity, including genetic diversity; changes to ecosystem structure and function as a result of fishing, including trophic effects; and effects of aquaculture and fishery enhancement on the environment and on fishing. Where possible, AEWG may explore the implications of any effects, including with respect to any standards, reference points, and relevant indicators. The AEWG is a technical forum to assess the effects of fishing or environmental status and make projections. It has no mandate to make management recommendations or decisions. Membership of AEWG is open (attendees for 2014 are listed in Appendix 16.2).

The two main responsibilities of BRAG are: to review, discuss, and convey views on the results of marine biodiversity research projects contracted by the Ministry; and to discuss, evaluate, make recommendations and convey views on Medium Term Biodiversity Research Plans and constituent individual projects. Both tasks have hitherto been undertaken in the context the strategic goals in the New Zealand Biodiversity Strategy (2000) and the Strategy for New Zealand Science in Antarctica and the Southern Ocean (2010), but the focus of the programme is currently being reviewed to align it with more recent strategic documents. BRAG also administers some large cross-government projects such as NORFANZ, BIOROSS, Fisheries and Biodiversity Ocean Survey 20/20; and International Polar Year (IPY) Census of Antarctic Marine Life (IPY-CAML).

Following consideration at one or more meetings of appropriate working groups, reports from individual projects are also technically reviewed by the Ministry before they are finalised for use in management and/or for public release. Fisheries Assessment Reports, FARs, and Aquatic Environment and Biodiversity reports, AEBRs, are also subject to editorial review whereas Final Research Reports, FRRs, and Research Progress Reports, RPRs, are not. Finalised FARs, AEBRs, historical FARDs (Fisheries Assessment Research Documents) and MMBRs (Marine Biodiversity and Biosecurity Reports), and some FRRs can be found in the Document library at: http://fs.fish.govt.nz/Page.aspx?pk=61&tk=209. More recent reports are available from the MPI website at: http://www.mpi.govt.nz/news-and-resources/publications/.

1.5 REFERENCES

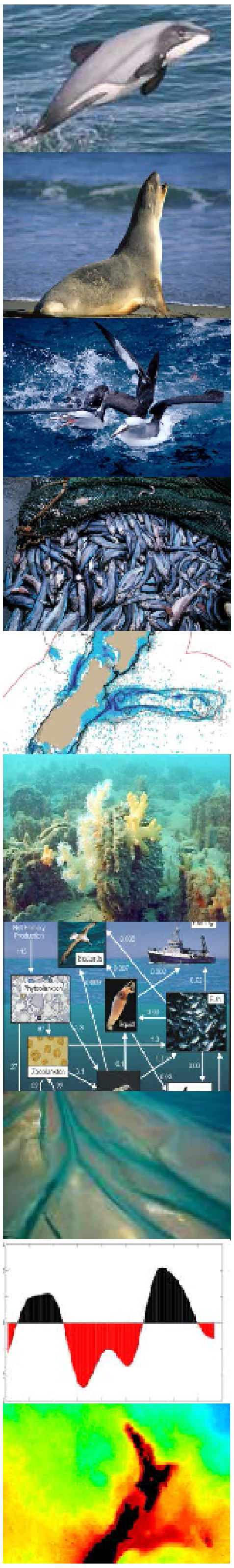
Ministry for Primary Industries (2014a). Fisheries Assessment Plenary, May 2014: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1381 p.

Ministry for Primary Industries (2014b). Fisheries Assessment Plenary, November 2014: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 618 p.

2 RESEARCH THEMES COVERED IN THIS DOCUMENT

The Ministry has identified four broad categories of research on the environmental effects of fishing (Figure 2.1): incidental capture and fishing-related mortality of protected species; bycatch of non-protected species, primarily non-QMS fish; modification of benthic habitats (including seamounts); and various ecosystem effects (including fishing and non-fishing effects on habitats of particular significance for fisheries management and trophic relationships). This edition also includes the effects of aquaculture on the environment and wild-capture fisheries within the ecosystem effects theme, although this structure may be reconsidered in future. Other emerging issues (such as the genetic consequences of selective fishing) are not dealt with in detail in this edition but it is anticipated that those that turn out to be important will be dealt with in future iterations. A fifth theme for this document is MPI research on marine biodiversity. The research has been driven largely by the Biodiversity Strategy but has strategic importance for fisheries in that it provides for better understanding of the ecosystems that support fisheries productivity.

Our understanding is not uniform across these themes and, for example, our knowledge of the quantum and consequences of fishing-related mortality of protected species is much better developed than our knowledge of the consequences of mortalities of non-target fish, bottom trawl impacts, or land management choices for ecosystem processes or fisheries productivity. Ultimately, the goal of research described in this synopsis is to complement information on fishstocks to ensure that the Ministry has the information required to underpin the ecosystem approach to fisheries management envisaged in Fisheries 2030. Stock assessment results have been published for many years in Fisheries Assessment Reports, Final Research Reports, and the Annual Report from the Fishery Assessment Plenary (“the plenary”). Collectively, these provide a rich and well-understood resource for fisheries managers and stakeholders. In 2005, an environmental section was included in the hoki plenary report as part of the characterisation of that fishery and to highlight any particular environmental issues. Similar, fishery-specific sections have since been developed for several other fisheries and included in the plenary, but work on environmental issues has otherwise been more difficult to access for fisheries managers and stakeholders. The Ministry explored better ways to document, review, publicise, and integrate information from environmental assessments with traditional fishery assessments, including annual publication of this document. This will rely heavily on studies that are published in Aquatic Environment and Biodiversity Reports and Final Research Reports but, given the overlapping mandates and broader scope of work in this area, also on results published by other organisations and in the scientific literature. The integration of all this work into a single source document analogous to the Report from the Fishery Assessment Plenary has advanced considerably since the first edition in 2011 but it will take time for all issues to be included.



THEME	RESEARCH QUESTIONS	CURRENT WORK
1. PROTECTED SPECIES • Marine mammals • Seabirds • Turtles • Protected fish • Corals	• How many of each NZ-breeding protected species are caught and killed in our fisheries (and out of zone)? • How many unobserved deaths are caused? • What is the likely effect of fishing-related mortality on protected species populations? • What levels of fatalities would lead to different population outcomes? • Which species or populations are most at risk? • Which fisheries cause the most risk and where are the most cost-effective gains in mitigation to be made? • What mitigation approaches are most successful and in what circumstances?	• Estimation of annual captures of protected species by fishery • Abundance and productivity of at-risk seabird populations • Abundance and productivity of Hector's & Māui dolphins • Refining the semi-quantitative risk assessment for seabirds • Finalising a semi-quantitative risk assessment for marine mammals • Full quantitative risk assessment for selected at-risk populations • Modelling of distribution of key protected species to improve risk assessments
2. OTHER BYCATCH • Non-QMS fish & invertebrates	• How much non-target fish is caught and discarded in our fisheries? • What is the effect of that mortality? • What do trends in bycatch show?	• Continued monitoring for deepwater and highly migratory • Risk assessment for tier 3 deepwater species and sharks
3. BENTHIC EFFECTS • Distribution of habitats & trawling • Effects of trawling on each	• What seabed habitats occur where in our TS/EEZ and how much of each is affected by trawling or shellfish dredging? • How sensitive is each habitat to disturbance and how do ecosystem services change when each is disturbed? • What are the consequences of different management approaches?	• Assessment of sensitivity and recovery rate of key habitats • Monitoring deepwater and coastal trawl footprints • Modelling to predict biogenic and other sensitive habitats • Determination of the best way to assess overall benthic impacts
4. ECOSYSTEM EFFECTS • Trophic studies • Habitats of significance • Ecosystem indicators • Land-use effects • Climate variability • Climate Change • System productivity	• How do the ecosystems that support our fisheries function? • What are the key predator-prey or synergistic relationships in these systems? • Are our fisheries affecting food webs or ecosystem services? • What changes are occurring in the ecosystems that support our fisheries? • How do fisheries and/or land management affect fish habitat and fisheries production? • What are the major risks and opportunities from ocean-climate variability and trends?	• Monitoring various indicators, including those generated by other themes • This theme is not as obviously amenable to the risk assessment approach applied to other themes and various broad approaches are being considered.
5. MARINE BIODIVERSITY • Characterising NZ biodiversity • Functional ecology • Genetic diversity • Ocean climate • Metrics & indicators • Threats & impacts • Ross Sea & IPY	• What are the key drivers of pattern in New Zealand's marine biodiversity? • How does biodiversity contribute to the resilience of ecosystems to perturbation and climate change? • What drives genetic connectivity within species? • What do we need to measure and monitor to assess risks and change? • How are biota adapted to polar conditions and what is their sensitivity to perturbation?	• Mapping key biogenic habitats • SPRFMO benthic habitats • Modelling seabed response and recovery from disturbance • Isoscapes for trophic studies • Experimental response of shellfish to warming and acidification • Monitoring surface plankton • Implications of ocean acidification for plankton productivity • Marine environmental monitoring

Figure 2.1: Summary of themes in the Aquatic Environment and Biodiversity Annual Review 2014.

CURRENT STATE OF KNOWLEDGE

- Aggregate "on deck" captures of seabirds (and approximate species composition), marine mammals, and large sharks known reasonably well for offshore trawl and longline fisheries, but less well for inshore fisheries (where observer coverage has historically been low).
- Incidental, cryptic, or unobserved mortality are poorly known (and difficult to assess).
- Factors affecting fishing related mortality are well known for most seabirds and marine mammals.
- Knowledge of population abundance is increasing for some key seabird species and well known for sea lions, but poorly known or dated for other seabirds, some species of dolphins, fur seals, and most sharks.
- Rigorous semi-quantitative or fully quantitative risk assessments have been completed for almost all seabirds and Hector's / Maui's dolphins, and sea lions. Rigorous semi-quantitative risk assessment across all marine mammals is almost complete.
- We rely heavily on risk assessment to assess impacts of fishing-related mortality on most protected species and these can now be used to identify key knowledge gaps.
- Some methods of mitigating fishing-related mortality have been formally tested.

- Bycatch and discards are estimated using observer records for the main deepwater and HMS fisheries.
- Formal risk assessments are under development based on the spatial overlap approach developed for seabirds and marine mammals.
- Bycatch and discards for inshore vessels remain poorly known.
- Some mitigation approaches have been assessed (e.g., for scampi trawl).

- Modelled predictions are available of the distribution of seabed habitats at a broad scale using classifications (BOMEC) and at finer scale for seamounts and some biogenic habitats.
- Excellent understanding of the distribution of bottom trawling in offshore and coastal waters, although information for most Danish seine and shellfish dredge fisheries remains very coarse.
- Good understanding of the effects of trawling, especially in nearshore habitats.
- General understanding of the effects of trawling on biogeochemical processes and ecosystem services.
- General understanding of the relative sensitivity of different habitats.

- Variability in the diets of key commercial species in the Chatham Rise ecosystem have been described.
- A preliminary trophic model of the Sub-Antarctic ecosystem suggests a low productivity system supporting a simple food chain with high transfer efficiencies.
- Atlases have been developed showing the distribution of spawning, pupping, egg-laying, and juveniles of key species and these are likely to be updated and refreshed soon.
- A review of land-based effects on fish habitat and coastal biodiversity has been completed.
- A start has been made on assessing ecosystem change over time (through fish-based indicators calculated from trawl survey data and acoustic time series of mesopelagic biomass)
- A summary of ocean climate variability and change has been produced.
- Broad reviews have been completed of the impacts of climate variability on fisheries (especially recruitment), but the likely impacts of ocean climate change or acidification remain poorly known.
- Work in this theme is conducted by a wide variety of organisations including CRIs (including National Science Challenges), DOC, and the universities. Integrating that knowledge is challenging.

- Taxonomy and ID Guides have been produced and specimens recorded in National Collections.
- Biodiversity surveys completed on local scale (seamounts, biogenic habitats, seagrass meadows) and larger fishery scale (Louisville Ridge, Chatham Rise).
- Measures and indicators for marine biodiversity measures and ecosystem have been developed.
- Predictive modelling techniques have been applied and habitat classification methods improved
- Productivity in benthic communities has been measured.
- Specimens from New Zealand have been genetically assessed and entered into the barcode of life.
- Seamount connectivity, land-sea connectivity, and endemism have been studied.
- A plan for monitoring the marine environment for long-term change is under development.
- Demersal fish trophic studies on the Chatham Rise have been completed.
- A review of NZ data from deep-sea and abyssal habitats has been completed.
- A multidisciplinary study of longterm (1000 years) changes to NZ marine ecosystem is complete.
- Latitudinal gradient project, ICECUBE and 2 large scale surveys in the Ross Sea have been conducted.
- This theme has links and synergies with MBIE, DOC, universities and the MPI AEWG programmes

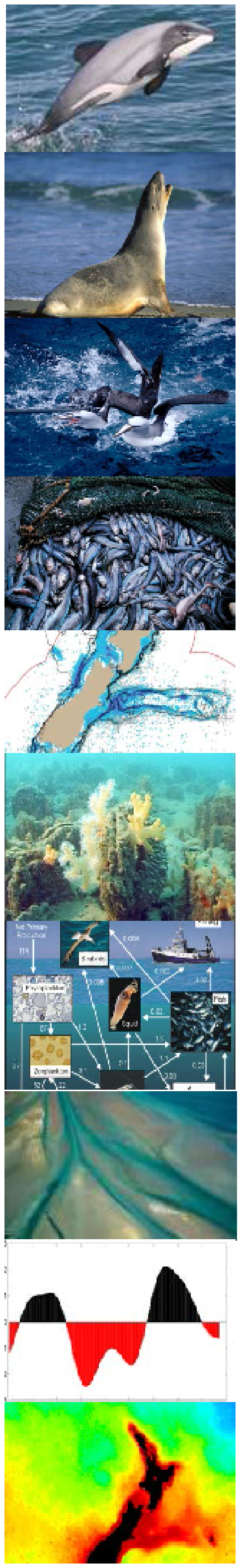


Figure 2.1 continued: Summary of Themes in the Aquatic Environment & Biodiversity Review 2014

THEME 1: PROTECTED SPECIES

3 NEW ZEALAND SEA LION (*PHOCARCTOS HOOKERI*)

Scope of chapter	This chapter outlines the biology of New Zealand (or Hooker's) sea lions (*Phocarctos hookeri*), the nature of fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
Area	Southern parts of the New Zealand EEZ and Territorial Sea.
Focal localities	Areas with significant fisheries interactions include the Auckland Islands Shelf, the Stewart/Snares Shelf and Campbell Plateau.
Key issues	Improving estimates of incidental captures in some trawl fisheries (e.g. scampi), improving estimates of SLED post-exit survival, improving understanding of interaction rate and improving understanding of the demographic processes underlying recent population trends.
Emerging issues	Assessing potential impacts of resource competition and/or resource limitation through ecosystem effects on NZ sea lion population viability. The role of fisheries impacts in light of declines in population size. Estimation of interactions given low numbers of observed captures in fisheries using SLEDs.
MPI Research (current)	PRO2013-01 *Estimating the nature & extent of incidental captures of seabirds, marine mammals & turtles in New Zealand commercial fisheries*; PRO2012-02 *Assess the risk posed to marine mammal populations from New Zealand fisheries*; PRO2014-02 *Quantitative risk assessment for New Zealand sea lions; SEA2014-12 New Zealand sea lion stable isotope analysis.* Joint funding with Deep Water Group; *New Zealand sea lion population project (Campbell Islands).* Joint funding with DOC: *Independent expert panel workshop (to support the development of PRO2014-02, Quantitative risk assessment for New Zealand sea lions).*
NZ Government Research (current)	DOC Marine Conservation Services Programme (CSP): INT2014-01 *Observing commercial fisheries*; INT2013-03 *Identification of marine mammals, turtles and protected fish captured in New Zealand fisheries*; POP2014-01 *New Zealand sea lion population project (Auckland Islands)*; MIT2014-01 *Protected species bycatch newsletter.* NIWA Research: SA123098 *Multispecies modelling to evaluate the potential drivers of decline in New Zealand sea lions*; TMMA103 *Conservation of New Zealand's threatened iconic marine megafauna.*
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
Related chapters/issues	See the New Zealand fur seal chapter.

Note: This chapter has been updated for the AEBAR 2014.

3.1 CONTEXT

Management of fisheries impacts on New Zealand (NZ) sea lions is legislated under the Marine Mammals Protection Act (MMPA) 1978 and the Fisheries Act (FA) 1996. Under s.3E of the MMPA, the Minister of Conservation, with the concurrence of the Minister for Primary Industries (MPI; formerly the Minister of Fisheries), may approve a population management plan (PMP). Although a NZ sea lion PMP was proposed by the Department of Conservation (DOC) in 2007 (DOC 2007), following consultation DOC decided not to proceed with the PMP.

All marine mammal species are designated as protected species under s.2(1) of the FA. In 2005, the Minister of Conservation approved the Conservation General Policy, which specifies in Policy 4.4 (f) that "*Protected marine species should be managed for their long-term viability and recovery throughout their natural range.*" DOC's Regional Conservation Management Strategies outline specific policies and objectives for protected marine species at a regional level. New Zealand's sub-Antarctic islands, including Auckland and Campbell islands, were inscribed as a World Heritage area in 1998.

The Minister of Conservation gazetted the NZ sea lion as a threatened species in 1997. In 2009, DOC approved the

New Zealand sea lion species management plan[2]*: 2009–2014* (DOC 2009). It aims: "*To make significant progress in facilitating an increase in the New Zealand sea lion population size and distribution.*" The plan specifies a number of goals, of which the following are most relevant for fisheries interactions:

"To avoid or minimise adverse human interactions on the population and individuals.
To ensure comprehensive protection provisions are in place and enforced.
To ensure widespread stakeholder understanding, support and involvement in management measures."

In the absence of a PMP, the Ministry for Primary Industries manages fishing-related mortality of NZ sea lions under s.15(2) of the FA. Under that section, the Minister "*may take such measures as he or she considers are necessary to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species, and such measures may include setting a limit on fishing-related mortality.*"

Management of incidental captures of NZ sea lion aligns with Fisheries 2030 Objective 6: *Manage impacts of fishing and aquaculture*. Further, the management actions follow Strategic Action 6.2: *Set and monitor environmental standards, including for threatened and protected species and seabed impacts*.

The relevant National Fisheries Plan for the management of incidental captures of NZ sea lions is the National Fisheries Plan for Deepwater and Middle-depth Fisheries (the National Deepwater Plan). Under the National Deepwater Plan, the objective most relevant for management of NZ sea lions is Management Objective 2.5: *Manage deepwater and middle-depth fisheries to avoid or minimise adverse effects on the long-term viability of endangered, threatened and protected species*.

Specific objectives for the management of incidental captures of NZ sea lion is outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ sea lions are most likely to interact (Ministry of Fisheries 2010). These fisheries include trawl fisheries for arrow squid (SQU1T and SQU6T), southern blue whiting (SBW) and scampi (SCI). The SBW chapter of the National Deepwater Plan is complete and includes Operational Objective 2.2: *Ensure that incidental New Zealand sea lion mortalities, in the southern blue whiting fishery at Campbell Island (SBW6I), do not impact the long term viability of the sea lion population and captures are minimised through good operational practices*. The chapter in the National Deepwater Plan for arrow squid is under development, while the chapter for scampi is nearly finalised.

Currently, MPI limits the actual or estimated mortality of sea lions in the SQU6T trawl fishery based on tests of the likely performance of candidate mortality limit control rules (and, hence, mortality limits) using an integrated population and fishery model (Breen et al 2010). Candidate rules are assessed against the following two criteria:

a. A rule should provide for an increase in the sea lion population to more than 90% of carrying capacity[3], or to within 10% of the population size that would have been attained in the absence of fishing, and that these levels must be attained with 90% certainty, over 20-year and 100-year projections.
b. A rule should attain a mean number of mature mammals that exceeded 90% of carrying capacity in the second 50 years of 100-year projection runs.

These management criteria were developed and approved in 2003 by a Technical Working Group comprised of MFish, DOC, squid industry representatives, and environmental groups.

Likely performance is also assessed against two additional criteria proposed by DOC:

[2] The species management plan differs from the draft Population Management Plan in that it is quite broad in scope; providing a framework to guide the Department of Conservation in its management of the NZ sea lion over the next 5 years. The draft population management plan focused on options for managing the extent of incidental mortality of NZ sea lions from fishing through establishing a maximum allowable level of fishing-related mortality (MALFiRM) for all New Zealand fisheries waters.

[3] Carrying capacity in this instance applies to the current range. For managing the SQU6T fishery, carrying capacity refers to the maximum number of NZ sea lions that could be sustained on the Auckland Islands.

a. A rule should maintain numbers above 90% of the carrying capacity in at least 18 of the first 20 years.
b. A rule should lead to at least a 50% chance of an increase in the number of mature animals over the first 20 years of the model projections.

In March 2014, the Minister of Conservation, Nick Smith, and the Minister for Primary Industries, Nathan Guy, announced their intention to develop a Threat Management Plan which will look at all possible threats to New Zealand sea lions. The TMP for New Zealand sea lions is being developed by DOC and MPI. The TMP is needed because New Zealand's sea lion population is declining and the reasons for their decline are unclear. The plan will review all threats to sea lions and explore measures to ensure their survival.

3.2 BIOLOGY

3.2.1 TAXONOMY

The NZ sea lion (*Phocarctos hookeri*, Gray, 1844) is one of only two species of otariid (eared seals, including fur seals and sea lions) native to New Zealand, the other being the NZ fur seal (*Arctocephalus forsteri*, Lesson, 1828). The NZ sea lion is New Zealand's only endemic pinniped.

3.2.2 DISTRIBUTION

Before human habitation, NZ sea lions ranged around the North and South Islands of New Zealand. Pre-European remains of NZ sea lions have been identified from at least 47 archaeological sites, ranging from Stewart Island to North Cape, with most occurring in the southern half of the South Island (Smith 1989, 2011, Childerhouse & Gales 1998, Gill 1998. Analysis of Holocene remains indicated that breeding populations once occurred around NW Nelson and that prehistoric mainland colonies were genetically distinct from contemporary NZ sea lions, though became extinct shortly after the arrival of Polynesian settlers (Collins et al 2014a, 2014b). Subsistence hunting on the mainland and subsequent commercial harvest from outlying islands of NZ sea lions for skins and oil resulted in population decline and contraction of the species' range (Gales 1995, Childerhouse & Gales 1998, Nagaoka 2001, 2006). Currently, most NZ sea lions are found in the New Zealand Sub-Antarctic, with individuals ranging to the NZ mainland and Macquarie Island.

NZ sea lion breeding colonies[4] are highly localized, with most pups being born at two main breeding areas, the Auckland Islands and Campbell Island (Wilkinson et al 2003, Chilvers 2008). At the Auckland Islands, there are three breeding colonies: Enderby Island (mainly at Sandy Bay and South East Point); Dundas Island; and Figure of Eight Island. On Campbell Island there is one breeding colony at Davis Point, another colony at Paradise Point, plus a small number of non-colonial breeders (Wilkinson et al 2003, Chilvers 2008, Maloney et al 2009, Maloney et al 2012). Breeding on the Auckland Islands represents 71–87% of the pup production for the species, with the remaining 13–29% occurring on Campbell Island (based on concurrent pup counts in 2003, 2008 and 2010; see Section 3.2.5).

Although breeding is concentrated on the Auckland Islands and Campbell Island, some births have been reported from the Snares and Stewart Islands (Wilkinson et al 2003, Chilvers et al 2007), though there have been no recorded births of sea lions at the Snares Islands in 15 years (L. Chilvers, pers comm). Twenty-five sea lion pups were captured and tagged around Stewart Island during a DOC recreational hut and track maintenance trip in March 2012, and 26 pups were tagged at Stewart Island in March 2013 (L. Chilvers, pers comm). Breeding also is taking place on the New Zealand mainland at the Otago Peninsula, mainly the result of a single female arriving in 1992 and giving birth in 1993 (McConkey et al 2002).

On land, NZ sea lions are able to travel long distances and climb high hills, and are found in a variety of habitats including sandy beaches, grass fields, bedrock, and dense bush and forest (Gales 1995, Augé et al 2012). Following the end of the females' oestrus cycle in late January, adult and sub-adult males disperse throughout the species' range, whereas dispersal of females (both breeding and non-breeding) are more restricted (Marlow 1975, Robertson et al 2006, Chilvers & Wilkinson 2008).

[4] DOC (2009) defines colonies as "haul-out sites where 35 pups or more are born each year for a period of 5 years or more." Haul-out sites are defined as "terrestrial sites where NZ sea lions occur but where pups are not born, or where fewer than 35 pups are born per year over 5 consecutive years."

3.2.3 FORAGING ECOLOGY

Foraging studies have been conducted on lactating female NZ sea lions from Enderby Island (Chilvers et al 2005a, 2006, Chilvers & Wilkinson 2009, Chilvers et al 2013), as well as throughout the Auckland Islands and the Otago Peninsula (see Augé et al 2011a, b, 2013 and Chilvers et al 2011), and Leung et al (2012, 2013a, 2014a) have investigated foraging in juvenile NZ sea lions from Enderby Island, Auckland Islands in contrast with juvenile animals from Otago Peninsula (Leung et al 2013b) and in mother-yearling pairs from Enderby Island (Leung et al 2014b). Work also is underway at Campbell Island under NIWA project *Conservation of New Zealand's threatened iconic marine megafauna*. These show that females from Enderby Island forage primarily within the Auckland Islands continental shelf and its northern edge, and that individuals show strong foraging site fidelity both within and across years. Satellite tagging data from lactating females showed that the mean return distance travelled per foraging trip is 423 ± 43 km (n = 26), which is greater than that recorded for any other sea lion species (Chilvers et al 2005a). While foraging, about half of the time is spent submerged, with a mean dive depth of 130 ± 5 m (max. 597 m) and a mean dive duration of 4 ± 1 minutes (max. 14.5 minutes; Chilvers et al 2006). Both juvenile (2-5 years old) female and male sea lions foraged to the north of the Auckland Islands, but mean distance travelled per foraging trip was shorter in females (99 ± 12 km, n = 19) compared to males (184 ± 25 km, n = 12), and the mean maximum distance from the colony for males (93 ±10 km) was about twice that for females (51 ± 5 km. Leung et al 2012). A study of seven dependent yearling NZ sea lions Leung et al (2013a) found that dive depth was negatively related with animal mass (lighter sea lions dived to greater depths: overall mean dive depth 35 m), but in juvenile (2-5 years old) NZ sea lions, diving ability (dive depth, dive duration and bottom time per dive) improved with both mass and age and 5 year old male NZ sea lions had similar dive capability to adult females (Leung et al 2014a). NZ sea lions, like most pinnipeds, may use their whiskers to help them capture prey at depths where light does not penetrate (Marshall 2008, Hanke et al 2010). Leung et al (2014b) found no evidence that yearling NZ sea lions were developing foraging skills through observational learning of maternal behaviours in a study of seven mother-yearling partnerships at Enderby Island.

Studies conducted on female NZ sea lions suggest that the foraging behaviour of each individual falls into one of two distinct categories, benthic or meso-pelagic (Chilvers & Wilkinson 2009). Benthic divers have fairly consistent dive profiles, reaching similar depths (120 m on average) on consecutive dives in relatively shallow water to presumably feed on benthic prey. Meso-pelagic divers, by contrast, exhibit more varied dive profiles, undertaking both deep (> 200 m) and shallow (< 50 m) dives over deeper water. Benthic divers tend to forage further from their breeding colonies, making their way to the north-eastern limits of Auckland Islands' shelf, whereas meso-pelagic divers tend to forage along the north-western edge of the shelf over depths of approximately 3000 m (Chilvers & Wilkinson 2009). Meynier et al (2014), employing fatty acid (FA) analyses of blubber samples, found that FA profiles were different in benthic-diving and meso-pelagic-diving lactating NZ sea lions suggesting a different utilisation of prey resources, and that while prey species taken were similar across both dive types, the proportion of particular prey differed between the two dive categories. Further, Meynier et al (2014) found that the body condition index (BCI: the residual between the measured and predicted body mass from the mass-length regression provided by Childerhouse et al (2010b)) was significantly greater in meso-pelagic divers compared to benthic divers.

The differences in dive profiles have further implications for the animals' estimated aerobic dive limits (ADL; Gales & Mattlin 1997; Chilvers et al 2006), defined as the maximum amount of time that can be spent underwater without increasing blood lactate concentrations (a by-product of anaerobic metabolism). If animals exceed their ADL and accumulate lactate, they must surface and go through a recovery period in order to aerobically metabolize the lactate before they can undertake subsequent dives. Chilvers et al (2006) estimated that lactating female NZ sea lions exceed their ADL on 69% of all dives, a much higher proportion than most other otariids (which exceed their ADL for only 4–10% of dives; Chilvers et al 2006). NZ sea lions that exhibit benthic diving profiles are estimated to exceed their ADL on 82% of dives, compared with 51% for meso-pelagic divers (Chilvers 2008).

Chilvers et al (2006) and Chilvers & Wilkinson (2009) suggested that the long, deep diving behaviour, the propensity to exceed their estimated ADL, and differences in physical condition and age at first reproduction from animals at Otago together indicate that females from the Auckland Islands may be foraging at or near their physiological limits. However, Bowen (2012) suggested a lack of relationship between surface time and anaerobic diving would seem to indicate that ADL has been underestimated. Further, given a number of studies of diving behaviour were conducted during early lactation when the demands of offspring are less than they would be later in lactation, Bowen (2012) considered it unlikely that females are operating at or near a physiological limit.

Adult females at Otago are generally heavier for a given age, breed earlier, undertake shorter foraging trips, and have shallower dive profiles compared with females from the Auckland Islands (Table 3.1). Any observed differences may reflect differences in habitat (including prey availability) comparing the Auckland Islands and the Otago peninsula, a founder effect, or a combination of these or other factors. Similarly, Leung et al (2013b) compared foraging characteristics in juvenile (2-3 years old) female NZ sea lions at Enderby Island and Otago Peninsula. Overall, females at Otago were heavier (3 year old mean 96 kg) than females at Enderby (3 year old mean 72 kg), and exhibited shorter mean foraging trip distance (19 km at Otago, 103 km at Enderby), shallower mean dive depth (15 m at Otago, 69 m at Enderby) and shorter mean dive duration (1.8 min at Otago, 3.2 min at Enderby). Leung et al (2013b) concluded that the Auckland Islands are less optimal habitat compared to Otago.

Table 3.1: Comparison of selected characteristics between adult female NZ sea lions from the Auckland Islands and those from the Otago peninsula (Chilvers et al 2006, Augé et al 2011a, 2011b, 2011c). Data are means ± SE (where available).

Characteristic	Auckland Islands	Otago
Reproduction at age 4	< 5% of females	> 85% of females
Average mass at 8–13 years of age	112 kg	152 kg
Foraging distance from shore	102.0 ± 7.7 km (max = 175 km)	4.7 ± 1.6 km (max = 25 km)
Time spent foraging at sea	66.2 ± 4.2 hrs	11.8 ± 1.5 hrs
Dive depth	129.4 ± 5.3 m (max = 597 m)	20.2 ± 24.5 m (max = 389 m)
Dives estimated to exceed ADL	68.7 ± 4.4 percent	7.1 ± 8.1 percent

NZ sea lions are generalist predators with a varied diet that includes marine mammal prey (NZ fur seal *Arctocephalus forsteri*), seabirds (yellow-eyed penguin *Megadyptes antipodes*, blue penguin *Eudyptula minor*, southern royal albatross *Diomedea epomophora*), elasmobranchs (rough skate *Raja nasuta*), teleost fish (e.g. opalfish *Hemerocoetes* spp., hoki *Macruronus novaezelandiae*, red cod *Pseudophycis bachus*, jack mackerel *Trachurus* spp., barracouta *Thyrsites atun*), cephalopods (e.g. octopus *Enteroctopus zelandicus* and *Macroctopus maorum*, squid *Nototodarus sloanii*), crustaceans (e.g. lobster krill *Munida gregaria*, scampi *Metanephrops challengeri*) and other invertebrates (e.g. salps) (Cawthorn et al 1985; Moore & Moffat 1992; Bradshaw et al 1998; Childerhouse et al 2001; Lalas et al 2007; Moore et al 2008; Meynier et al 2009; Augé et al 2012; Lalas et al 2014; Lalas & Webster 2014). The three main methods used to assess NZ sea lion diets involve analyses of stomach contents, scats and regurgitate, and the fatty acid composition of blubber (Meynier et al 2008). Stomach contents of by-caught animals tend to be biased towards the target species of the fishery concerned (e.g. squid in the SQU6T fishery), whereas scats and regurgitates are biased towards less digestible prey (Meynier et al 2008). Stomach, scat and regurgitate approaches tend to reflect only recent prey (Meynier et al 2008). By contrast, analysis of the fatty acid composition of blubber provides a longer-term perspective on diets ranging from weeks to months (although individual prey species are not identifiable). This approach suggests that the diet of female NZ sea lions at the Auckland Islands tends to include proportionally more arrow squid and hoki and proportionally fewer red cod and scampi than for male NZ sea lions, while lactating and non-lactating females do not differ in their diet (Meynier et al 2008; Meynier 2010). Within a sample of lactating female NZ sea lions, Meynier et al (2014) used fatty acid analyses to show that the diet of benthic-diving and meso-pelagic-diving animals consisted of similar prey, though different mass contributions for each prey species.

Previous assessments have identified considerable spatial (comparing colonies) and temporal (inter-annual and seasonal) variation in the diet composition of NZ sea lions. For instance, jack mackerel and baracoutta were identified as the main prey of the Otago Peninsula population (Augé et al 2012), though were less prevalent in winter and spring when inshore species dominated diet composition (Lalas 1997) and were infrequent prey of the Auckland Islands population (Childerhouse et al 2001; Stewart-Sinclair 2013). A long-term diet assessment of the Sandy Bay colony at the Auckland Islands (1994-95 to 2012-13) identified a decrease in the occurrence of large-sized prey (e.g. *Enteroctopus zealandicus*) and an increasing trend in small-sized prey (e.g. opalfish, rattails and *Octopus* spp.) (Childerhouse et al 2001; Stewart-Sinclair 2013).

3.2.4 REPRODUCTIVE BIOLOGY

NZ sea lions exhibit marked sexual dimorphism, with adult males being larger and darker in colour than adult females (Walker & Ling 1981, Cawthorn et al 1985). Cawthorn et al (1985) and Dickie (1999) estimated the maximum age of males and females to be 21 and 23 years, respectively, but Childerhouse et al (2010a) reported a maximum estimated age for females of 28 years (although the AEWG had some concerns about the methods used and this estimate may not be reliable). Females can become sexually mature as early as age 2 and give birth the following year, most do not breed until they are 6 years old (Childerhouse et al 2010a). Males generally reach sexual maturity at 4 years of age, but because of their polygynous colonial breeding strategy (i.e., males actively defend territories and mate with multiple females within a harem) they are only able to successfully breed at 7–9 years old, once they have attained sufficient physical size (Marlow 1975, Cawthorn et al 1985). Reproductive rate in females increases rapidly between the ages of 3 and 7, reaching a plateau until the age of approximately 15 and declining rapidly thereafter, with the maximum recorded age at reproduction being 26 years (Breen et al 2010, Childerhouse et al 2010b, Chilvers et al 2010). Chilvers et al (2010) estimated from tagged sea lions that the median lifetime reproductive output of a female NZ sea lion was 4.4 pups, and 27% of all females that survive to age 3 never breed. Analysis of tag-resight data from female New Zealand sea lions on Enderby Island indicates the average probability of breeding is approximately 0.30-0.35 for prime-age females that did not breed in the previous year (ranges reflect variation relating to the definition of breeders) and 0.65-0.68 for prime-age females that did breed in the previous year (MacKenzie 2011).

NZ sea lions are philopatric (i.e., they return to breed at the same location where they were born, although more so for females than males). Breeding is highly synchronised and starts in late November when adult males establish territories (Robertson et al 2006, Chilvers & Wilkinson 2008). Pregnant and non-pregnant females appear at the breeding colonies in December and early January, with pregnant females giving birth to a single pup in late December before entering oestrus 7–10 days later and mating again (Marlow 1975). Twin births and the fostering of pups in NZ sea lions are rare (Childerhouse & Gales 2001). Shortly after the breeding season ends in mid-January, the harems break up with the males dispersing offshore and females often moving away from the rookeries with their pups (Marlow 1975, Cawthorn et al 1985).

Pups birth weight is 8–12 kg and parental care is restricted to females (Walker & Ling 1981, Cawthorn et al 1985, Chilvers et al 2006). Females remain ashore for about ten days after giving birth before alternating between foraging trips lasting approximately two days out at sea and returning for about one day to suckle their pups (Gales & Mattlin 1997, Chilvers et al 2005). New Zealand pup growth rates are lower than those reported for other sea lion species, and may be linked to a relatively low concentration of lipids in the females' milk during early lactation (Chilvers 2008, Riet-Sapriza et al 2012). Riet-Sapriza et al (2012) also found that there was a temporal (year and month) effect on milk quality, reflecting individual sea lion characteristics and environmental factors, and that maternal BCI was positively correlated with milk lipid concentration, energy content and milk protein concentration: lactating females in good condition produced more energy-rich milk than did relatively lean females. Pups are weaned after about 10–12 months (Marlow 1975, Gales & Mattlin 1997).

3.2.5 POPULATION BIOLOGY

For NZ sea lions, the overall size of the population is indexed using estimates of the number of pups that are born each year (Chilvers et al 2007). Since 1995, the Department of Conservation (DOC) has conducted mark-recapture counts at each of the main breeding colonies at the Auckland Islands to estimate annual pup production (i.e., the total number of pups born each year, including dead and live animals; Robertson & Chilvers 2011). Pup censuses have been less frequent for other colonies, including the large population at Campbell Island

(Maloney et al 2012). For the Auckland Islands population, the data show a decline in pup production from a peak of 3021 in 199798 to a low of 1501 ± 16 pups in 200809 (Chilvers & Wilkinson 2011, Robertson & Chilvers 2011; Table 3.2), with the largest single-year decline (31%) occurring between the 200708 and 200809 counts. The most recent estimate of pup production for the Auckland Islands population was 1575 pups in 201314, of which 284 ± 7 were counted at Sandy Bay and 1141 ± 12 were counted at Dundas Island, using the mark-recapture method. A direct ground count at Figure of Eight Island resulted in 62 ± 0.6 live pups (Childerhouse et al 2014). In 2013, an aerial survey made during the same time as the ground surveys for Sandy Bay and Dundas Island resulted in 349 (compared to 374) for Sandy Bay and 1398 (compared to 1491) for Dundas Island, dead pups included. Due to the forested terrain no aerial survey was made of Figure of Eight Island (Baker et al 2013, Childerhouse et al 2013). Six counts were made at South East Point in 2014 but no pups were observed (Childerhouse et al 2014).

Table 3.2: Pup production and population estimates of NZ sea lions from the Auckland Islands from 1995 to 2013. Pup production data are direct counts or mark-recapture estimates from Chilvers et al (2007), Robertson and Chilvers (2011), Chilvers (2012a), and Childerhouse et al (2014), noting that counts of dead pup began later in 2013 & 2014 and this is likely to have led to a negative bias in estimates for these years. Standard errors apply only to the portion of pup production estimated using mark-recapture methods. Population estimates from P.A. Breen, estimated in the model by Breen et al 2010. Year refers to the second year of a breeding season (e.g., 2010 refers to the 2009-10 season).

Year	Pup production estimate		Population size estimate	
	Mean	Standard error (for mark recapture estimates)*	Median	90% confidence interval
1995	2 518	21	15 675	14 732–16 757
1996	2 685	22	16 226	15 238–17 318
1997	2 975	26	16 693	15 656–17 829
1998	3 021	94	16 911	15 786–18 128
1999	2 867	33	15 091	13 932–16 456
2000	2 856	43	15 248	14 078–16 586
2001	2 859	24	15 005	13 870–16 282
2002	2 282	34	13 890	12 856–15 079
2003	2 518	38	14 141	13 107–15 295
2004	2 515	40	14 096	13 057–15 278
2005	2 148	34	13 369	12 383–14 518
2006	2 089	30	13 110	12 150–14 156
2007	2 224	38	13 199	12 231–14 215
2008	2 175	44	12 733	11 786–13 757
2009	1 501	16	12 065	11 160–13 061
2010	1 814	36		
2011	1 550[5]	41		
2012	1 684	22		
2013**	1 940	50		
2014**	1 575	19		

*Calculated as the sum of standard errors associated with estimates for Sandy Bay and Dundas (estimates for other rookeries from direct count rather than mark-recapture); **Field season began later in these years and pups that died early in the pupping period were unlikely to have been included in pup production estimates

[5] Due to extreme weather conditions there was some delay in making the 2010/11 pup count which may affect comparability with previous years. However DOC's analysis suggests any such effect is unlikely to be large (Chilvers & Wilkinson 2011).

Total NZ sea lion abundance (including pups, though not including aerial surveys) at the Auckland Islands has been estimated using Bayesian population models (Breen et al 2003, Breen & Kim 2006a, Breen & Kim 2006b, Breen et al 2010). Although other abundance estimates are available (e.g. Gales & Fletcher 1999), the integrated models are preferred because they take into account a variety of age-specific factors (breeding, survival, maturity, vulnerability to fishing, and the proportion incidentally captured by fishing), as well as data on the re-sighting of tagged animals and pup production estimates, to generate estimates of the overall size of the NZ sea lion population inhabiting the Auckland Islands (Table 3.2). The most recent estimate of NZ sea lion abundance for the Auckland Islands population was 12 065 animals (90% CI: 11 160–13 061) in 2009. The integrated model suggested a net decline at the Auckland Islands of 23% between 1995 and 2009, or 29% between the maximum estimated population size in 1998 and 2009. No update currently is available.

For the Campbell Island population, minimum pup production was estimated at 681 pups in 2010 (Maloney et al 2012). Pup production estimates at Campbell Island appear to be increasing over time, although there have been changes to the methodology (Maloney et al 2009). Early pup mortality at Campbell Island has been relatively high in all recent census years, including: 1998 (31%), 2003 (36%), 2008 (40%) and 2010 (55%, the highest recorded at any NZ sea lion breeding site) (Childerhouse et al 2005, Maloney et al 2009; Maloney et al 2012; McNally et al 2001). Maloney et al. (2012) hypothesised that the observed increase in pup production is not expected to continue with such high rates of pup mortality. Previous estimates of total pup production were: 150 in 1992-93; 385 in 2003; and 583 in 2007-08 (Cawthorn 1993, Childerhouse et al 2005, Maloney et al 2009). There were also minimum pup counts of 51 in 1987-88, 122 in 1991-92 and 78 (from a partial count) in 1997-98 (Moore & Moffat 1990, McNally et al 2001, M. Fraser, unpubl. data cited in Maloney et al 2009).

For the Otago Peninsula site, annual pup production has ranged from 0 to 6 pups since the 1994-95 breeding season, with five recorded in 2012-13 (two later died and *Klebsiella* infection was the diagnosed cause of death for one) and three recorded in 2013-14 (McConkey et al 2002, Augé 2011, J. Fyfe pers comm). A modelling exercise suggested that this population can expand to 9–22 adult females by 2018 (Lalas & Bradshaw 2003), though the maximum pup production of 6 pups in 2005-06 was not exceeded in subsequent years. Sea lions at Otago are of special interest because they highlight the potential for establishing new breeding colonies, in this case from a single pregnant female (McConkey et al 2002).

Sea lions have also been found at Stewart Island, where 25 pups were tagged during a DOC hut and track maintenance trip in March 2012. Increasing numbers of pups were tagged in subsequent years including 26 in 2013 and 32 in 2014 (Chilvers 2014, L. Chilvers pers comm). The latest count is thought to be a good estimate of total pup production at Stewart Island in that season (Chilvers 2014).

Established anthropogenic sources of mortality in NZ sea lion include: historic subsistence hunting and commercial harvest (Gales 1995, Childerhouse & Gales 1998); pup entrapment in rabbit burrows prior to rabbit eradication from Enderby Island in 1993 (Gales & Fletcher 1999); human disturbance, including attacks by dogs, vehicle strikes and deliberate shooting on mainland New Zealand (Gales 1995); and incidental captures in fisheries (see below).

In addition to the established effects, there are a number of other anthropogenic effects that may influence NZ sea lion mortality. However their role, if any, is presently unclear. These include: possible competition for resources between NZ sea lions and the various fisheries (Robertson & Chilvers 2011, Bowen 2012); effects of organic and inorganic pollutants, including polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and heavy metals such as mercury and cadmium (Baker 1999, Robertson & Chilvers 2011); and impacts of eco-tourism.

Other sources of mortality include epizootics, particularly *Campylobacter* that killed 1600 pups (53% of pup production) and at least 74 adult females on the Auckland Islands in 1997-98 (Wilkinson et al 2003, Robertson & Chilvers 2011) and *Klebsiella pneumoniae* that killed 33% and 21% of pups diagnosed pups at the Auckland Islands in 2001-02 and 2002-03, respectively (Wilkinson et al 2006) and 55 % of pups between 2009 and 2014 (Roe et al 2014). A highly sticky strain of *K. pneumoniae* was isolated from a number of pups that died in field seasons 2005-06 to 2009-10 (Roe 2011). In this period, disease-related mortalities occurred late in the field season relative to the period 1998-99 to 2004-05 and were still occurring up to the end of sampling (Castinel et al 2007; Roe 2011). The 1998 epizootic event may have affected the fecundity of the surviving pups, reducing their breeding rate relative to other cohorts (Gilbert & Chilvers 2008), though their pupping rate estimate for this cohort is likely to have been negatively biased by particularly high tag shedding rate for individuals tagged in that year (Roberts et al 2014). There are also occurrences of predation by sharks (Cawthorn et al 1985, Robertson & Chilvers 2011), starvation of pups if they become separated from their mothers (Walker & Ling 1981, Castinel et al 2007), drowning in wallows and male aggression towards females and pups (Wilkinson et al 2000, Chilvers et al 2005b).

Despite a historic reduction in population size as a result of subsistence hunting and commercial harvest, the NZ sea lion population does not display low genetic diversity at microsatellite loci and thus does not appear to have suffered effects of genetic drift and inbreeding depression (Robertson & Chilvers 2011).

3.2.6 RELATING DEMOGRAPHIC RATES TO DRIVERS OF POPULATION CHANGE

Demographic assessments have been conducted to identify the proximate demographic causes of population decline at the Auckland Islands. An assessment using mark-resighting data from the Enderby Island sub-population yielded estimates of average annual survival for prime-age females of 0.90 for females that did not breed and 0.95 for females that did breed (MacKenzie 2011). In another assessment, state space demographic models fitted to pup production estimates, age distribution observations and a long time series of mark-resighting observations were developed using NIWA's demographic modelling software SeaBird to estimate year-varying survival, probability of pupping and age-at-first-pupping (Roberts et al 2014). This study concluded that low pupping rate (including occasional years with very low rate), a declining trend in cohort survival to age 2 and to age 5 since the early 1990s and relatively low adult survival (age 6-14) since 1999-00 explain declining pup production at Sandy Bay since the late 1990s. In addition, very low pup survival estimates were obtained for all years since 2004-05, which will compromise breeder numbers and pup production resulting from births at Sandy Bay in the immediate future (Figure 3.1) (Roberts et al 2014). The demographic causes of population change will be further examined in a quantitative risk assessment of potential threats to NZ sea lions in 2014-15.

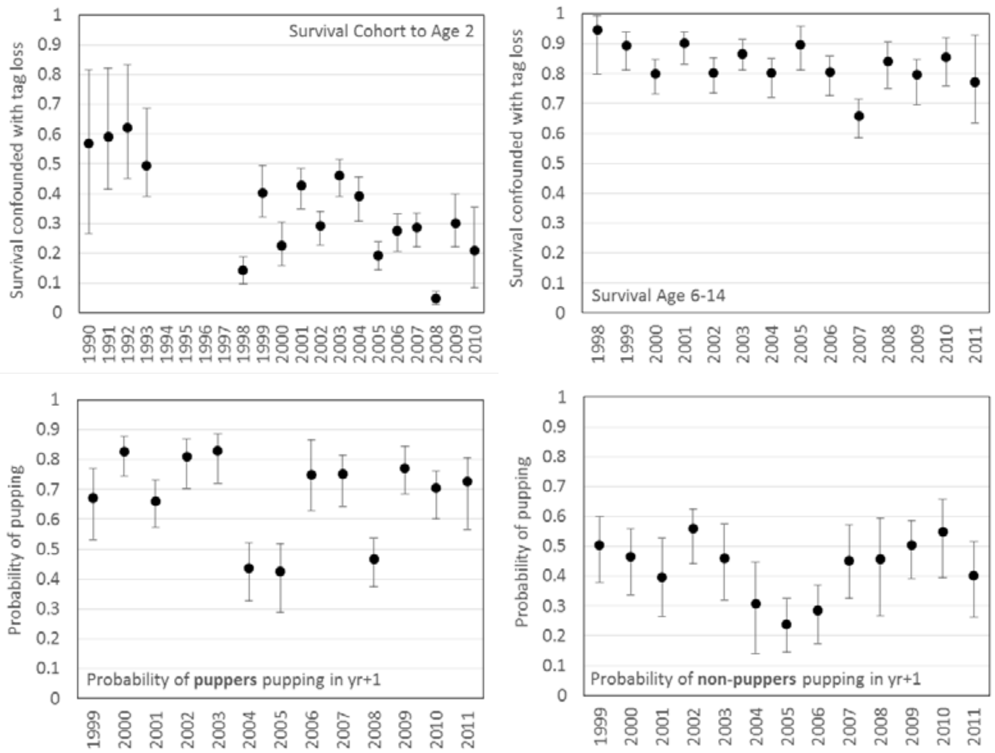


Figure 3.1: Annual estimates of cohort-specific survival to age 2 (top-left), survival at age 6-14 (top-right), probability of puppers pupping (bottom-right) and non-puppers pupping (bottom-right) of female NZ sea lions at Sandy Bay; survival estimates confounded with tag loss and likely to be lower than true values; points are median estimates, bars are 95%CI (Roberts et al., 2014).

A correlative assessment was then conducted to identify the causes of varying demographic rates at Sandy Bay, for which hypothetical models developed with expert consultation were used as a framework for testing relationships between demographic rate estimates, biological observations (e.g. diet composition, maternal body condition or pup mass) and candidate drivers of population change (e.g. changes in prey availability, disease-related pup mortality or direct fishery-related mortalities) (Roberts & Doonan 2014).

Climate indices including Inter-decadal Pacific Oscillation (IPO) and sea surface height (SSH) were well-correlated with the occurrence of an array of key prey species in scats (Childerhouse et al 2001; Stewart-Sinclair 2013). A weak, though significant positive correlation was identified between maternal body condition and pup mass in seasons prior to 2004-05. In this time period, pup mass at 3-weeks appeared to have been a good predictor of cohort-specific survival to age 2, though there was no relationship with cohorts born 2004-05 to 2009-10, for which survival estimates were consistently low despite high pup mass (Figure 3.2). A correlation between cohort survival to age 2 and the rate of pup mortalities attributed to *K. pneumonia* infection late in the field season (Castinel et al 2007, Roe 2011) was consistent with disease-related mortality affecting a decline in pup/yearling survival after 2004-05. Survival at ages 2-5 (juveniles) or age 6-14 (adults) were not well correlated with estimated captures or interactions in the Auckland Islands Southern arrow squid trawl fishery (SQU6T) and estimated captures are relatively low in other commercial fisheries around the Auckland Islands (Thompson et al 2011). However, from 1998-99 to 2003-04 survival at age 6-14 was negatively correlated with the survival of pups born in the previous year, consistent with the high energetic costs of lactation compromising maternal survival.

In most cases observations were available for a short time period and longer series would be required to identify a causative relationship. However, broad changes in diet composition (e.g. an increased prevalence of small sized-prey species), reduced maternal body condition and depressed pupping rates, are all consistent with a sustained period of nutritional stress negatively affecting the productivity of NZ sea lions at the Auckland Islands. In addition, disease-related mortality of pups since 2005-06 (Roe 2011) has caused a decline in pup/yearling survival, which may further compromise breeder numbers at the Auckland Islands in immediate future.

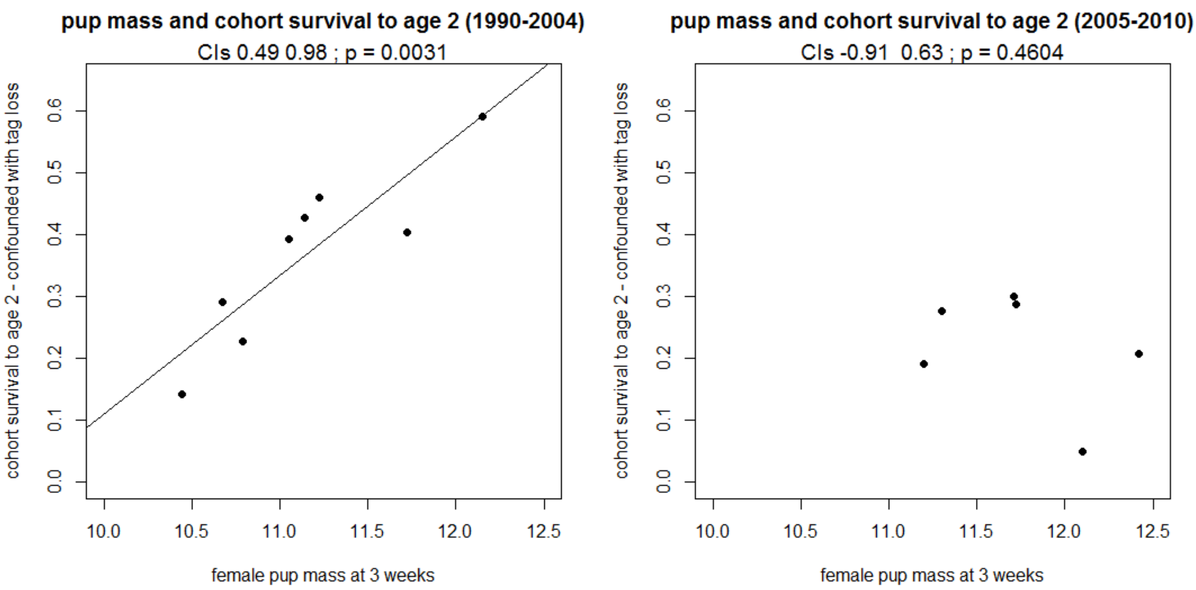


Figure 3.2: Pup mass of females and demographic modelling estimate of cohort survival to age 2; survival estimates confounded with tag loss rate; regression line shown for correlations significant at the 5% level.

3.2.7 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

Threat classification is an established approach for identifying species at risk of extinction (IUCN 2010). The risk of extinction for NZ sea lions has been assessed under two threat classification systems, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2010) and the New Zealand Threat Classification System (Townsend et al 2008).

In 2008, the IUCN updated the Red List status of NZ sea lions, listing them as Vulnerable, A3b[6] on the basis of a marked (30%) decline in pup production in the last 10 years, at some of the major rookeries (Gales 2008). The IUCN further recommended that the species should be reviewed within a decade in light of what they considered to be the current status of NZ sea lions (i.e., declining pup production, reducing population size, severe disease outbreaks).

In 2010, DOC updated the New Zealand Threat Classification status of all NZ marine mammals (Baker et al 2010). In the revised list, NZ sea lions had their threat classification increased from At Risk, Range Restricted[7] to Nationally Critical under criterion C[8] with a Range Restricted qualifier based on the recent rate of decline (Baker et al 2010).

[6] A taxon is listed as 'Vulnerable' if it is considered to be facing a high risk of extinction in the wild. A3b refers to a reduction in population size (A), based on a reduction of ≥ 30% over the last 10 years or three generations (whichever is longer up to a maximum of 100 years (3); and when considering an index of abundance that is appropriate to the taxon (b; IUCN 2010).

[7] A taxon is listed as 'Range Restricted' if it is confined to specific substrates, habitats or geographic areas of less than 1000 km^2 (100 000 ha); this is assessed by taking into account the area of occupied habitat of all sub-populations (Townsend et al 2008).

[8] A taxon is listed as 'Nationally Critical' under criterion C if the population (irrespective of size or number of sub-populations) has a very high (rate of) ongoing or predicted decline; greater than 70% over 10 years or three generations, whichever is longer (Townsend et al 2008).

3.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

Reviews of fisheries interactions among pinnipeds globally can be found in Read et al (2006), Woodley & Lavigne (1991), Katsanevakis (2008) and Moore et al (2009). Because NZ sea lions are endemic to New Zealand, the global understanding of fisheries interactions for this species is outlined under state of knowledge in New Zealand. For related information on fishing interactions for NZ fur seals, both within New Zealand and overseas, see the NZ fur seal chapter.

3.4 STATE OF KNOWLEDGE IN NEW ZEALAND

NZ sea lions interact with some trawl fisheries resulting in incidental capture and subsequent drowning of the sea lion. These interactions are confined to trawl fisheries in Sub-Antarctic waters (Figure 3.3); particularly the Auckland Islands arrow squid fishery (SQU6T), but also the Auckland Islands scampi fishery (SCI6A), other Auckland Islands trawl fisheries, the Campbell Island southern blue whiting (*Micromesistius australis*) fishery (SBW6I) and the Stewart-Snares shelf fisheries targeting mainly arrow squid (SQU1T; Thompson & Abraham 2010, Thompson et al 2011, 2013).[9]

NZ sea lions forage to depths of up to 600 m (Table 3.1) and overlap with trawling at up to 500 m depth for arrow squid, 250–600 m depth for spawning southern blue whiting, and 350–550 m depth for scampi (Tuck 2009, Ministry of Fisheries 2011). There is seasonal variation in the distribution overlap between NZ sea lions and the target species fisheries (Table 3.3). Breeding male sea lions are ashore between November and January with occasional trips to sea, then migrate away from the Auckland Island area (Robertson et al 2006). Breeding females are in the Auckland Island area year round, ashore to give birth for up to 10 days during December and January and then dividing their time between foraging at sea (~2days) and suckling their pup ashore (~1.5 days; Chilvers et al 2005a). The SQU6T fishery currently operates between February and July, peaking between

[9] See the Report from the Fisheries Assessment Plenary, May 2011 (Ministry of Fisheries 2011) for further information regarding the biology and stock assessments for these species.

February and May, whereas the SQU1T fishery operates between December and May, peaking between January and April, before the squid spawn. The SBW6I fishery operates in August and September, peaking in the latter month, when the fish aggregate to spawn. The SCI6A fishery may operate at any time of the year but does not operate continuously.

Table 3.3: Monthly distribution of NZ sea lion activity and the main trawl fisheries with observed reports of NZ sea lion incidental captures (see text for details).

<table>
<tr><th>NZ sea lions</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th></tr>
<tr><td>Breeding males</td><td colspan="2">Dispersed at sea or at haulouts</td><td colspan="3">At breeding colony</td><td colspan="7">Dispersed at sea or at haulouts</td></tr>
<tr><td>Breeding females</td><td colspan="3">At sea</td><td colspan="2">At breeding colony</td><td colspan="7">At breeding colony and at-sea foraging and suckling</td></tr>
<tr><td>New Pups</td><td colspan="3"></td><td colspan="9">At breeding colony</td></tr>
<tr><td>Non-breeders</td><td colspan="12">Dispersed at sea, at haulouts, or breeding colony periphery</td></tr>
<tr><th>Major fisheries</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th></tr>
<tr><td>Hoki trawl</td><td></td><td colspan="8">Chatham Rise and Stewart-Snares Shelf</td><td colspan="3">Cook Strait, west coast South Island, Puysegur</td></tr>
<tr><td>Squid</td><td colspan="3"></td><td colspan="2">Stewart-Snares Shelf</td><td colspan="6">Auckland Islands and Stewart-Snares Shelf</td><td></td></tr>
<tr><td>Southern blue whiting</td><td colspan="2">Pukaki Rise and Campbell Rise</td><td colspan="9"></td><td>Bounty Islands</td></tr>
<tr><td>Scampi</td><td colspan="12">Auckland Islands</td></tr>
</table>

3.4.1 QUANTIFYING FISHERIES INTERACTIONS

Since 1988, incidental captures of NZ sea lion have been monitored by government observers on-board a proportion of the fishing fleet (Wilkinson et al 2003). Between 1995 and 2012, observers observed an overall average of 10–42% of trawl tows each year (Table 3.4). In the SQU6T fishery, observer effort was generally around 20–40% in the same period, but reached almost 100% during the 200001 season (Table 3.4). Observer coverage in non-squid trawl fisheries operating adjacent to Auckland Islands was 0–15% in scampi fisheries, and 4–66% in other target fisheries (e.g., jack mackerel, orange roughy and hoki) (Table 3.6). In the Campbell Island southern blue whiting fishery, observer coverage was 27–76%, compared with 8–50% observer coverage in Stewart-Snares shelf trawl fisheries (primarily targeting squid, but also hoki, jack mackerel and barracouta; Table 3.4). Unobserved trips tended to report NZ sea lion captures at a lower rate than observed trips across all observed fisheries. Fishers reported 177 NZ sea lion captures between 1998–99 and 2008–09, compared with 196 captures reported by observers over the same period (Abraham & Thompson 2011).

The number of NZ sea lion captures reported by observers has been used in increasingly sophisticated models to estimate the total number of captures across the entire fishing fleet in each fishing year (Smith and Baird 2007b, Thompson and Abraham 2010, Abraham and Thompson 2011, Abraham et al in prep.). This approach is currently being applied using information collected under DOC project INT2014-01 and analysed under MPI project PRO2013-01. Estimates for the SQU6T and Campbell Island fisheries were generated using Bayesian models, whereas those for Auckland Islands scampi fisheries, other Auckland Islands trawl fisheries, and the Stewart-Snares shelf fisheries were generated using ratio estimates (see Tables Table 3.5, Table 3.6, and Table 3.7, and detailed information in Thompson et al 2013, Abraham et al in prep.). Captures comprise the number of NZ sea lions brought on deck (both dead and alive), and necessarily exclude the unknown fraction of animals that exit trawls through Sea Lion Exclusion Devices (SLEDs), as well as those individuals that were decomposed upon capture or that climbed aboard vessels (Smith & Baird 2007b, Thompson & Abraham 2010, Thompson et al 2013). Interactions are defined as the number of sea lions that would be predicted to have been caught if no SLEDs had been used (i.e., in the SQU6T fishery), with a corresponding strike rate (the estimated number of interactions per 100 tows) (Thompson et al 2013). For trawl fisheries that do not deploy SLEDs, the number of interactions is equivalent to the number of estimated captures.

In the years since SLEDs were introduced in the SQU6T fishery in 2001-02, both the observed and estimated numbers of NZ sea lion captures have generally declined (Table 3.5). The same trend is present in the mean estimated number of interactions, however these estimates have become increasingly uncertain with the most recent interaction estimates being effectively unbounded. Observed and estimated numbers of NZ sea lion captures in the Campbell Island southern blue whiting fishery increased after 2004-05 reaching 21 individuals observed caught in 2012-13 (Table 3.7) and SLEDs were voluntarily introduced to that fishery in response to the relatively high level of captures in that year. For the Auckland Islands scampi and other target fisheries, and the Stewart-Snares shelf trawl fisheries, the observed and estimated numbers of NZ sea lion captures have fluctuated without trend (Table 3.6).

Capture rate is defined as the number of NZ sea lions caught per 100 tows. Strike rate is defined as the number of NZ sea lions that would be caught per 100 tows if no SLEDs were fitted. Models suggest that the interaction rate of female NZ sea lions (equivalent to the capture rate were no SLEDs fitted) is influenced by a number of factors, including year, distance e from the rookery, tow duration, and change of tow direction (Smith & Baird 2005). Conversely, the interaction rate of male NZ sea lions is influenced by year, the number of days into the fishery (males leave the rookeries soon after mating whereas females remain with the pups), and time of day (Smith & Baird 2005).

3.4.2 MANAGING FISHERIES INTERACTIONS

For NZ sea lions, efforts to mitigate incidental captures in fisheries have focused on the SQU6T fishery. Spatial and/or temporal closures have been put in place, SLEDs were developed by industry, codes of practice were introduced, and mortality limits imposed. In 1982 the Minister of Fisheries established a 12 nautical mile exclusion zone around the Auckland Islands from which all fishing activities were excluded (Wilkinson et al 2003). In 1995, the exclusion zone was replaced with a Marine Mammal Sanctuary with the same controls on fishing (Chilvers 2008). The area was subsequently designated as a Marine Reserve in 2003. In addition to these area-based measures, mitigation devices in the form of SLEDs were introduced in the SQU6T fishing fleet in 2001-02 (Figure 3.4), with widespread and standardised use by all the fleet since 2004/05. The use of SLEDs is not mandatory, but almost all tows now include a certified SLED because this is required by the current industry body (the Deepwater Group) and is necessary to receive the discount factor on tows applied by MPI. SLED deployment is monitored by MPI observers. In 1992, the Ministry adopted a fisheries-related mortality limit (FRML; previously referred to as a maximum allowable level of fisheries-related mortality or MALFiRM) to set an upper limit on the number of NZ sea lions that could be incidentally drowned each year in the SQU6T trawl fishery (Chilvers 2008). If this limit is reached, the fishery may be mandatorily closed for the remainder of the season. Mandatory closures have occurred seven times (1996 to 1998, 2000, and 2002 to 2004) since this plan was first adopted in 1993 (Table 3.8; Robertson & Chilvers 2011).

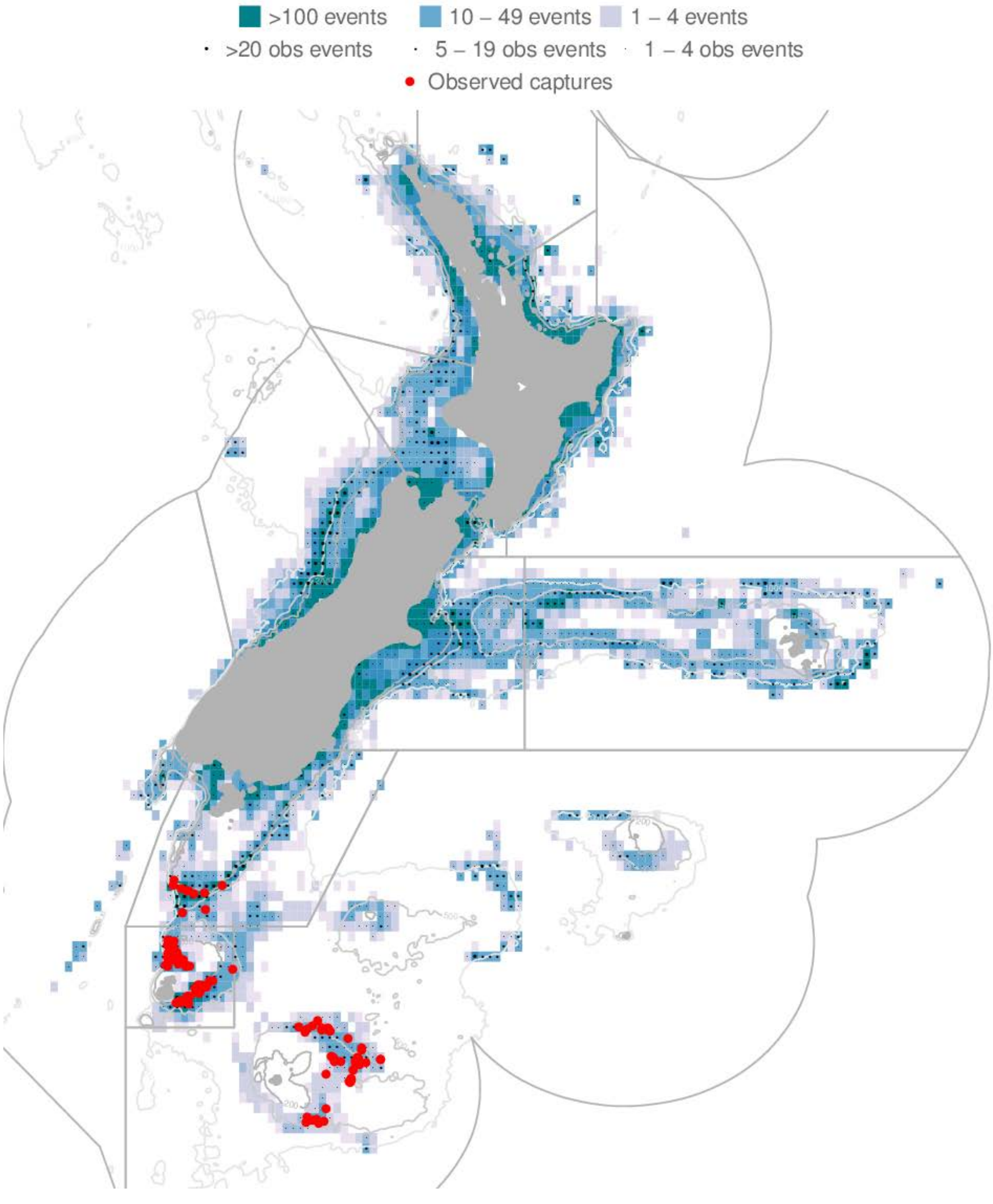


Figure 3.3: Distribution of trawl fishing effort and observed NZ sea lion captures, 2002-03 to 2012-13 (http://data.dragonfly.co.nz/psc/ Data Version v20140131). Fishing effort is mapped into 0.2-degree cells, with the colour of each cell indicating the amount of effort (number of fishing events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 94.2% of the effort is shown.

Table 3.4: Sea lion captures in all commercial trawl fisheries in New Zealand's Exclusive Economic Zone between 1995 and 2013 (http://data.dragonfly.co.nz/psc/ Data version v201040131). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model, ratio estimate, or both combined), the number of estimated sea lion captures, estimated interactions, and estimated strike rate (with 95% confidence intervals, c.i.). Interactions are defined as the number of sea lion that would have been caught if no Sea Lion Exclusion Devices (SLEDs) had been used, with a corresponding strike rate (the estimated number of interactions per 100 tows)(see Thompson et al (2013) and Abraham et al. (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures			Estimated interactions		Estimated strike rate	
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995-96	10 075	10	16	1.5	Both	143	81-239	143	81-234	1.4	0.8-2.4
1996-97	10 954	15	28	1.7	Both	152	102-225	152	101-224	1.4	0.9-2.1
1997-98	9 972	14	14	1	Both	74	45-116	74	43-118	0.7	0.5-1.2
1998-99	10 566	16	6	0.4	Both	31	19-46	31	17-48	0.3	0.2-0.4
1999-00	9 049	23	28	1.4	Both	87	60-125	87	58-129	1	0.7-1.4
2000-01	8 928	39	46	1.3	Both	59	51-70	82	58-111	0.7	0.6-0.8
2001-02	9 946	19	23	1.2	Both	62	44-83	92	60-137	0.6	0.4-0.8
2002-03	8 311	19	11	0.7	Both	31	21-44	59	35-90	0.4	0.3-0.5
2003-04	10 021	23	21	0.9	Both	59	41-81	221	120-384	0.6	0.4-0.8
2004-05	11 083	23	14	0.5	Both	51	34-73	187	93-339	0.5	0.3-0.7
2005-06	9 303	21	14	0.7	Both	49	33-71	172	85-332	0.5	0.4-0.8
2006-07	6 724	24	15	0.9	Both	42	28-61	116	55-237	0.6	0.4-0.9
2007-08	6 534	33	8	0.4	Both	30	20-43	137	38-514	0.5	0.3-0.7
2008-09	6 664	27	3	0.2	Both	20	10-33	114	24-478	0.3	0.2-0.5
2009-10	5 522	34	15	0.8	Both	45	30-64	160	51-563	0.8	0.5-1.2
2010-11	6 455	31	6	0.3	Both	27	16-41	87	25-316	0.4	0.2-0.6
2011-12	5 466	42	1	0	Both	12	5-21	55	11-227	0.2	0.1-0.4
2012-13	5 582	64	25	0.7	Both	33	27-40	83	35-288	0.6	0.5-0.7

Table 3.5: Sea lion captures in the Auckland Islands squid trawl fishery between 1995 and 2013 (http://data.dragonfly.co.nz/psc/ Data version v20140131). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model, ratio estimate, or both combined), the number of estimated sea lion captures, estimated interactions, and estimated strike rate (with 95% confidence intervals, c.i.). Interactions are defined as the number of sea lion that would have been caught if no Sea Lion Exclusion Devices (SLEDs) had been used, with a corresponding strike rate (the estimated number of interactions per 100 tows) (see Thompson et al (2013) and Abraham et al. (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures			Estimated interactions		Estimated strike rate	
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995-96	4 466	12	13	2.4	Model	128	67-222	128	66-218	2.9	1.6-4.8
1996-97	3 716	19	28	3.9	Model	140	91-213	140	89-212	3.8	2.5-5.6
1997-98	1 441	22	13	4.2	Model	59	32-101	59	30-102	4.1	2.4-6.8
1998-99	402	39	5	3.2	Model	14	46204	14	46844	3.5	2.1-5.8
1999-00	1 206	36	25	5.7	Model	69	45-106	70	42-110	5.8	4.0-8.6
2000-01	583	99	39	6.7	Model	39	39-40	62	39-89	10.6	8.7-13.4
2001-02	1 648	34	21	3.7	Model	42	29-62	73	42-116	4.4	3.0-6.7
2002-03	1 470	29	11	2.6	Model	18	46722	46	23-76	3.1	1.9-4.9
2003-04	2 594	30	16	2	Model	40	25-61	202	101-366	7.8	4.0-14.0
2004-05	2 706	30	9	1.1	Model	30	17-50	166	73-319	6.1	2.8-11.7
2005-06	2 462	28	9	1.3	Model	27	15-44	149	63-307	6.1	2.7-12.3
2006-07	1 320	41	7	1.3	Model	15	45901	89	30-209	6.8	2.4-15.6
2007-08	1 265	47	5	0.8	Model	11	43983	119	20-495	9.4	1.8-39.8
2008-09	1 925	40	2	0.3	Model	7	42036	102	12-464	5.3	0.7-24.5
2009-10	1 190	25	3	1	Model	12	46143	128	21-535	10.8	1.9-44.8
2010-11	1 586	34	0	0	Model	4	0-10	64	4-291	4	0.3-17.9
2011-12	1 281	44	0	0	Model	2	0-6	45	2-216	3.5	0.3-16.5
2012-13	1 027	86	3	0.3	Model	4	41793	54	7-261	5.3	0.8-24.5

* SLEDs introduced.

^ SLEDs standardised and in widespread use.

Table 3.6 Sea lion captures in trawl fisheries targeting scampi and targeting other species adjacent to the Auckland Islands between 1995 and 2013 (http://data.dragonfly.co.nz/psc/ Data version v20140131). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model or ratio estimate), and the number of estimated sea lion captures (with 95% confidence interval, c.i.)(see Thompson et al (2013) and Abraham et al (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.
Auckland Islands scampi							
1995-96	1 306	5	2	3.1	Ratio	10	4-18
1996-97	1 224	15	0	-	Ratio	6	4-14
1997-98	1 107	12	0	-	Ratio	6	1-13
1998-99	1 254	2	0	-	Ratio	8	2-16
1999-00	1 383	5	0	-	Ratio	8	2-16
2000-01	1 417	6	4	4.8	Ratio	12	6-21
2001-02	1 604	9	0	-	Ratio	9	3-18
2002-03	1 351	11	0	-	Ratio	7	2-15
2003-04	1 363	12	3	1.8	Ratio	10	5-18
2004-05	1 275	0	NA	NA	Ratio	8	2-16
2005-06	1 331	9	1	0.9	Ratio	9	3-16
2006-07	1 328	7	1	1.1	Ratio	9	3-16
2007-08	1 327	7	0	-	Ratio	8	2-15
2008-09	1 457	4	1	1.6	Ratio	10	3-18
2009-10	940	10	0	-	Ratio	5	1-11
2010-11	1 401	15	0	-	Ratio	7	2-15
2011-12	1 247	10	0	-	Ratio	7	2-15
2012-13	1 067	10	0	-	Ratio	6	1-13
Auckland Islands other							
1995-96	406	6	1	4	Ratio	2	1-6
1996-97	296	4	0	-	Ratio	1	0-4
1997-98	684	17	1	0.8	Ratio	3	1-8
1998-99	525	10	1	1.8	Ratio	3	1-7
1999-00	750	13	0	-	Ratio	3	0-8
2000-01	578	7	0	-	Ratio	2	0-7
2001-02	589	4	0	-	Ratio	2	0-7
2002-03	543	13	0	-	Ratio	2	0-6
2003-04	289	17	0	-	Ratio	1	0-4
2004-05	170	7	0	-	Ratio	1	0-3
2005-06	39	15	0	-	Ratio	0	0-1
2006-07	38	5	0	-	Ratio	0	0-1
2007-08	147	45	0	-	Ratio	0	0-2
2008-09	121	50	0	-	Ratio	0	0-2
2009-10	77	66	0	-	Ratio	0	0-1
2010-11	131	37	0	-	Ratio	0	0-2
2011-12	57	30	0	-	Ratio	0	0-1
2012-13	60	43	0	-	Ratio	0	0-1

Table 3.7 Sea lion captures in Campbell Island southern blue whiting (SBW) and in Stewart-Snares shelf trawl fisheries between 1995 and 2013 (http://data.dragonfly.co.nz/psc/ Data version v201404131). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model or ratio estimate), and the number of estimated sea lion captures (with 95% confidence interval, c.i.) (see Thompson et al (2013) and Abraham et al (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.
Campbell Island SBW							
1995-96	474	27	0	0	Model	0	0-3
1996-97	641	34	0	0	Model	0	0-3
1997-98	963	29	0	0	Model	1	0-5
1998-99	788	28	0	0	Model	1	0-5
1999-00	447	52	0	0	Model	0	0-3
2000-01	672	60	0	0	Model	0	0-2
2001-02	980	28	1	0.4	Model	4	1-11
2002-03	599	43	0	0	Model	0	0-3
2003-04	690	34	1	0.4	Model	3	1-9
2004-05	726	37	2	0.7	Model	5	2-12
2005-06	521	28	3	2.1	Model	10	3-22
2006-07	544	32	6	3.5	Model	15	6-29
2007-08	557	41	2	0.9	Model	8	5-14
2008-09	627	20	0	0	Model	1	0-7
2009-10	550	43	11	4.7	Model	24	15-37
2010-11	886	39	6	1.7	Model	15	8-24
2011-12	592	77	0	0	Model	1	0-3
2012-13	693	100	21	3	Model	21	21-22
Stewart-Snares (mainly squid)							
1995-96	3 423	8	0	-	Ratio	3	0-7
1996-97	5 077	10	0	-	Ratio	4	0-9
1997-98	5 777	10	0	-	Ratio	5	1-10
1998-99	7 597	16	0	-	Ratio	6	1-12
1999-00	5 263	23	3	0.3	Ratio	7	3-11
2000-01	5 678	43	3	0.1	Ratio	6	3-10
2001-02	5 125	18	1	0.1	Ratio	5	1-10
2002-03	4 348	16	0	-	Ratio	3	0-8
2003-04	5 085	21	1	0.1	Ratio	5	1-9
2004-05	6 206	24	3	0.2	Ratio	7	4-12
2005-06	4 950	19	1	0.1	Ratio	5	1-9
2006-07	3 494	24	1	0.1	Ratio	3	1-7
2007-08	3 238	36	1	0.1	Ratio	3	1-6
2008-09	2 534	31	0	-	Ratio	2	0-5
2009-10	2 765	43	1	0.1	Ratio	2	1-5
2010-11	2 451	36	0	-	Ratio	1	0-4
2011-12	2 289	50	1	0.1	Ratio	2	1-4
2012-13	2 735	68	1	0.1	Ratio	2	1-4

*SLEDs introduced in that year

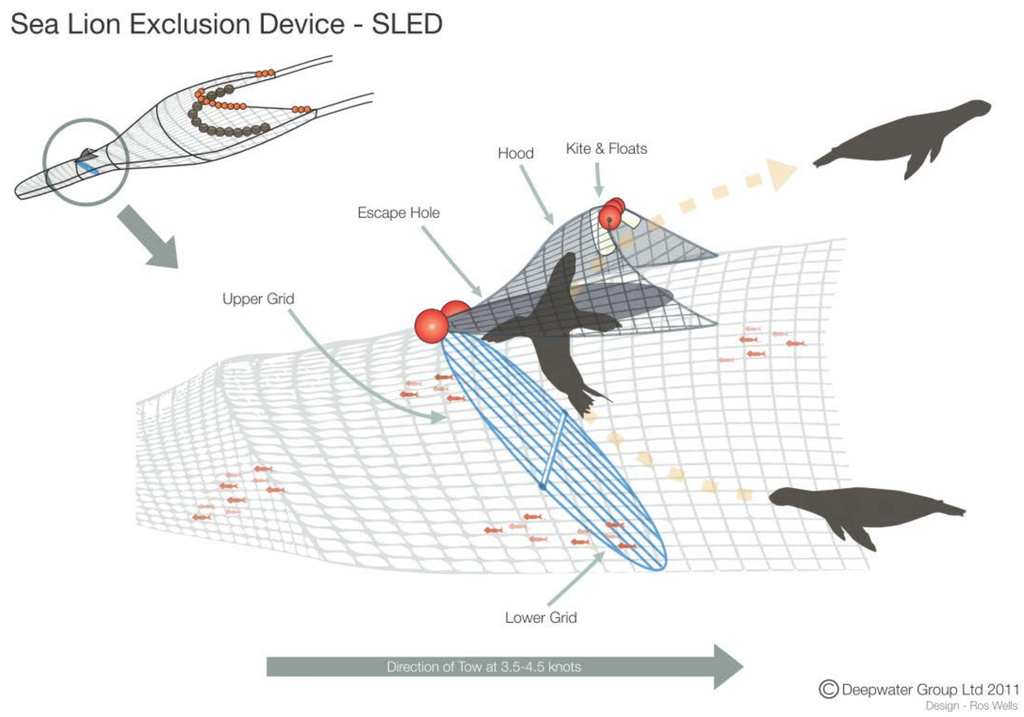


Figure 3.4: Diagram of a NZ sea lion exclusion device (SLED) inside a trawl net. Image courtesy of the Deepwater Group.

Before the widespread use of SLEDs, NZ sea lions incidentally caught during fishing were usually retained in trawl nets and hauled on board, allowing observers to gain an accurate assessment of the number of NZ sea lions being captured on observed tows in a given fishery. This enabled a robust estimation of the total number of NZ sea lions killed. However, following the introduction of SLEDs, the number of NZ sea lions interacting with trawls and the proportion of those surviving are considerably more difficult to estimate. Since the introduction of SLEDs, therefore, estimates of the number of NZ sea lions interacting with trawls to monitor performance against any mortality limits set have had to be made using a predetermined strike rate. Using a predetermined strike rate enables the FRML to be converted into a number of tows for management purposes. The rate of 5.65% assumed by MPI for the SQU6T fishery is based on rates observed on vessels without SLEDs from 2003-04 to 2005-06 and is also assumed as part of the fishery implementation within an integrated management procedure evaluation model (named the BFG model after its authors, see Section 3.4.3). A strike rate of 5.89 is currently assumed, reflecting a slight increase in the long-term average estimated from the model. The most recent strike rates are given in Table 3.4 (see also Thompson et al 2013).

The current management regime for the SQU6T fishery provides for a "discounted" strike rate to apply to all tows when an approved SLED is used (because SLEDs allow some NZ sea lions to escape and survive their encounters with trawl nets; Thompson & Abraham 2010, see Table 3.8). The SLED discount rate is a fisheries management setting and should not be confused with the actual survival of NZ sea lions that encounter a trawl equipped with a SLED, but the discount mechanism is duplicated in the BFG simulations. The current discount rate of 82% means that the strike rate is reduced from 5.89% to 1.06% so that, for every 100 tows using an approved SLED, 1.06 NZ sea lions are presumed killed. Ideally, the discount rate would be equal to the survival rate of NZ sea lions that encounter a trawl in circumstances that would be fatal if no SLED were fitted. This survival rate is the product of the proportion of animals that exit a trawl with a SLED and their post-exit survival.

Table 3.8: Maximum allowable level of fisheries-related mortality (MALFiRM) or fisheries-related mortality limit (FRML) from 1991 to 2014. Note, however, that direct comparisons among years of the limits in Table 3.8 are not possible because the assumptions underlying the MALFiRM or FRML changed over time.

Year	MALFiRM or FRML	Discount rate	Management actions
1991–92	16 (female only)		
1992–93	63		
1993–94	63		
1994–95	69		
1995–96	73		Fishery closed by MFish (4 May)
1996–97	79		Fishery closed by MFish (28 March)
1997–98	63		Fishery closed by MFish (27 March)
1998–99	64		
1999–00	65		Fishery closed by MFish (8 March)
2000–01	75		Voluntary withdrawal by industry
2001–02	79		Fishery closed by MFish (13April)
2002–03	70		Fishery closed by MFish (29 March), overturned by High Court
2003–04	62 (124)	20%	Fishery closed by MFish (22 March), overturned by High Court FRML increased
2004–05	115	20%	Voluntary withdrawal by industry on reaching the FRML
2005–06	97 (150)	20%	FRML increased in mid-March due to abundance of squid
2006–07	93	20%	
2007–08	81	35%	
2008–09	113 (95)	35%	Lower interim limit agreed due to the decrease in pup numbers
2009–10	76	35%	
2010–11	68	35%	
2011–12	68	35%	
2012–13	68	82%	
2013–14	68	82%	

In 2004, the Minister of Fisheries requested that the squid fishery industry organisation (Squid Fishery Management Company), government agencies and other stakeholders with an interest in sea lion conservation work collaboratively to develop a plan of action to determine SLED efficacy. In response, an independently chaired working group (the SLED Working Group) was established to develop an action plan to determine the efficacy of SLEDs, with a particular focus on the survivability of NZ sea lions that exit the nets via the exit hole in the SLED. The group undertook a number of initiatives, most notably the standardisation of SLED specifications (including grid spacing) across the fleet (DOC CSP project MIT 2004/05 - Clement and Associates Ltd. 2007) and the establishment of an underwater video monitoring programme to help understand what happens when a NZ sea lion exits a SLED. White light and infra-red illuminators were tested. Sea lions were observed outside the net on a number of occasions, but only one fur seal and one NZ sea lion were observed exiting the net via the SLED (on tows when white light illumination was used). The footage contributed to understanding of SLED performance, but established that video monitoring was only suitable for tows using mid water gear, as the camera view was often obscured on tows where bottom gear was used (Middleton & Banks 2008). The SLED Working Group was disbanded in early 2010.

The original “MALFiRM” was calculated using the potential biological removal approach (PBR; Wade 1998) and was used from 1992-93 to 2003-04 (Smith & Baird 2007a). Since 2003-04 the FRML has been translated into a maximum permitted number of tows after which the SQU6T fishing season may be halted by the Minister regardless of the observed NZ sea lion mortality. This approach has been taken because NZ sea lion mortality can no longer be monitored directly since the introduction of SLEDs.

3.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

The population-level impact of fisheries interactions has been assessed for the Auckland Islands via a management procedure evaluation model for the SQU6T fishery (see below). The impact of fisheries interactions for all NZ sea lion populations (and other marine mammal populations) will be assessed as part of the marine mammal risk assessment project (PRO2012-02). The goal of this project is to assess the risk posed to marine mammal populations from New Zealand fisheries by applying a similar approach to the recent seabird risk assessment (Richard et al 2011). In this approach, risk is defined as the ratio of total estimated annual fatalities due to mortality in fisheries, to the level of PBR (Wade 1998). The results of this project should be available in 2014. Note that the PBR approach was recently also used to identify the level of fishery interactions that would cause adverse effects on the Campbell Island subpopulation (Roberts et al 2014).

Since 2000, an integrated Bayesian management procedure evaluation model having both population and fishery components has been used to assess the likely performance of a variety of management control rules, each of which can be used to determine the FRML for a given SQU6T season (Breen et al 2003, Breen & Kim 2006a, Breen & Kim 2006b, and Breen, Fu & Gilbert 2010). The model underwent several iterations. An early version, developed in 2000-01, was a relatively simple deterministic, partially age-structured population model with density-dependence applied to pup production (Breen et al 2003). An updated version called the Breen-Kim model was built in 2003 to render it fully age-structured and to incorporate various datasets supplied by DOC (Breen & Kim 2006a, 2006b). This model was further revised in 2007-08 to incorporate the latest NZ sea lion population data and to address various model uncertainties and called the BFG model (after its authors, Breen, Fu & Gilbert 2010). In 2009, the model was again updated to incorporate the low NZ sea lion pup counts observed in 2008-09 (and thus better reflect the observed variability in pup survival and pupping rates), as well as incidental captures in fisheries other than SQU6T. The BFG model was re-run in 2011 using the same underlying data and structure as in 2009 to evaluate the effect of different model assumptions about the survival of NZ sea lions that exit trawl nets via SLEDs (see below). Additional details on the NZ sea lion population model can be found in Breen et al (2010).

The BFG model incorporates various population dynamics observations (tag re-sighting observations, pup births and mortality, age at maturity) as well as incidental captures and catch-at-age data from the SQU6T trawl fishery. The model was projected into the future by applying the observed dynamics and a virtual fishery model that is managed in roughly the same way as the real SQU6T fishery. A large number of projections were run and used to assess the likely performance of a wide range of different management control rules against the four performance criteria described in Section 3.1: Context (two MFish criteria and two DOC criteria). For each set of runs the population indicators were summarised and the rules compared in tables. The BFG model is sensitive to several key assumptions (see Sources of uncertainty, below).

SLEDs are effective in allowing most NZ sea lions to exit a trawl but some are retained and drowned and others may not survive the encounter. An experimental approach to assessing non-retained fatality rate involved intentionally capturing animals as they exited the escape hole of a SLED between 1999-2000 and 2002-03. Cover nets were added over the escape holes of some SLEDs and sea lions were restrained in these nets after they exited the SLED proper. An underwater video camera was deployed in 2001 to assess the behaviour and the likelihood of post-exit survival of those animals that were retained in the cover nets (Wilkinson et al 2003, Mattlin 2004). The low number of captures filmed and the inability to assess longer term survival meant that this approach could not be used to determine likely survival rates (e.g., Roe 2010).

Necropsies were conducted on animals recovered from the cover net trials and on those incidentally caught and recovered from vessels operating in the SQU6T, SQU1T and SBW6I fisheries. Although all of the NZ sea lions returned for necropsy died as a result of drowning rather than physical trauma from interactions with the trawl gear including the SLED grid; (Roe & Meynier 2010, Roe 2010), necropsies were designed to assess the nature and severity of trauma sustained during capture and to infer the survival prognosis had those animals been able to exit the net (Mattlin 2004). However, problems associated with this approach limited the usefulness of the results. For example, NZ sea lions had to be frozen on vessels and stored for periods of up to several months before being thawed for 3–5 days to allow necropsy. Roe & Meynier (2010) concluded that this freeze-thaw process created artefactual lesions that mimic trauma but, particularly in the case of brain trauma, could also obscure real lesions. Further, two reviews in 2011 concluded that the lesions in retained animals may not be representative of the injuries sustained by animals that exit a trawl via a SLED (Roe & Meynier 2010, Roe 2010). As a result of these reviews, the use of necropsies to further infer the survival of sea lions interacting with SLEDs was discontinued.

Notwithstanding the limitations of the necropsy data in assessing trauma for previously frozen animals, it was possible to determine that none of the necropsied animals sustained sufficient injuries to the body (excluding the head) to compromise survival (Roe & Meynier 2010, Roe 2010). Any head trauma, most likely due to impacts with the SLED grid, could not be ruled out as a potential contributing factor (Roe & Meynier 2010, Roe 2010). In order to quantify the likelihood of a NZ sea lion experiencing physical trauma sufficient to render the animal insensible (and therefore likely to drown) after a collision with a SLED grid, a number of factors need to be assessed. These include the likelihood of a head-first impact, the speed of impact, the angle of impact relative to individual grid bars and relative to the grid plane, the location of impact on the grid, head mass, and the risk of brain injury for a given impact speed and head mass. The effect of multiple impacts also needs to be considered. Estimates for each of these factors were obtained from a number of sources, including necropsies (for head mass), video footage of Australian fur seals interacting with Seal Exclusion Devices (SEDs) (for impact speed, location and body orientation) and biomechanical modelling of impacts on the SLED grid (for the risk of brain injury).

In the absence of sufficient video footage of NZ sea lion interacting with SLEDs, footage of fur seals (thought to be Australian fur seals) interacting with SEDs in the Tasmanian small pelagic mid-water trawl fishery has been used (Lyle 2011). The SEDs are similar, but not identical, to the New Zealand SLEDs in that both have sloping steel grids to separate the catch from pinnipeds and guide the latter toward an escape hole in the trawl. The angle of slope and the number of sections in the steel grids are variable (either two or three sections, depending on the vessel). Lyle & Willcox (2008) conducted a camera trial between January 2006 and February 2007 to assess the efficacy of the SED and documented 457 interactions for about 170 individual fur seals. Lyle (2011) reanalysed the footage to estimate impact speed, impact location across the SED grid and body orientation at the time of impact. The situation faced by NZ sea lions in a squid trawl is not identical to that faced by the fur seals studied by Lyle and co-workers, but these are closely related otariids of similar size and, in the absence of specific data, Australian fur seals are considered a reasonable proxy to estimate impact speed, impact location and body orientation.

The risk of brain injury was assessed by biomechanical testing and modelling. Tests using an artificial “head form” (as used in vehicular “crash test” studies) were used to assess the likelihood of brain injury to NZ sea lions colliding with a SLED grid (Ponte et al 2010, 2011). In an initial trial (Ponte et al 2010), the head form (weighing 4.8 kg) was launched at three locations on the SLED grid at a speed of 10 $m.s^{-1}$ (about 20 knots). This was considered a “worst feasible case” collision representing the combined velocities of a sea lion swimming with a burst speed of 8 $m.s^{-1}$ (after Ray 1963, Fish 2008) and a net being towed at 2 $m.s^{-1}$ (about 4 knots). A head injury criterion (HIC, a predictor of the risk of brain injury) was calculated based on criteria validated against human-vehicle impact studies and translated into the probability of mild traumatic brain injury (MTBI) for a given collision, taking into account differences between human and sea lion head and brain masses. MTBI is assumed to have the potential to lead to insensibility or disorientation and subsequent death through drowning for a NZ sea lion experiencing such an injury at depth. Ponte et al (2010) calculated that a collision at the stiffest part of the SLED grid at this highest feasible speed had a very high risk of MTBI, especially for smaller sea lions (female and small, immature males). This provides an upper bound for the assessment of risk but Ponte et al (2010) also imputed risk at speeds below the maximum tested (10 $m.s^{-1}$).

In a follow-up study, after a research advisory group meeting with other experts, Ponte et al (2011) tested a wider variety of impact locations on the grid and various angles of impact relative to the bars and to the plane of the grid and combined these to produce a HIC “map” for a SLED grid. This HIC map can be used to estimate the risk of MTBI for a collision by a sea lion at any given speed, location, and orientation used to model the risk of MTBI.

The data collected from the footage of Australian fur seal SED interactions (Lyle 2011) and the biomechanical modelling (Ponte et al 2010, 2011) were combined in a simulation-based probabilistic model to estimate the risk of a sea lion suffering a mild traumatic brain injury when striking a SLED grid (Abraham 2011). The simulation involved selecting an impact location on the SLED grid (from the fur seal data), selecting a head mass (from NZ sea lion necropsy data) and an impact speed (from the fur seal data), calculating the head impact criterion (HIC) (from the HIC map), scaling the HIC to the head mass and impact speed and calculating the expected probability of mild traumatic brain injury, MTBI. Both 45° and 90° degree impacts were considered, with the former, reflecting the angle of a grid when deployed, adopted as the base case. The head masses used may be at the lower end of the range of head masses for NZ sea lions, due to the possible bias in those that were caught and necropsied. Impact speeds were drawn from the distribution of speeds observed for fur seals colliding with SEDs (2–6 $m.s^{-1}$) and these are broadly consistent with the combined tow speed and observed swimming speeds of NZ sea lions in the wild (Crocker et al 2001). Different scaling of HIC values was assessed to gauge sensitivity.

For the base case, the simulation results indicated there was a 3.3% chance of a single head-first collision resulting in MTBI with a 95 percentile of 15.7% risk of MTBI (Abraham 2011). Sensitivities modulating single parameters resulted in up to 6.2% probability of a single collision resulting in MTBI. One sensitivity trial involving changes in multiple parameters resulted in a 10.9% probability of MTBI. This scenario considered impact speeds 20% above those measured for fur seals, multiple collisions with the grid, and the least favourable values of scaling exponents used in scaling the test HIC values and calculating MTBI from the HIC (Abraham 2011). These results are probabilities of MTBI resulting from a single head first collision but, because each individual can have multiple interactions with the grid while in a trawl, and some of these will not be head-first. Using Australian observations, Abraham (2011) estimated the number of head-first collisions per interaction as 0.74, leading to an estimated probability of MTBI for a NZ sea lion interacting with a trawl of 2.7%. Single parameter sensitivity runs increased this to up to 4.6% and the multiple parameter sensitivity using the scenario described above increased it to 8.2% (Abraham 2011). Assuming synergistic interaction between successive head-first strikes (each collision carrying 5 times more risk than previous ones) did not appreciably increase the overall risk because few fur seals had multiple head-first collisions. These results indicate that the risk of mortality for NZ sea lions interacting with the SLED grid is probably low, although some remaining areas of uncertainty were identified (see below).

3.4.4 PBR ASSESSMENT FOR CAMPBELL ISLAND POPULATION

Following an unprecedented number of incidental captures of NZ sea lions in the Campbell Rise Southern blue whiting fishery (SBW6I) in 2013, the Deepwater Group requested an expedited audit to assess whether or not the fishery was still in conformance with the Marine Stewardship Council Fisheries Standard (i.e. were interactions below the level that would cause adverse effects on sea lion population size). A review was conducted of PBR guidelines and relevant scientific literature to inform the selection of appropriate PBR parameter values for the Campbell Island sub-population (Roberts, Roux & Ladroite, 2014). The PBR is a standard approach to defining a safe level of human related mortalities of marine mammals, which was originally developed for the US Marine Mammals Protection Act (Wade 1998). It is calculated as:

$$PBR = N_{min} \times {}^{R_{max}}/_{2} \times F_R$$

where R_{max} is the population growth rate at very low population size with only natural morality operating, N_{min} is a “minimum” estimate of the total population size and F_R is a recovery factor applied to account for uncertainty or biases that may otherwise lead to overestimation of the PBR and so hinder recovery to an optimum sustainable population (OSP) level. The value of F_R may also be adjusted to meet different population management objectives.

The latest pup census at Campbell Island (681 pups in 2009-10; Maloney et al, 2012) was taken as a robust lower estimate of total pup production. A matrix modelling analysis was conducted to estimate plausible pup to whole of population multipliers of 4.5 and 5.5, which were applied to the pup census estimate to calculate N_{min} values of 3 065 and 3 746. The rate of increase in pup counts from a time series of pup censuses was used as an approximation to whole of population growth rate for estimating a credible lower limit of R_{max}. Values of 0.06, 0.08 and 0.10 were used in PBR calculations, with the upper and lower limits considered as plausible bounds for this parameter used in a sensitivity analysis. The Auckland Islands and Campbell Island sub-populations are likely to constitute demographically independent populations (DIPs) and so, according to the latest guidelines on PBR assessment, may be assessed as separate stocks (Moore &

Merrick 2011). Therefore the recovery factor (F_R) of 0.5 was used for stocks of a threatened species with unknown (or not declining) population trajectory. The latest PBR guidance literature recommends a more conservative F_R of 0.1 for stocks of an endangered species and is the lower limit that might be considered for declining populations of a threatened species (Roberts, Roux & Ladroite 2014).

Previous to 200506 the annual number of captures was very low, though capture rate appears to have increased since, with the greatest number of captures in 2012–13 (Table 3.7). Running means of capture levels (3 and 5-year) were also calculated for comparison with PBR estimates. For an F_R of 0.5, and the selected estimates of N_{min} (3,065) and R_{max} (0.08) the calculated PBR was 61. Estimated captures did not exceed the PBR in any year when the default F_R of 0.5 was used, regardless of which other parameter values used. When the lower F_R of 0.1 was used, the calculated PBR of 12 was exceeded in two years when using a 3-year running mean of captures and in one year with a 5-year running mean of captures. When a F_R of 0.2 was used, the calculated PBR of 25 was not exceeded in any year. There has been a very strong bias towards males in observed captures (Thompson et al 2013). An array of female-only PBRs was estimated by halving the PBR for all animals and was not exceeded by female captures in any year regardless of which combination of parameter values was used (Roberts, Roux & Ladroite 2014).

3.4.5 SOURCES OF UNCERTAINTY

There are several outstanding sources of uncertainty in modelling the effects of fisheries interactions on NZ sea lions at the Auckland Islands, including uncertainty relating to the Bayesian management procedure evaluation model (the BFG model, Breen et al 2010), uncertainty in the modelling of strike rate (Thompson et al 2013) and uncertainty relating to the biomechanical modelling (Ponte et al 2010, 2011, Abraham 2011, Lyle 2011).

The BFG model is sensitive to several key parameters. Some relate mostly to uncertainty about the productivity of the NZ sea lion population (including maximum population growth rate, abundance relative to carrying capacity, maximum rate of pup production, and density dependence), whereas others relate to how the fishery works and is managed (including strike rates and the survival of NZ sea lions that interact with SLEDs but are not retained in the net). Conclusions drawn from the BFG model results are sensitive to prior assumptions about how fast this NZ sea lion population is able to grow. The maximum population growth rate (lambda, λ) for this population of NZ sea lions is not known. Fitting the model to the observed data with an uninformative prior led to an estimated maximum rate of less than 1% per year. This is a very low maximum growth rate for a pinniped (some suggest a default value of 12% per year, Wade 1998), so a prior of 8% was applied to the base model. In a sensitivity run, the model was fitted using a prior of 5% per year, and the results were more consistent with the observed data than when 8% was used. An independent review in 2013 (details below) identified that the survival parameter for late stage juveniles and the first two years of life was pushed up against its upper bound (implying that higher survival rates than the imposed upper limit of 95% would fit the model better). A model using a limit of 99% instead of 95% estimated much higher survival for these animals and was able to estimate lambda, λ, for the population as 6.8% with relatively little impact from its prior. This model was considered plausible as a base case by the review panel but has not been fully reviewed by AEWG.

The estimated abundance of NZ sea lions relative to the carrying capacity of mature individuals at the Auckland Islands (K) is another source of uncertainty. When the model is run in the absence of fishing, the median numbers of mature animals after 100 years was only 94.4% of K as estimated from the model. Although the population is not presently near K, over this timescale, the population would normally be expected to approach K. This is thought to be an artefact of the parameterisation of survival rates in the model, which renders the model conservative when assessing performance against K (Breen et al 2010).

A review of life-history traits such as pup mass, pup survival or female fecundity found no evidence for density dependent responses in the Auckland Islands population (Chilvers 2012b). However a number of indicators of nutritional stress have been identified during the period of population decline, including a temporal shift in diet composition to small-sized prey (Childerhouse et al 2001, Stewart-Sinclair 2013), low pupping rate/delayed age at first pupping (Childerhouse et al 2010b, Roberts et al 2014), low pup/yearling survival rate (Roberts et al 2014) and reduced maternal condition (Riet-Sapriza et al 2012; Roberts & Doonan 2014) – all of which are common density dependent responses. These responses have become more apparent as the population has decreased in size indicating that changes in carrying capacity may have occurred.

Ecological principles suggest that, as numbers in a population decline or as key resources increase, individuals compete less with one another for resources. Less competition may result in NZ sea lions growing faster as well as having lower mortality rates and higher rates of pup production and survival. The effect of this type of response is that populations tend to recover from events that reduce their numbers, and populations with strong density dependence recover more strongly than those with weak density dependence. In the BFG model, the shape of the density dependent response was "hard wired" in the model and assumed to occur entirely in the mortality rate of pups. The actual strength of this response is unknown, and there was no information to support a strong preference for any of the assumed values used in sensitivity runs. This means the base model results may be either conservative or optimistic.

The maximum rate of pup production for this population is not known but can be estimated in the population model. Other modelling conducted for DOC (albeit using different assumptions, Breen et al 2010) suggests that the maximum rate of pup production is <0.28 pups per mature adult per year (Gilbert & Chilvers 2008), a level thought to be below that required to replace the population (Breen et al 2010). When this value is fixed in the BFG model, the fitting procedure does not converge successfully. The BFG model authors progressively increased the fixed value until overall fitting was successful at 0.315 pups per mature adult per year. Thus, the BFG model estimates, and can accommodate, only maximum rates of pup production that are roughly 15% higher than those estimated by direct modelling.

In addition to sources of uncertainty for inputs in the BFG model, there are other sources of uncertainty relevant to the management of fisheries interactions. For example, the estimated strike rate has varied considerably over time, and the model estimates of both the number of interactions and strike rates for recent years are effectively unbounded (Thompson et al 2013, Table 3.4). Although year on year variation in strike rate is unlikely to appreciably affect the conclusions from the simulations, if the long-term average strike rate is higher or lower than that assumed within the fishery component of the simulations, or if the strike rate or catchability has increased since the introduction of SLEDs, then there may be some bias. If NZ sea lion catchability has increased, as a result of the increased average tow duration in the SQU6T fishery since the introduction of SLEDs (Table 3.9), or by some other factor, then this would make the simulations optimistic.

Table 3.9: Tow duration in the SQU6T fishery (based on trawl fishing targeting SQU in statistical areas 602 and 618). Years are calendar years. Data from MPI databases.

Year	No. of tows	Mean tow duration (hours)	Percentage of tows		
			Less than 4 hours	Between 4 & 8 hours	More than 8 hours
1995	4 014	3.7	64.2	33.5	2.2
1996	4 474	3.6	64.3	34.2	1.5
1997	3 719	3.8	62.7	33.7	3.7
1998	1 446	3.2	74.4	24.7	0.9
1999	403	3.5	73.0	24.3	2.7
2000	1 213	3.5	70.3	27.0	2.7
2001	583	3.3	72.9	26.6	0.5
2002	1 647	3.8	59.8	38.8	1.4
2003	1 467	4.1	52.4	44.0	3.6
2004	2 598	5.0	36.7	53.6	9.7
2005	2 693	4.7	43.7	48.6	7.7
2006	2 462	6.3	26.0	49.6	24.3
2007	1 317	7.3	18.9	46.3	34.8
2008	1 265	6.2	20.4	58.7	20.9
2009	1 925	6.5	21.1	51.4	27.5
2010	1 190	7.9	16.4	37.4	46.2
2011	1 585	6.8	24.7	42.8	32.4
2012	1 283	6.6	23.5	49.3	27.3
2013	1 027	7.1	18.7	49.4	31.9
2014	737	6.9	17.8	51.5	30.7

There are a number of possible sources of uncertainty relating to the biomechanical modelling (Ponte et al 2010, 2011, Abraham 2011, Lyle 2011). The use of linear acceleration, as opposed to rotational (angular) acceleration, in the biomechanical modelling may underestimate the risk of MTBI, although this was thought to be accounted for at least in part by sensitivity analysis of the scaling of HIC values. The testing used an artificial "head form" based on human anatomy, so the effect of NZ sea lion scalp thickness and skull morphology is unknown, although differences in head and brain masses are accounted for. Potential effects of differences in the angle of the head on impact (relative to the neck) were not tested. Impact speeds, locations and orientations of NZ sea lions may differ from those of Australian fur seals, although the fur seal data were considered to be a reasonable proxy by a Research Advisory Group. The head mass values used may be lower than average for NZ sea lions; this would mean risk is likely to be overestimated. This approach assesses risk associated with collisions with the grid of a SLED and cannot be used to assess other sources of mortality resulting, for example, from an animal being retained in a net long enough for them to exceed their dive limit before reaching the surface after escaping from either the SLED or the front of the net. Such sources of cryptic mortality have always existed, are presently unquantified and are not reflected in the estimated overall survival rate of encounters with trawls.

The Breen-Fu-Gilbert model was reviewed by a diverse, independent panel of experts in July 2013 (Bradshaw, Haddon & Lonergan 2013). The panel found that the model was correctly implemented and appeared to be an acceptable basis for continued development. However, the panel also noted that some of the assumptions of the model included unknown and unaccounted for uncertainty, and some of these were potentially important for the assessment of risk (i.e., the chance of meeting the agreed management criteria). Key among these were:

- post-exit SLED mortality of sea lions (i.e., cryptic mortality)
- the nature and strength of the density-dependent response
- the relationship between tow length and the chance of sea lion captures

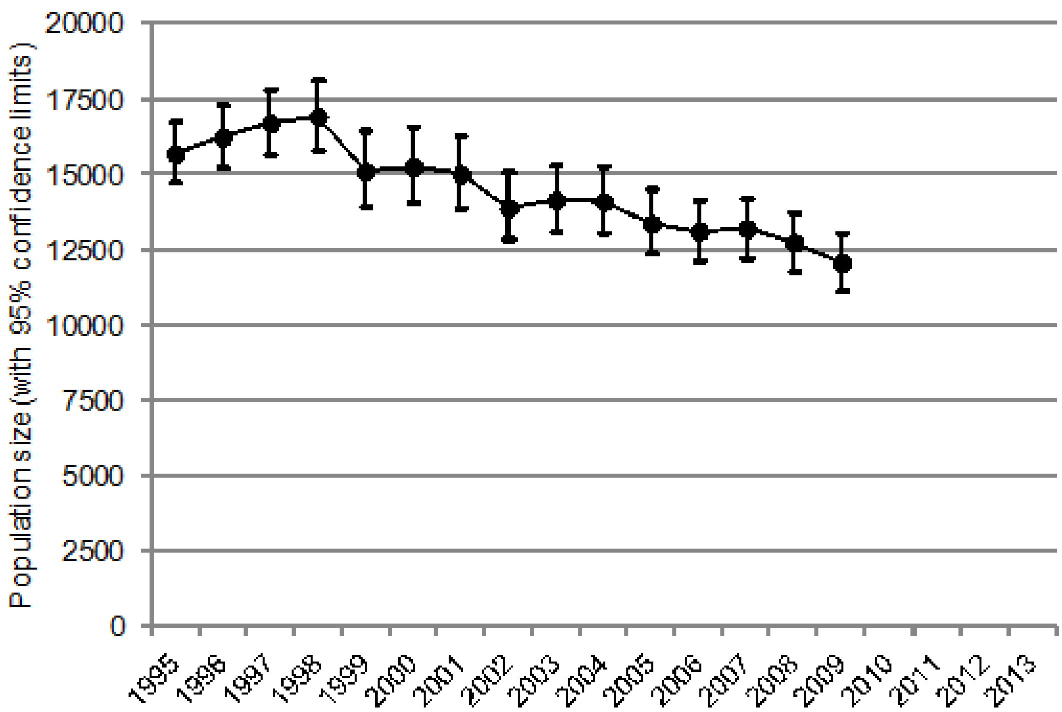
The panel made several suggestions for further testing and modification of the model and expected these to resolve many of the issues identified. Specific recommendations included consideration of a female-only model and an assessment of the sensitivity of outputs to the choice of time series of incidental captures, including pre-1980 estimates. Where no data exist, and are likely to be difficult to obtain, the panel suggested explicit acknowledgement of all subjective judgements and assumptions in the model and its predictions. The panel concluded that, until the model has been modified, tested and re-run, it would not be possible to test explicitly whether the current limits upon the SQU6T fishery will succeed in meeting the agreed management criteria. MPI is working through these comments and recommendations.

3.4.6 POTENTIAL INDIRECT THREATS

In addition to sources of uncertainty associated with direct fisheries interactions, there is the possibility that indirect fisheries effects may have population-level consequences for NZ sea lions. Such indirect effects may include competition for food resources between various fisheries and NZ sea lions (Robertson & Chilvers 2011). In order to determine whether resource competition is present and is having a population-level effect on NZ sea lions, research must identify if there are resources in common for NZ sea lions and the various fisheries within the range of NZ sea lions, and if those resources are limiting. Diet studies have demonstrated overlap in the species consumed by NZ sea lions and those caught in fisheries within the range of NZ sea lions, particularly hoki and arrow squid (Cawthorn et al 1985, Childerhouse et al 2001, Meynier et al 2009). A recent study focused on energy and amino acid content of prey determined that the selected prey species contained all essential amino acids and were of low to medium energy levels (Meynier 2010). This study concluded that given low energy densities of prey, sea lions may be able to sustain energy requirements, but not necessarily store energy reserves and, thus, sea lions may be sensitive to factors that negatively affect trophic resources. Meynier (2010) also developed a bio-energetic model and used it to estimate the amount of prey consumed by NZ sea lions at 17 871 tonnes (95% CI 17 738–18 000 t) per year. This is equivalent to ~30% of the tonnage of arrow squid, and ~15% of the hoki harvested annually by the fisheries in the Sub-Antarctic between 2000 and 2006 (Meynier 2010). Comparison of the temporal and spatial distributions of sea lion prey, sea lion foraging and of historical fishing extractions may help to identify the mechanisms whereby resource competition might occur (Bowen 2012). The effects of fishing on sea lion prey species are likely to be complicated by food web interactions and multispecies models may help to assess the extent to which resource competition can impact on sea lion populations, such as those currently being developed by NIWA. In addition, multispecies models may provide a means for simultaneously assessing multiple drivers of sea lion population change (a review of potential causes is given in Robertson & Chilvers 2011) which may be a more effective approach than focussing on single factor explanations for the recent observed decline in NZ sea lions (Bowen 2012).

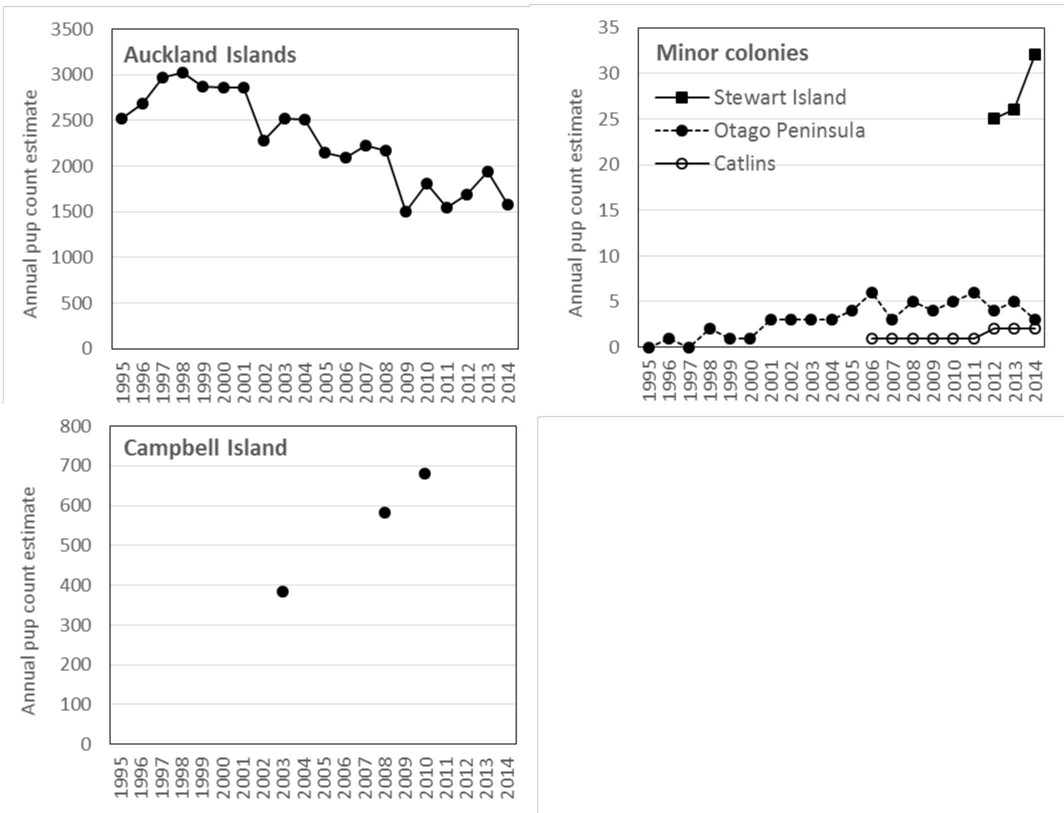
3.5 INDICATORS AND TRENDS

<table>
<tr><td>Population size</td><td>12 065 animals (including pups < 1 yr old) at the Auckland Islands (90% CI: 11 160–13 061) in 2009 (most recent model estimate)[10]
1 575 pups at the Auckland Islands in 201314[11]
681 pups at Campbell Island in 2010[12]
32 pups tagged at Stewart Island in 2014[13]
3 pups at the Otago Peninsula in 201314[14]</td></tr>
<tr><td>Population trend</td><td>Estimated abundance at the Auckland Islands:



Estimated pup production at the Auckland Islands, Campbell Island and minor colonies:</td></tr>
</table>

[10] Breen et al (2010).
[11] Childerhouse et al (2014)
[12] Robertson & Chilvers (2011), Maloney et al (2012)
[13] Chilvers (2014)
[14] Fyfe pers. comm.

	
Threat status	NZ: Nationally Critical, Criterion C[15], Range Restricted[16], in 2010[17] IUCN: Vulnerable, A3b[18], in 2008[19]
Number of interactions[20]	No estimate of the number of interactions was made for 2011/12 13 estimated captures (95% ci: 5–23) in trawl fisheries in 2011/12 1 observed capture in trawl fisheries in 2011-12

Trends in interactions	Observed and estimated captures in all trawl fisheries:

[15] A taxon is listed as 'Nationally Critical' under criterion C if the population (irrespective of size or number of sub-populations) has a very high (rate of) ongoing or predicted decline; greater than 70% over 10 years or three generations, whichever is longer (Townsend et al 2008).

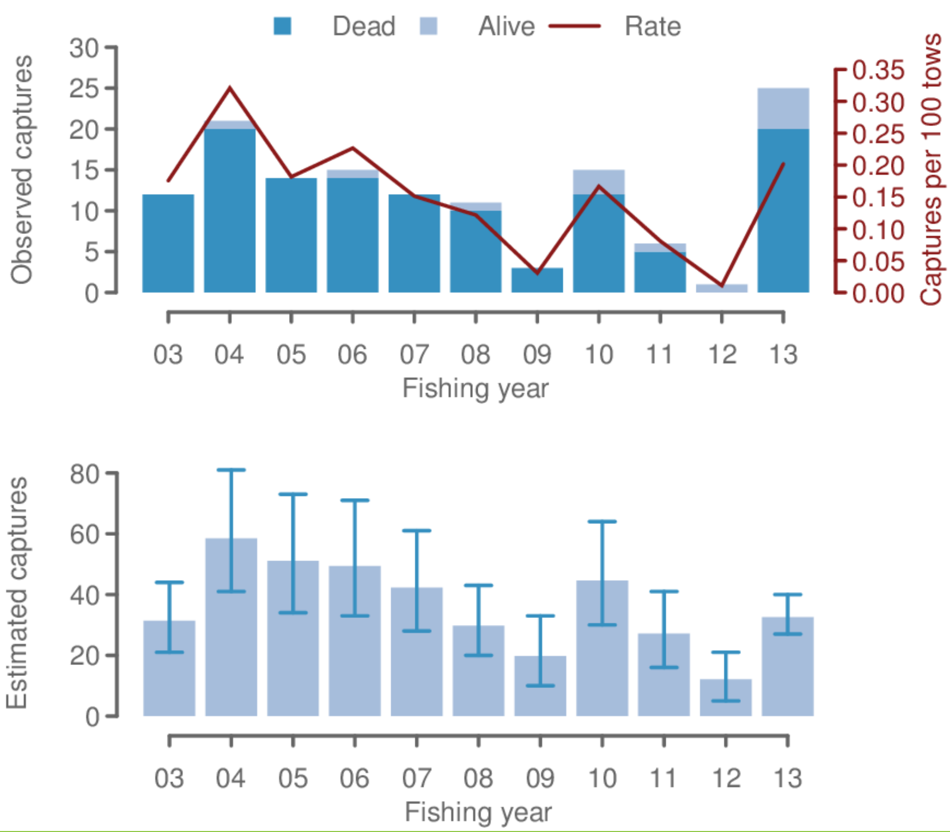
[16] A taxon is listed as 'Range Restricted' if it is confined to specific substrates, habitats or geographic areas of less than 1000 km^2 (100 000 ha); this is assessed by taking into account the area of occupied habitat of all sub-populations (Townsend et al 2008).

[17] Baker et al (2010)

[18] A taxon is listed as 'Vulnerable' if it is considered to be facing a high risk of extinction in the wild. A3b refers to a reduction in population size (A), based on a reduction of ≥ 30% over the last 10 years or three generations (whichever is longer up to a maximum of 100 years (3); and when considering an index of abundance that is appropriate to the taxon (b; IUCN 2010)

[19] Gales (2008)

[20] For more information, see: http://data.dragonfly.co.nz/psc/.



3.6 REFERENCES

Abraham, E R (2011) Probability of Mild Traumatic Brain Injury for sea lions interacting with SLEDs. Final Research Report for Ministry of Fisheries project SRP2011-03 (Unpublished report held by the Ministry for Primary Industries, Wellington). 21 pages.

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. (Unpublished report held by the Ministry for Primary Industries, Wellington.) 170 p.

Anonymous (2009). DWG and MFish SLED Specification for SQU 6T 2010 Operation Plan (MK 3/13). Report presented to SLED WG September 2009, Wellington, NZ.

Augé, A A (2006) Terrestrial spatial ecology of female New Zealand sea lions. Unpublished MSc thesis, University of Otago, Dunedin.

Augé, A A; Chilvers, B L; Moore, A B; Davis, L S (2011b) Foraging behaviour indicates marginal habitat for New Zealand sea lions: remnant vs recolonising. Marine Ecology Progress Series 432:247–256.

Augé, A A; Chilvers, B L; Davis, L S; Moore, A B (2011c) In the shallow end: diving behaviour of recolonising female New Zealand sea lions (*Phocarctos hookeri*) around the Otago Peninsula. Canadian Journal of Zoology 89:1195–1205.

Augé, A A; Lalas, C; Davis, L S; Chilvers, B L (2012) Autumn diet of recolonizing female New Zealand sea lions based at Otago Peninsula, South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 46: 97-110.

Augé, A A; Chilvers, B L; Moore, A B; Davis, L S (2013) Importance of studying foraging site fidelity for spatial conservation measures in a mobile predator. Animal Conservation DOI 10.1111/acv.12056.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand Marine Mammals (suborders Cetacea and Pinnipedia), 2009. New Zealand Journal of Marine and Freshwater Research 44: 101–115.

Baker, A J (1999) Unusual mortality of the New Zealand sea lion, *Phocarctos hookeri*, Auckland Islands, January–February 1998: A report of a workshop held 8–9 June 1998, Wellington, and a contingency plan for future events. pp. 29–33, Department of Conservation, Te Papa Atawhai, Wellington, New Zealand.

Baker, B; Jensz, K; Chilvers, L (2013) DRAFT Final Report for the Department of Conservation, Conservation Services Programme. Aerial survey of New Zealand sea lions – Auckland Islands 2012/2013. Latitude 42 Environmental Consultants Pty Ltd. 11 p.

Bradshaw, C J A; Lalas, C; McConkey, S (1998) New Zealand sea lion predation on New Zealand fur seals. New Zealand Journal of Marine and Freshwater Research 32: 101-104.

Bradshaw, C J A; Haddon, M; Lonergan, M (2013) Review of models and data underpinning the management of fishing-related mortality of New Zealand sea lions (*Phocarctos hookeri*), in the SQU6T trawl fishery, July 2013. Report of an independent review panel to Ministry for Primary Industries Fisheries Management Science Team, 28 September 2013. 69 p.

Breen, P A (2008) Sea lion data for use in the population model for Project IPA200609. Final Research Report for Ministry of Fisheries, 30 March 2008. 18 p. plus Confidential Appendix of 6 p. (Unpublished report held by Ministry for Primary Industries.)

Breen, P A; Hilborn, R; Maunder, M N; Kim, S W (2003) Effects of alternative control rules on the conflict between a fishery and a threatened sea lion (*Phocarctos hookeri*). Canadian Journal of Fisheries and Aquatic Sciences 60: 527–541.

Breen, P A; Kim, S W (2006a) Exploring alternative management procedures for controlling bycatch of Hooker's sea lions in the SQU 6T squid fishery. Final Research Report for Ministry of Fisheries Project M0F2002/03L, Objective 3. Revision 5, 3 February 2006. 88 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Breen, P A; Kim, S W (2006b) An integrated Bayesian evaluation of Hooker's sea lion bycatch limits. pp. 471-493 In: Trites, A; Atkinson, S; DeMaster, D.; Fritz, L; Gelatt, T; Rea, L; Wynne, K (eds.). Sea lions of the world. Alaska Sea Grant College Program, University of Alaska Fairbanks.

Breen, P A; Fu, D; Gilbert, D J (2010) Sea lion population modelling and management procedure evaluations: Report for Project SAP2008/14, Objective 2. Presented to AEWG March 22 2010, Wellington, New Zealand.

Bowen, W D (2012) A review of evidence for indirect effects of commercial fishing on New Zealand sea lions (*Phocarctos hookeri*) breeding on the Auckland Islands. Final Report May 2012, Contract Number: POP 2010/01 (Objectives 4 and 5). Department of Conservation, Wellington. 41 p.

Castinel, A; Duignan, P J; Pomroy, W E; López-Villalobos, N; Gibbs, N J; Chilvers, B L; Wilkinson, I S (2007) Neonatal mortality in New Zealand sea lions (*Phocarctos hookeri*) at Sandy Bay, Enderby Island, Auckland Islands from 1998 to 2005. Journal of Wildlife Diseases 43: 461–474.

Cawthorn, M W (1993) Census and population estimation of Hooker's sea lion at the Auckland Islands, December 1992–February 1993. DOC Technical Series 2. Wellington, Department of Conservation. 34 p.

Cawthorn, M W; Crawley, M C; Mattlin, R H; Wilson, G J (1985) Research on pinnipeds in New Zealand. Wildlife Research Liaison Group Report No. 7, Wellington, New Zealand.

Childerhouse, S; Gales, N (1998) The historic distribution and abundance of the New Zealand sea lion *Phocarctos hookeri*. New Zealand Journal of Zoology 25: 1–16.

Childerhouse, S J; Gales, N J (2001) Fostering behavior in New Zealand sea lions *Phocarctos hookeri*. New Zealand Journal of Zoology 28:189–195.

Childerhouse, S J; Dix, B; Gales, N J (2001) Diet of New Zealand sea lions (*Phocarctos hookeri*) at the Auckland Islands. Wildlife Research 28:291–298.

Childerhouse, S J; Gibbs, N; McAlister, G; McConkey, S; McConnell, H; McNally, N; Sutherland, D (2005) Distribution, abundance and growth of New Zealand sea lion *Phocarctos hookeri* pups on Campbell Island. New Zealand Journal of Marine and Freshwater Research 39: 889–898.

Childerhouse, S J; Dawson, S M; Slooten, E; Fletcher, D J; Wilkinson, I S (2010a) Age distribution of lactating New Zealand sea lions: interannual and intersite variation. Marine Mammal Science 26: 123–139.

Childerhouse, S J; Dawson, S M; Fletcher, D J; Slooten, E; Chilvers, B L (2010b) Growth and reproduction of female New Zealand sea lions. Journal of Mammalogy 91:165–176.

Childerhouse, S J; Amey, J; Hamer, D; McCrone, A (2013) DRAFT Final Report for CSP Project 4426 New Zealand sea lion ground component 2012/2013. Unpublished Report to the Conservation Services Programme, Department of Conservation, Wellington, New Zealand. Version 1.0. 20 p.

Childerhouse, S J; Hamer, D; Maloney, A; Michael, S; Donnelly, D; Schmitt, N (2014) Final report for CSP Project 4522 New Zealand sea lion ground component 2013/14. Unpublished report to the Conservation Services Programme, Department of Conservation, Wellington, New Zealand. Version 1.1. 31 p.

Chilvers, B L (2008) New Zealand sea lions *Phocarctos hookeri* and squid trawl fisheries: bycatch problems and management options. Endangered Species Research 5: 193–204.

Chilvers, B L (2009) Foraging locations of a decreasing colony of New Zealand sea lions (*Phocarctos hookeri*). New Zealand Journal of Ecology 33:106–113.

Chilvers, B L (2012a) Research to assess the demographic parameters of New Zealand sea lions, Auckland Islands: Final Research Report November 2012, Contract Number: POP 2011/01. Department of Conservation, Wellington. 11 p.

Chilvers, B L (2012b) Using life-history traits of New Zealand sea lions, Auckland Islands to clarify potential causes of decline. Journal of Zoology 287: 240–249.

Chilvers, B L (2014) Report of the survey to assess distribution and pup production of New Zealand sea lions on Stewart Island 2014. Report prepared for the Department of Conservation.

Chilvers, B L; Wilkinson, I S (2008) Philopatry and site fidelity of New Zealand sea lions (*Phocarctos hookeri*). Wildlife Research 35: 463–470.

Chilvers, B L; Wilkinson, I S (2009) Diverse foraging strategies in lactating New Zealand sea lions. Marine Ecology Progress Series 378: 299–308.

Chilvers, B L; Wilkinson, I S (2011) Research to assess the demographic parameters of New Zealand sea lions, Auckland Islands: Draft Final Report November 2011, Contract Number: POP 2010/01. Department of Conservation, Wellington. 20 p.

Chilvers, B L; Wilkinson, I S; Duignan, P J; Gemmell, N J (2005a) Summer foraging areas for lactating New Zealand sea lions *Phocarctos hookeri*. Marine Ecology Progress Series 304:235–247.

Chilvers, B L; Robertson, B C; Wilkinson, I S; Duignan, P J; Gemmell, N J (2005b) Male harassment of female New Zealand sea lions: mortality, injury and harassment avoidance. Canadian Journal of Zoology 83:642–648.

Chilvers, B L; Wilkinson, I S; Duignan, P J; Gemmell, N J (2006) Diving to extremes: are New Zealand sea lions pushing their limits in a marginal habitat? Journal of Zoology 269:233–240.

Chilvers, B L; Wilkinson, I S; Childerhouse, S J (2007) New Zealand sea lion, *Phocarctos hookeri*, pup production–1995 to 2006. New Zealand Journal of Marine and Freshwater Research 41: 205–213.

Chilvers, B L; Wilkinson, I S; Mackenzie, D I (2010) Predicting life-history traits for female New Zealand sea lions, *Phocarctos hookeri*: integrating short-term mark–recapture data and population modelling. Journal of Agricultural, Biological, and Environmental Statistics 15: 259–278.

Chilvers, B L; Amey, J M; Huckstadt, L A; Costa, D P (2011) Investigating foraging utilization distribution of female New Zealand sea lions, Auckland Islands. Polar Biology 34:565–574.

Chilvers, B L; Childerhouse, S J; Gales, N J (2013) Winter foraging behaviour of lactating New Zealand sea lions (*Phocarctos hookeri*). New Zealand Journal of Marine and Freshwater Research 47: 125-138.

Clement & Associates Ltd. (2007) Squid trawl fleet sea lion escape device audit. A report commissioned by the Department of Conservation for Project CSP MIT2004/05. Department of Conservation, Wellington. 19 p.

Collins, C J; Rawlence, NJ; Prost, S; Anderson, CNK; Knapp, M; Scofield, P; Robertson, B; Smith, I; Matisoo-Smith, EA; Chilvers, BL; Waters, JM (2014a) Extinction and recolonization of coastal megafauna following human arrival in New Zealand. Proc. R. Soc. B, 281: no. 1786.

Collins, C J; Rawlence, NJ; Worthy, TH; Scofield, RP; Tennyson, AJD; Smith, I; Knapp, M; Waters, JM (2014b) Pre-human New Zealand sea lion (*Phocarctos hookeri*) rookeries on mainland New Zealand. Journal of the Royal Society of New Zealand, 44: 1-16.

Costa, D P; Gales, N J (2000) Foraging energetic and diving behaviour of lactating New Zealand sea lions, *Phocarctos hookeri*. Journal of Experimental Biology 203:3655–3665.

Crocker, D E; Gales, N J; Costa, D P (2001) Swimming speed and foraging strategies of New Zealand sea lions, *Phocarctos hookeri*. Journal of Zoology 254: 267–277.

Department of Conservation. (2007) Draft Population Management Plan for New Zealand Sea Lion. Draft Document for Public Consultation, August 2007. Department of Conservation, Wellington. http://www.doc.govt.nz/getting-involved/consultations/closed/nz-sea-lion-management/.

Department of Conservation. (2009) New Zealand sea lion species management plan: 2009–2014. Department of Conservation, Wellington. 31 p.

Dickie, G (1999) Population dynamics of New Zealand fur seals (*Arctocephalus forsteri*) and New Zealand sea lions (*Phocarctos hookeri*). M.Sc. thesis. University of Otago, Dunedin, New Zealand. 117 p.

Fish, F (2008) Streamlining. pp. 1123–26. In: Perrin, W F; Wursig, B; Thewissen, J G M (eds.). Encyclopedia of Marine Mammals. Academic Press.

Gales, N J (1995) New Zealand (Hooker's) sea lion recovery plan. Threatened Species Recovery Plan Series 17. Department of Conservation, Wellington.

Gales, N J (2008) *Phocarctos hookeri*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org. Downloaded on 1 June 2011.

Gales, N J; Fletcher, D J (1999) Abundance, distribution and status of the New Zealand sea lion, *Phocarctos hookeri*. Wildlife Research 26: 35–52.

Gales, N J; Mattlin, R H (1997) Summer diving behaviour of lactating female New Zealand sea lions. Canadian Journal of Zoology 75:1695–1706.

Gilbert, D J; Chilvers, B L (2008) Final report on New Zealand sea lion pupping rate. POP2006-01 Objective 3. Analysis from sea lion database to estimate pupping rate and associated parameters. NIWA Report WLG2008-77. 26 p.

Gill, B J (1998) Prehistoric breeding sites of New Zealand sea lions (*Phocarctos hookeri*, *Carnivora: Otariidae*) at North Cape. Records of the Auckland Museum 35: 55–64.

Hankel, W; Witte, M; Miersch, L; Brede, M; Oeffner, J; Michael, M; Hankel, F; Leder, A; Dehnhardt, G (2010) Harbor seal vibrissa morphology suppresses vortex-induced vibrations. Journal of Experimental Biology 213: 2665–2672.

IUCN (2010) IUCN Red List of Threatened Species. Version 2010.4. http://www.iucnredlist.org. Downloaded on 1 June 2011.

Katsanevakis, S (2008) Marine debris, a growing problem: Sources, distribution, composition, and impacts. In: Hofer, T N (ed)

Marine Pollution: New Research. Nova Science Publishers, New York. pp. 53–100.

Lalas, C (1997) Prey of Hooker's sea lions *Phocarctos hookeri* based at Otago Peninsula, New Zealand. Pp. 130-136. In: Hindell, M; Kemper, C (eds.). Marine Mammal Research in the Southern Hemisphere, Status, Ecology and Medicine, vol 1. Surrey Beatty and Sons, Chipping Norton.

Lalas, C; Bradshaw, C J A (2003) Expectations for population growth at new breeding locations for the vulnerable New Zealand sea lion using a simulation model. Biological Conservation 114:67–78.

Lalas, C; Ratz, H; McEwan, K; McConkey, S D (2007) Predation by New Zealand sea lions (*Phocarctos hookeri*) as a threat to the viability of yellow-eyed penguins (*Megadyptes antipodes*) at Otago Peninsula, New Zealand. Biological Conservation 135: 235-246.

Lalas, C; McConnell, H M; Meynier, L (2014) Estimating size of opalfish from otoliths: implications for analyses of New Zealand sea lion diet. New Zealand Journal of Marine and Freshwater Research 48: 1-14.

Lalas, C; Webster, T (2014) Contrast in the importance of arrow squid as prey of male New Zealand sea lions and New Zealand fur seals at The Snares, subantarctic New Zealand. Marine Biology 161: 631-643.

Leung, E S; Chilvers, B L; Moore, A B; Nakagawa, S; Robertson, B C (2012) Sexual segregation in juvenile New Zealand sea lion foraging ranges: implications for intraspecific competition, population dynamics and conservation. PLoS ONE 7(9): e45389.

Leung, E S; Chilvers, B L; Moore, A B; Robertson, B C (2013a) Mass and bathymetry influences on the foraging behaviour of dependent yearling New Zealand sea lions (*Phocarctos hookeri*). New Zealand Journal of Marine and Freshwater Research 47: 38-50.

Leung, E S; Augé, A A; Chilvers, B L; Moore, A B; Robertson, B C (2013b) Foraging behaviour of juvenile female New Zealand sea lions (*Phocarctos hookeri*) in contrasting environments. PLoS ONE 8(5): e62728.

Leung, E S; Chilvers, B L; Nakagawa, S; Robertson B C (2014a) Size and experience matter: diving behaviour of juvenile New Zealand sea lions (*Phocarctos hookeri*). Polar Biology 37: 15-26.

Leung, E S; Chilvers, B L; Moore, A B; Robertson B C (2014b) Do yearling New Zealand sea lions (*Phocarctos hookeri*) learn foraging behaviour from their mothers? Marine Mammal Science 30: 1220-1228.

Lyle, J M (2011) SRP2010-03: Fur seal interactions with SED excluder device. Final Research Report for Ministry of Fisheries, 26 July 2011. 20 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Lyle, J M; Willcox, S T (2008) Dolphin and seal interactions with mid-water trawling in the Commonwealth small pelagic fishery, including an assessment of bycatch mitigation. Final Report Project R05/0996. Australian Fisheries Management Authority, National Library of Australia. 39 p.

MacKenzie, D I (2011) Estimation of demographic parameters for New Zealand sea lions breeding on the Auckland Islands. Final Report November 2012, Contract Number: Objective 3: POP 2011/01. Department of Conservation, Wellington. 88 p.

Maloney, A; Chilvers, B L; Haley, M; Muller, C G; Roe, W D; Debski, I (2009) Distribution, pup production and mortality of New Zealand sea lion (*Phocarctos hookeri*) on Campbell Island / Motu Ihupuku, 2008. New Zealand Journal of Ecology 33: 97–105.

Maloney, A; Chilvers, B L; Muller, C G; Haley, M (2012) Increasing pup production of New Zealand sea lions at Campbell Island/Motu Ihupuku: can it continue? New Zealand Journal of Zoology 39:19–29.

Marshall, C D (2008) Feeding Morphology. pp. 406-413. In Perrin, W F; Wursig, B; Thewissen, J G M (eds.). Encyclopedia of Marine Mammals. Academic Press.

Mattlin, R H (2004) QMA SQU6T New Zealand sea lion incidental catch and necropsy data for the fishing years 2000–01, 2001–02 and 2002–03. Report prepared for the NZ Ministry of Fisheries, Wellington, NZ. July 2004. 21 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Marlow, B J (1975) The comparative behaviour of the Australasian sea lions *Neophoca cinerea* and *Phocarctos hookeri*. Mammalia 39:159–230.

McConkey, S; McConnell, H; Lalas, C; Heinrich, S; Ludmerer, A; McNally, N; Parker, E; Borofsky, C; Schimanski, K; McIntosh, M (2002). A northward spread in the breeding distribution of the New Zealand sea lion. Australian Mammalogy 24:97–106.

McNally, N; Heinrich, S; Childerhouse, S J (2001) Distribution and breeding of New Zealand sea lions *Phocarctos hookeri* on Campbell Island. New Zealand Journal of Zoology 28: 79–87.

Meynier, L (2010) New Zealand sea lion bio-energetic modelling: Final Report for Project IPA2009-09. Presented to AEWG May 17 2011, Wellington, New Zealand. 34 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Meynier, L; Morel, P C H; Chilvers, B L; Mackenzie, D D S; MacGibbon, A; Duignan, P J (2008) Temporal and sex differences in the blubber fatty acid profiles of the New Zealand sea lion *Phocarctos hookeri*. Marine Ecology Progress Series 366: 271–278.

Meynier, L; Mackenzie, D D S; Duignan, P J; Chilvers, B L; Morel, P C H (2009) Variability in the diet of New Zealand sea lion (*Phocarctos hookeri*) at the Auckland Islands, New Zealand. Marine Mammal Science 25: 302–326.

Meynier, L; Morel, P C H; Chilvers, B L; Mackenzie, D D S (2014) Foraging diversity in lactating New Zealand sea lions: insights from qualitative and quantitative fatty acid analysis. Canadian Journal of Fisheries and Aquatic Sciences 71: 984-991.

Middleton, D A J; Banks, D A (2008) Analysis of underwater video footage of SELDs from the 2008 squid fishery. Deepwater Group Ltd.

Ministry of Fisheries (2010) National Fisheries Plan for Deepwater and Middle-depth Fisheries. Ministry of Fisheries, Wellington, New Zealand. 59 p. http://www.fish.govt.nz/en-nz/Consultations/Archive/2010/National+Fisheries+Plan+for+Deepwater+and+Middle-Depth+Fisheries/default.htm

Ministry of Fisheries. (2011) Report from the Fisheries Assessment Plenary, May 2011: stock assessments and yield estimates. Ministry of Fisheries, Wellington, New Zealand. 1178 p.

Moore, J.E., and Merrick, R., editors. 2011. Guidelines for Assessing Marine Mammal Stocks: Report of the GAMMS III Workshop, February 15 – 18, 2011, La Jolla, California. Dept. of Commerce, NOAA Technical Memorandum NMFS-OPR-47.

Moore, J M; Wallace, B; Lewison, R L; Zydelis, R; Cox, T; Crowder, L (2009) A review of marine mammal, sea turtle and seabird bycatch in USA fisheries and the role of policy in shaping management. Marine Policy 33:435–451.

Moore, P J; Moffat, R D (1990) Research and management projects on Campbell Island 1987–88. Science and Research Internal Report Series 57. Wellington, Department of Conservation. 101 p.

Moore, P J; Moffat, R D (1992) Predation of yellow-eyed penguin by Hooker's sealion. Notornis 39: 68-69.

Moore, P J; Charteris, M; Larsen, E J (2008) Notes on New Zealand mammals 8. Predation on nesting southern royal albatrosses *Diomedea epomophora* by a New Zealand sea lion *Phocarctos hookeri*. New Zealand Journal of Zoology 35: 201-204.

Nagaoka, L (2001) Using Diversity Indices to Measure Changes in Prey Choice at the Shag River Mouth Site, Southern New Zealand. International Journal of Osteoarchaeology 11: 101–111.

Nagaoka, L (2006) Prehistoric seal carcass exploitation at the Shag Mouth site, New Zealand. Journal of Archaeological Science 33: 1474–1481.

Ponte, G; van den Berg, A; Anderson, R W G (2010) Impact characteristics of the New Zealand Fisheries sea lion exclusion device stainless steel grid. Final Research Report for Ministry of Fisheries project IPA2009-06, Oct. 2010. 24 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Ponte, G; van den Berg, A; Anderson, R W G (2011) Further analysis of the impact characteristics of the New Zealand Fisheries sea lion exclusion device stainless steel grid. Final Research Report for Ministry of Fisheries project SRP2010-05, Sept. 2011. 36 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Ray, G C (1963) Locomotion in pinnipeds. Natural History 72: 10–21.

Read, A J; Drinker, P; Northridge, S (2006) Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20:163–169.

Richard, Y; Abraham, E R; Filippi, D (2011) Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for research projects IPA2009-19 and IPA2009-20. (Unpublished report held by Ministry for Primary Industries, Wellington.). 66 p.

Riet-Sapriza, F G (2007) Milk composition of the New Zealand sea lion and factors that influence it. PhD thesis, Massey University, Palmerston North, New Zealand.

Riet-Sapriza, F G; Duignan, P J; Chilvers, B L; Wilkinson, I S; Lopez-Villalobos, N; Mackenzie, D D S; MacGibbon, A; Costa, D P; Gales, N (2012) Interannual and individual variation in milk composition of New Zealand sea lions (*Phocarctos hookeri*). Journal of Mammology 93: 1006-1016.

Roberts, J; Fu, D; Doonan, I; Francis, R I C C (2014) New Zealand sea lions – demographic assessment of the cause of decline at the Auckland Islands (POP2012—02): demographic model options – demographic assessment. Report for the NZ Department of Conservation.

Roberts, J; Doonan, I (2014) New Zealand sea lions – demographic assessment of the cause of decline at the Auckland Islands (POP2012—02): demographic model options – correlative assessment. Report for the NZ Department of Conservation.

Roberts, J; Roux, M-J; Ladroit, Y (2014). PBR assessment for the Campbell Island sub-population of New Zealand sea lions. Report prepared for the Deepwater Group. NIWA Client Report WLG2014-8.

Robertson, B C; Chilvers, B L (2011) The population decline of the New Zealand sea lion *Phocarctos hookeri*: a review of possible causes. Mammal Review 41: 253–275.

Robertson, B C; Chilvers, B L; Duignan, P J; Wilkinson, I S; Gemmel, N J (2006) Dispersal of breeding adult male *Phocarctos hookeri*: implications for disease transmission, population management and species recovery. Biological Conservation 127:227–236.

Roe, W D (2010) External review of NZ sea lion bycatch necropsy data and methods. Report prepared for the NZ Ministry of Fisheries, Wellington. 8 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Roe, W D; Meynier, L (2010) Review of Necropsy Records for Bycaught NZ sea lions (*Phocarctos hookeri*), 2000–2008. Report for NZ Ministry of Fisheries project PRO2008-03, Wellington. 46 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Roe, W D (2011) A study of brain injury in New Zealand sea lion pups. Ph.D. Thesis, Massey University, Palmerston North.

Roe, W D; Roberts, J; Childerhouse, S (2014). Discussion paper on New Zealand pup mortality: causes and mitigation.

Smith, I W G (1989) Maori Impact on the Marine Magafauna: Pre-European Distributions of New Zealand Sea Mammals. In Sutton, D G (ed.) Saying so doesn't make it so. Papers in Honour of B. Foss Leach. New Zealand Archaeological Association Monograph. 17:76–108.

Smith, I W G (2011) Estimating the magnitude of pre-European Maori marine harvest in two New Zealand study areas. New Zealand Aquatic Environment and Biodiversity Report No. 82.

Smith, M H; Baird, S J (2005) Factors that may influence the level of incidental mortality of New Zealand sea lions (*Phocarctos hookeri*) in the squid (*Nototodarus* spp.) trawl fishery in SQU 6T. New Zealand Fisheries Assessment Report 2005/20. 35 p.

Smith, M H; Baird, S J (2007a) Estimation of incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2003–04, with particular reference to the SQU 6T squid trawl fishery. New Zealand Fisheries Assessment Report 2007/7. 32 p.

Smith, M H; Baird, S J (2007b) Estimation of incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2004–05, with particular reference to the SQU 6T squid trawl fishery. New Zealand Aquatic Environment and Biodiversity Report No. 12. 31 p.

Stewart-Sinclair, P (2013) The role of long-term diet changes in the decline of the New Zealand sea lion population. M.Sc. Thesis, Massey University, Palmerston North.

Thompson, F N; Abraham, E R (2010) Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995–96 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 66.

Thompson, F N; Abraham, E R; Berkenbusch, K (2011) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by the Ministry for Primary Industries, Wellington). 80 p.

Thompson, F N; Berkenbush, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2011–12. New Zealand Aquatic Environment and Biodiversity Report No. 105. 76 p.

Thompson, F N; Abraham, E R; Berkenbusch, K (2012) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by the Ministry for Primary Industries, Wellington). 90 p.

Townsend, A J; de Lange, P J; Duffy, C A J; Miskelly, C M; Molloy, J; Norton, D (2008) New Zealand Threat Classification System Manual. Department of Conservation, Wellington, New Zealand.

Tuck, I D (2009) Characterisation of scampi fisheries and the examination of catch at length and spatial distribution of scampi in SCI 1, 2, 3, 4A and 6A. New Zealand Fisheries Assessment Report 2009/27:102 p.

Wade, P R (1998) Calculating limits to the allowable human caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14:1–37.

Wade, P R; Angliss, R (1997) Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop. NOAA Technical Memo NMFS-OPR-12.

Walker, G E; Ling, J K (1981) New Zealand sea lion. In Ridway S H; Harrisson. R J (eds.). Handbook of Marine Mammal, Vol. 1. Academic Press Inc., London, United Kingdom.

Wilkinson, I S; Burgess, J; Cawthorn, M W (2003) New Zealand sea lions and squid—managing fisheries impacts on a threatened marine mammal. pp 192–207 In: Gales, N; Hindell, M; Kirkwood, R (eds.). Marine mammals: Fisheries, tourism and management issues. CSIRO Publishing, Melbourne.

Wilkinson, I S; Childerhouse, S J; Duignan, P J; Gulland, F M D (2000) Infanticide and cannibalism in the New Zealand sea lion. Marine Mammal Science 16:495–500.

Wilkinson, I S; Duignan, P J; Grinberg, A; Chilvers, B L; Robertson, B C (2006) Klebsiella pneumonia epidemics: Possible impact on New Zealand sea lion recruitment. pp. 455–471. In: Trites, A; Atkinson, S; DeMaster, D; Fritz, L; Gelatt, T; Rea, L; Wynne, K (eds.). Sea lions of the world. Alaska Sea Grant College Program, University of Alaska Fairbanks.

Woodley, T H; Lavigne, D M (1991) Incidental capture of pinnipeds in commercial fishing gear. International Marine Mammal Association Technical Report 91-01: 35 p.

4 NEW ZEALAND FUR SEAL (*ARCTOCEPHALUS FORSTERI*)

Scope of chapter	This chapter outlines the biology New Zealand fur seals (*Arctocephalus forsteri*), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	Areas with significant fisheries interactions include waters over or close to the continental shelf surrounding the South Island and southern offshore islands, notably Cook Strait, West Coast South Island, Banks Peninsula, Stewart-Snares shelf, Campbell Rise, and the Bounty Islands, plus offshore of Bay of Plenty-East Cape. Interactions also occur off the west coast of the North Island.
Key issues	Improving estimates of incidental bycatch in some fisheries, and assessing the potential for populations to sustain the present levels of bycatch.
Emerging issues	Improving data and information sources for future ecological risk assessments.
MPI Research (current)	PRO2010-01 *Estimating the nature & extent of incidental captures of seabirds, marine mammals & turtles in New Zealand commercial fisheries*; PRO2012-02 *Assess the risk posed to marine mammal populations from New Zealand fisheries*.
NZ Government Research (current)	DOC Marine Conservation Services Programme (CSP): INT2014-01 *To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities*; INT2013-03 *To determine which marine mammal, turtle and protected fish species are captured in fisheries and their mode of capture*; INT2013-04 *To review the data collected by fisheries observers in relation to understanding the interaction with protected species, and refine efficient protocols for future data collection*; MIT2014-01 *Protected species bycatch newsletter*.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts
Related chapters/issues	See the New Zealand sea lion chapter.

Note: This chapter has been updated for the AEBAR 2014.

4.1 CONTEXT

Management of fisheries impacts on New Zealand (NZ) fur seals is legislated under the Marine Mammals Protection Act (MMPA) 1978 and the Fisheries Act (FA) 1996. Under s.3E of the MMPA, the Minister of Conservation, with the concurrence of the Minister for Primary Industries (formerly the Minister of Fisheries), may approve a population management plan (PMP). There is no PMP in place for NZ fur seals.

In the absence of a PMP, the Ministry for Primary Industries (MPI) manages fishing-related mortality of NZ fur seals under s.15(2) of the FA *"to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species, and such measures may include setting a limit on fishing-related mortality."*

All marine mammal species are designated as protected species under s.2(1) of the FA. In 2005, the Minister of Conservation approved the Conservation General Policy, which specifies in Policy 4.4 (f) that *"Protected marine species should be managed for their long-term viability and recovery throughout their natural range."* DOC's Regional Conservation Management Strategies outline specific policies and objectives for protected marine species at a regional level. Baker et al (2010) list NZ fur seals as Not Threatened in 2009, and the IUCN classification is Least Concern (Goldsworthy & Gales 2008).

In 2004, DOC approved the *Department of Conservation Marine Mammal Action Plan for 2005–2010*[21] (Suisted & Neale 2004). The plan specifies a number of species-specific key objectives for NZ fur seals, of which the following is most relevant for fisheries interactions: *"To control/mitigate fishing-related mortality of NZ fur seals in trawl fisheries (including the WCSI hoki and Bounty Island southern blue whiting fisheries)."*

[21] DOC has confirmed that the Marine Mammal Action Plan for 2005–2010 still reflects DOC's priorities for marine mammal conservation.

Management of NZ fur seal incidental captures aligns with Fisheries 2030 Objective 6: Manage impacts of fishing and aquaculture. Further, the management actions follow Strategic Action 6.2: *Set and monitor environmental standards, including for threatened and protected species and seabed impacts*.

All National Fisheries Plans except those for inshore shellfish and freshwater fisheries are relevant to the management of fishing-related mortality of NZ fur seals.

Under the National Deepwater Plan, the objective most relevant for management of NZ fur seals is Management Objective 2.5: *Manage deepwater and middle-depth fisheries to avoid or minimise adverse effects on the long-term viability of endangered, threatened and protected species*.

Specific objectives for the management of NZ fur seal bycatch are outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ fur seals are most likely to interact. These fisheries include hoki (HOK), southern blue whiting (SBW), hake (HAK) and jack mackerel (JMA). The HOK chapter of the National Deepwater Plan (completed in 2010) includes Operational Objective (OO) 2.11: *Ensure that incidental marine mammal captures in the hoki fishery are avoided and minimised to acceptable levels (which may include standards) by 2012*. The SBW chapter (2011) includes OO2.3: *Ensure that incidental New Zealand fur seal mortalities, in the southern blue whiting fishery at the Bounty Islands (SBW6B), do not impact the long term viability of the fur seal population and captures are minimised through good operational practices*. The HAK plan (active from 2013–14) includes OO2.4: *Ensure that incidental marine mortalities in hake fisheries are mitigated and minimised*. The JMA plan (active from 2013–14) includes OO2.2: *Ensure that incidental marine mammal captures, particularly common dolphins, do not impact the long term viability of the population and captures are minimised through good operational practices*.

Management Objective 7 of the National Fisheries Plan for Highly Migratory Species (HMS) is to "*Implement an ecosystem approach to fisheries management, taking into account associated and dependent species.*" This comprises four components: Avoid, remedy, or mitigate the adverse effects of fishing on associated and dependent species, including through maintaining food chain relationships; Minimise unwanted bycatch and maximise survival of incidental catches of protected species in HMS fisheries, using a risk management approach; Increase the level and quality of information available on the capture of protected species; and Recognise the intrinsic values of HMS and their ecosystems, comprising predators, prey, and protected species.

The Environment Objective is the same for all groups of fisheries in the draft National Fisheries Plan for Inshore Finfish, to "*Minimise adverse effects of fishing on the aquatic environment, including on biological diversity*". The draft National Fisheries Plans for Inshore Shellfish and Freshwater have the same objective, but are unlikely to be relevant to management of fishing-related mortality of NZ fur seals.

4.2 BIOLOGY

4.2.1 TAXONOMY

The NZ fur seal (*Arctocephalus forsteri* (Lesson 1828)) is an otariid seal (Family Otariidae – eared seals, including fur seals and sea lions), one of two native to New Zealand, the other being the New Zealand sea lion (*Phocarctos hookeri* (Gray,1844)).

4.2.2 DISTRIBUTION

Pre-European archaeological evidence suggests that NZ fur seals were present along much of the east coasts of the North Island (except the less rocky coastline of Bay of Plenty and Hawke Bay) and the South Island, and, to a lesser extent, on the west coasts, where fewer areas of suitable habitat were available (Smith 1989, 2005, 2011). A combination of subsistence hunting and commercial harvest resulted contraction of the species' range and in population decline almost to the point of extinction (Smith 1989, 2005, 2011, Ling 2002, Lalas 2008). NZ fur seals became fully protected in the 1890s and, with the exception of one year of licensed harvest in the 1950s, have remained protected since.

Currently, NZ fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40ºS to Macquarie Island. On land, NZ fur seals are distributed around the New Zealand coastline, on offshore islands, and on sub-Antarctic islands (Crawley & Wilson 1976, Wilson 1981, Mattlin 1987). The recolonisation of the coastline by NZ fur seals has resulted in the northward expansion of the distribution of breeding colonies and haulouts (Lalas & Bradshaw 2001), and breeding colonies are now present on many exposed rocky areas (Baird 2011). The extent of breeding colony distribution in New Zealand waters is bounded to the north by a very small (space-limited) colony at Gannet Island off the North Island west coast (latitude 38°S), to the east by colonies of unknown sizes at the Chatham Islands group, to the west by colonies of unknown size on Fiordland offshore islands, and to the south by unknown numbers on Campbell Island. Outside New Zealand waters, breeding populations exist in South and Western Australia (Shaughnessy et al 1994, Shaughnessy 1999, Goldsworthy et al 2003), with smaller colonies in Tasmania (Gales et al 2010).

The seasonal distribution of the NZ fur seals is determined by the sex and maturity of each animal. Males are generally at the breeding colonies from late October to late January then move to haulout areas around the New Zealand coastline (see Bradshaw et al 1999), with peak density of males and sub-adult males at haulouts during July–August and lowest densities in September–October (Crawley & Wilson 1976). Females arrive at the breeding colony from November and lactating females remain at the colony (apart from short foraging trips) for about 10 months until the pups are weaned, usually during August–September (Crawley & Wilson 1976).

4.2.3 FORAGING ECOLOGY

Most foraging research in New Zealand has focused on lactating NZ fur seals at Open Bay Islands off the South Island west coast (Mattlin et al 1998), Otago Peninsula (Harcourt et al 2002), and Ohau Point, Kaikoura (Boren 2005), using time-depth-recorders, satellite-tracking, or very-high-frequency transmitters. Individual females show distinct dive pattern behaviour and may be relatively shallow or deep divers, but most forage at night and in depths shallower than 200 m. At Open Bay Islands, dives were generally deeper and longer in duration during autumn and winter. Females can dive to at least 274 m (for a 5.67 min dive in autumn) and remain near the bottom at over 237 m for up to 11.17 min in winter (Mattlin et al 1998). Females in some locations undertook longer dive trips, with some to deeper waters, in autumn (in over 1000 m beyond the continental shelf; Harcourt et al 2002).

The relatively shallow dives and nocturnal feeding during summer suggested that seals fed on pelagic and vertical migrating prey species (for example, arrow squid, *Nototodarus sloanii*). Conversely, the deeper dives and increased number of dives in daylight during autumn and winter suggested that the prey species may include benthic, demersal, and pelagic species (Mattlin et al 1998, Harcourt et al 2002). The deeper dives enabled seals to forage along or off the continental shelf (within 10 km) of the colony studied (at Open Bay Islands). These deeper dives may be to the benthos or to depths in the water column where spawning hoki are concentrated.

Methods to analyse NZ fur seal diets have included investigation of freshly killed animals (Sorensen 1969), scats, and regurgitates (e.g. Allum & Maddigan 2012). Fish prey items can be recognised by the presence of otoliths, bones, scales, and lenses, while cephalopods are indicated by beaks and pens. Foraging appears to be specific to individuals and different diets may be represented in the scats and regurgitations of males and females as well as juveniles from one colony. These analyses can be biased, however, particularly if only one collection method is used, and this limits fully quantitative assessment of prey species composition.

Dietary studies of NZ fur seals have been conducted at colonies in Nelson-Marlborough, west coast South Island, Otago Peninsula, Kaikoura, Banks Peninsula, Snares Islands, and off Stewart Island, and summaries are provided by Carey (1992), Harcourt (2001), Boren (2010), and Baird (2011).

NZ fur seals are opportunistic foragers and, depending on the time of year, method of analysis, and location, their diet includes at least 61 taxa (Holborow 1999) of mainly fish (particularly lanternfish (myctophids) in all studied colonies except Tonga Island (in Golden Bay, Willis et al 2008), as well as anchovy (*Engraulis australis*), aruhu (*Auchenoceros punctatus*), barracouta (*Thrysites atun*), hoki (*Macruronus novaezelandiae*), jack mackerel (*Trachurus* spp.), pilchard (*Sardinops sagax*), red cod (*Pseudophycis bachus*), red gurnard (*Chelidonichthys kumu*), silverside (*Argentina elongate*), sprat (*Sprattus* spp.) and cephalopods (octopus (*Macroctopus maorum*), squid (*Nototodarus sloanii*, *Sepioteuthis bilineata*)). For example, myctophids were present in Otago scats throughout the year (representing offshore foraging), but aruhu, sprat, and juvenile red cod were present only during winter-spring (Fea et al 1999). Medium-large arrow squid predominated in summer and autumn. Jack mackerel species, barracouta, and octopus were dominant in winter and spring. Prey such as lanternfish and arrow squid rise in the water column at night, the time when NZ fur seals exhibit shallow foraging (Harcourt et al 1995, Mattlin et al 1998, Fea et al 1999).

Recent foraging and dietary studies include one on male fur seal diets by Lalas & Webster (2014) and one on lactating females by Meynier et al. (2013). Arrow squid was the most important dietary item in fur seal scats and regurgitations sampled from male fur seals at The Snares during February 2012 (Lalas and Webster 2014). Meynier et al (2013) assess the trophic and spatial overlap between fur seals from two different South Island locations with local fisheries using analyses of dietary fatty acids, stable isotope signals, and telemetry. Lactating females from the east coast rookery at Ohau Point fed on oceanic prey in summer and females from the west coast rookery at Cape Foulwind fed on benthic or coastal prey over the continental shelf in summer and winter. The west coast females spent 50% of their at-sea time in winter in and near the Hokitika Canyon, where the winter spawning hoki fishery operates.

4.2.4 REPRODUCTIVE BIOLOGY

NZ fur seals are sexually dimorphic and polygynous (Crawley & Wilson 1976); males may weigh up to 160 kg, whereas females weigh up to about 50 kg (Miller 1975; Mattlin 1978a, 1987; Troy et al 1999). Adult males are much larger around the neck and shoulders than females and breeding males are on average 3.5 times the weight of breeding females (Crawley and Wilson 1976). Females are philopatric and are sexually mature at 4–6 years, whereas males mature at 5–9 years (Mattlin 1987, Dickie & Dawson 2003). The maximum age recorded for NZ fur seals in New Zealand waters is 22 years for females (Dickie & Dawson 2003) and 15 years for males (Mattlin 1978a).

NZ fur seals are annual breeders and generally produce one pup after a gestation period of about 10 months (Crawley & Wilson 1976). Twinning can occur and females may foster a pup (Dowell et al 2008), although both are rare. Breeding animals come ashore to mate after a period of sustained feeding at sea. Breeding males arrive at the colonies to establish territories during October–November. Breeding females arrive at the colony from late November and give birth shortly after. Peak pupping occurs in mid December (Crawley & Wilson 1976).

Females remain at the colony with their newborn pups for about 10 days, by which time they have usually mated. Females then leave the colony on short foraging trips of 3–5 days before returning to suckle pups for 2–4 days (Crawley & Wilson 1976). As the pups grow, these foraging trips are progressively longer in duration. Pups remain at the breeding colony from birth until weaning (at 8–12 months of age).

Breeding males generally disperse after mating to feed and occupy haulout areas, often in more northern areas (Crawley & Wilson 1976). This movement of breeding adults away from the colony area during January allows for an influx of sub-adults from nearby areas. Little is described about the ratio of males to females on breeding colonies (Crawley & Wilson 1976), or the reproductive success. Boren (2005) reported a fecundity rate of 62% for a Kaikoura colony, based on two annual samples of between about 5 and 8% of the breeding female population. This rate is similar to the 67% estimated by Goldsworthy & Shaughnessy (1994) for a South Australian colony.

Newborn pups are about 55 cm long and weigh about 3.5 kg (Crawley & Wilson 1976). Male pups are generally heavier than female pups at birth and throughout their growth (Crawley & Wilson 1976, Mattlin 1981, Chilvers et al 1995, Bradshaw et al 2003b, Boren 2005). Pup growth rates may vary by colony (see Harcourt 2001). The proximity of a colony to easily accessible rich food sources will vary, and pup condition at a colony can vary markedly between years (Mattlin 1981, Bradshaw et al 2000, Boren 2005). Food availability may be affected by climate variation, and pup growth rates probably represent variation in the ability of mothers to provision their pups from year to year. The sex ratio of pups at a colony may vary by season (Bradshaw et al 2003a, 2003b, Boren 2005), and in years of high food resource availability, more mothers may produce males or more males may survive (Bradshaw et al 2003a, 2003b).

4.2.5 POPULATION BIOLOGY

Historically, the population of NZ fur seals in New Zealand was thought to number above 1.25 million animals (possibly as high as 1.5 to 2 million) before the extensive sealing of the early 19th century (Richards 1994). Present day population estimates for NZ fur seals in New Zealand are dated, few and highly localised. In the most comprehensive attempt to quantify the total NZ fur seal population, Wilson (1981) summarised population surveys of mainland New Zealand and offshore islands undertaken in the 1970s and estimated the population size within the New Zealand region at between 30,000 and 50,000 animals. Since then, several authors have suggested a population size of ~100,000 animals (Taylor 1990, see Harcourt 2001), but this estimate is very much an approximation and its accuracy is difficult to assess in the absence of comprehensive surveys.

Fur seal colonies provide the best data for consistent estimates of population numbers, generally based on pup production in a season (see Shaughnessy et al 1994). Data used to provide colony population estimates of NZ fur seals have been, and generally continue to be, collected in an ad hoc fashion. Regular pup counts are made at some discrete populations. A 20 year time series of Otago Peninsula colony data is updated, maintained, and published primarily by Chris Lalas (assisted by Sanford (South Island) Limited), and the most recent published estimate is 20 000–30 000 animals (Lalas 2008). Lalas & MacDiarmid (submitted) applied a logistic growth model, using established parameters, to 13 years of pup production estimates from colonies at Oamaru south to Slope Point, and indicated the 2009 population was at 95% of the asymptote of 19 600 animals (plausible range of 13 000–28 800). In this region, 90% of the population growth occurred over 24–27 years; and the growth rate was faster in seasons up to 1998, than in later years.

Similar population growth rates occurred at Kaikoura, where the population expanded by 32% per annum over the years 1990–2005 (Boren et al 2006). An estimate of 600 pups was reported for 2005 (Boren 2005), 1508 (s.e. = 28) pups were estimated for 2009, and 2390 (s.e. = 226) pups for 2011 (L. Boren, DOC, pers. comm.).

Since 1991, the Department of Conservation has monitored New Zealand fur seal pup production at three breeding colonies on the West Coast, at Cape Foulwind, Wekakura Point, and Taumaka (Open Bay Islands) (see Best 2011). A DOC-commissioned project is underway to compile the tag, measurement, and mark-recapture data from these colonies and create a New Zealand fur seal database. The data have been made available by the scientists who complete the fieldwork, most recently Hugh Best who coordinates the population monitoring programme, DOC Regional and District staff, Tai Poutini Papatipu Runanga, and the trustee owners of Taumaka me Popotai. Once the database has been through a quality assurance process, it will be made publically available. The pup production estimates for these colonies are derived using direct counts of dead pups and mark recapture methodology undertaken in the last week of January each year. At Taumaku Island, the largest of the Open Bay Islands and the most southern of these three colonies, approximately 800 pups are marked each year, and the first 100 pups of each sex are weighed and measured. At Cape Foulwind, approximately 200 pups are marked each year, and the first 50 of each sex are weighed and measured. At the most northern of the three colonies, Wekakura Point, approximately 500 pups are marked and 75 of each sex are weighed and measured.

Other studies of breeding colonies generally provide estimates for one or two seasons, but many of these are more than 10 years old. Published estimates suggest that populations have stabilised at the Snares Islands after a period of growth in the 1950s and 1960s (Carey 1998) and increased at the Bounty Islands (Taylor 1996), Nelson-Marlborough region (Taylor et al 1995), Kaikoura (Boren 2005), Otago (Lalas & Harcourt 1995, Lalas and Murphy 1998, Lalas 2008, Lalas and MacDiarmid (submitted)), and near Wellington (Dix 1993).

For many areas where colonies or haulouts exist, count data have been collected opportunistically (generally by Department of Conservation staff during their field activities) and thus data are not often comparable because counts may represent different life stages, different assessment methods, and different seasons (see Baird 2011). Known breeding locations (as at October 2012) are summarised in the NABIS supporting lineage document for the "*Breeding colonies distribution of New Zealand fur seal*" layer[22].

Baker et al (2010a) conducted an aerial survey of the South Island west coast from Farewell Spit to Puysegur Point and Solander Island in 2009, but their counts were quite different, i.e. lower than ground counts collected at

[22] The NABIS lineage document as well as layer details and associated metadata are available online: http://www2.nabis.govt.nz/LayerDetails.aspx?layer=Breeding colonies distribution of New Zealand fur seal

a similar time at the main colonies (Melina and Cawthorn 2009). This discrepancy was thought to be a result mainly of the survey design and the nature of the terrain. However, the aerial survey confirmed the localities shown by Wilson (1981) of potentially large numbers of pups at sites such as Cascade Point, Yates Point, Chalky Island, and Solander Island.

Population numbers for some areas, especially more isolated ones, are not well known. The most recent counts for the Chatham Islands were collected in the 1970s (Wilson 1981), and the most recent reported for the Bounty Islands were made in 1993–94. Taylor (1996) reported an increase in pup production at the Bounty Islands since 1980, and estimated that the total population was at least 21 500, occupying over 50% of the available area. Information is sparse for populations at Campbell Island, the Auckland Islands group and the Antipodes Islands

Little is reported about the natural mortality of NZ fur seals, other than reports of sources and estimates of pup mortality for some breeding colonies. Estimates of pup mortality or pup survival vary in the manner in which they were determined and in the number of seasons they represent, and are not directly comparable. Each colony will be affected by different sources of mortality related to habitat, location, food availability, environment, and year, as well as the ability of observers to count all the dead pups (may be limited by terrain, weather, or time of day).

Reported pup mortality rates vary: 8% for Otago Peninsula pups up to 30 days old and 23% for pups up to 66 days old (Lalas and Harcourt 1995); 20% from birth to 50 days and about 40% from birth to 300 days for Taumaka Island, Open Bay Islands pups (Mattlin 1978b); and in one year, 3% of Kaikoura pups before the age of 50 days (Boren 2005). Starvation was the major cause of death, although stillbirth, suffocation, trampling, drowning, predation, and human disturbance also occur. Pup survival of at least 85% was estimated for a mean 47 day interval for three Otago colonies, incorporating data such as pup body mass (Bradshaw et al 2003b), though pup mortality before the first capture effort was unknown. Other sources of natural mortality for NZ fur seals include predators such as sharks and NZ sea lions (Mattlin 1978b, Bradshaw et al 1998).

Human-induced sources of mortality include: fishing, for example, entanglement or capture in fishing gear; vehicle-related deaths (Lalas & Bradshaw 2001, Boren 2005, Boren et al 2006, 2008); and mortality through shooting, bludgeoning, and dog attacks. NZ fur seals are vulnerable to certain bacterial diseases and parasites and environmental contaminants, though it is not clear how life-threatening these are. The more obvious problems include tuberculosis infections, *Salmonella*, hookworm enteritis, phocine distemper, and septicaemia (associated with abortion) (Duignan 2003, Duignan & Jones 2007). Low food availability and persistent organohalogen compounds (which can affect the immune and the reproductive systems) may also affect NZ fur seal health.

Various authors have investigated fur seal genetic differentiation among colonies and regions in New Zealand (Lento et al 1994; Robertson & Gemmell (2005). Lento et al (1994) described the geographic distribution of mitochondrial cytochrome *b* DNA haplotypes. Robertson & Gemmell (2005) described low levels of genetic differentiation (consistent with homogenising gene flow between colonies and an expanding population) based on genetic material from NZ fur seal pups from seven colonies. One aim of the latter work is to determine the provenance of animals captured during fishing activities, through the identification and isolation of any colony genetic differences.

4.2.6 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

Threat classification is an established approach for identifying species at risk of extinction (IUCN 2010). The risk of extinction for NZ fur seals has been assessed under two threat classification systems: the New Zealand Threat Classification System (Townsend et al 2008) and the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2010).

In 2008, the IUCN updated the Red List status of NZ fur seals, listing them as Least Concern on the basis of their large and apparently increasing population size (Goldsworthy & Gales 2008). In 2010, DOC updated the New Zealand Threat Classification status of all NZ marine mammals (Baker et al 2010b). In the revised list, NZ fur seals were classified as Not Threatened with the qualifiers increasing (Inc) and secure overseas (SO) (Baker et al 2010b).

4.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

NZ fur seals are found in both Australian and New Zealand waters. Overall abundance has been suggested to be as high as 200 000, with about half of the population in Australian waters (Goldsworthy and Gales 2008). However, this figure is very much an approximation, and its accuracy is difficult to assess in the absence of comprehensive surveys.

Pinnipeds are caught incidentally in a variety of fisheries worldwide (Read et al 2006). Outside New Zealand waters, species captured include: NZ fur seals, Australian fur seals, and Australian sea lions in Australian trawl and inshore fisheries (e.g., Shaughnessy 1999, Norman 2000); Cape fur seals in South African fisheries (Shaughessy and Payne 1979); South Amercian sea lions in trawl fisheries off Patagonia (Dans et al 2003); and seals and sea lions in United States waters (Moore et al 2009).

4.4 STATE OF KNOWLEDGE IN NEW ZEALAND

NZ fur seals are attracted to feeding opportunities offered by various fishing gears. Anecdotal evidence suggests that the sound of winches as trawlers haul their gear acts as a cue. The attraction of fish in a trawl net, on longline hooks, or caught in a setnet provide opportunities for NZ fur seals to interact with fishing gear, which can result in capture and, potentially, death via drowning

Most captures occur in trawl fisheries and NZ fur seals are most at risk from capture during shooting and hauling (Shaughnessy & Payne 1979), when the net mouth is within diving depths. Once in the net some animals may have difficulty in finding their way out within their maximum breath-hold time (Shaughnessy & Davenport 1996). The operational aspects that are associated with NZ fur seal captures on trawlers include factors that attract the NZ fur seals, such as the presence of offal and discards, the sound of the winches, vessel lights, and the presence of ‘stickers’ in the net (Baird 2005). It is considered that NZ fur seals are at particular risk of capture when a vessel partially hauls the net during a tow and executes a turn with the gear close to the surface. At the haul, NZ fur seals often attempt to feed from the codend as it is hauled and dive after fish that come loose and escape from the net (Baird 2005).

Factors identified as important influences on the potential capture of NZ fur seals in trawl gear include the year or season, the fishery area, gear type and fishing strategies (often specific to certain nationalities within the fleet), time of day, and distance to shore (Baird & Bradford 2000, Mormede et al 2008, Smith & Baird 2009). These analyses did not include any information on NZ fur seal numbers or activity in the water at the stern of the vessel because of a lack of data. Other influences on NZ fur seal capture rate (of Australian and NZ fur seals) may include inclement weather and sea state, vessel tow and haul speed, increased numbers of vessels and trawl frequency, and potentially the weight of the fish catch and the presence of certain bycatch fish species (Hamer and Goldsworthy 2006). This Australian study found similar mortality rates for tows with and without Seal Exclusion Devices (see also Hooper et al 2005). The use of fur seal exclusion devices is not required in NZ fisheries.

The spatial and temporal overlap of commercial fishing grounds and NZ fur seal foraging areas has resulted in NZ fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf. Because the topography around much of the South Island and offshore islands slopes steeply to deeper waters, most captures occur close to colonies and haulouts. Locations of captures by trawl vessels and surface longline vessels are shown in Figure 4.1 and Figure 4.2.

Winter hoki fisheries attract NZ fur seals off the west coast South Island and in Cook Strait between late June and September (Table 4.1). In August–October, NZ fur seals are caught in southern blue whiting effort near the Bounty Islands and Campbell Island. In September–October captures may occur in hoki and ling fisheries off Puysegur Point on the southwestern coast of the South Island. Captures are also reported from the Stewart-Snares shelf fisheries that operate during summer months, mainly for hoki and other middle depths species and squid, and from fisheries throughout the year on the Chatham Rise though captures have not been observed east of longitude 180° on the Chatham Rise.

Captures were reported from trawl fisheries for species such as hoki, hake (*Merluccius australis*), ling (*Genypterus blacodes*), squid, southern blue whiting, Jack mackerel, and barracouta (Baird & Smith 2007, Abraham et al 2010b). Between 1 and 3% of observed tows targeting middle depths fish species catch NZ fur seals compared with about 1% for squid tows, and under 1% of observed tows targeting deepwater species such as orange roughy (*Hoplostethus atlanticus*) and oreo species (for example, *Allocyttus niger*, *Pseudocyttus maculatus*) (Baird & Smith 2007). The main fishery areas that contribute to the estimated annual catch of NZ fur seals (modelled from observed captures) in middle depths and deepwater trawl fisheries are Cook Strait hoki, west coast South Island middle depths fisheries (mainly hoki), western Chatham Rise hoki, and the Bounty Islands southern blue whiting fishery (Baird & Smith 2007, Thompson & Abraham 2010). Captures on longlines occur when the NZ fur seals attempt to feed on the fish catch during hauling. Most NZ fur seals are released alive from surface and bottom longlines, typically with a hook and short snood or trace still attached.

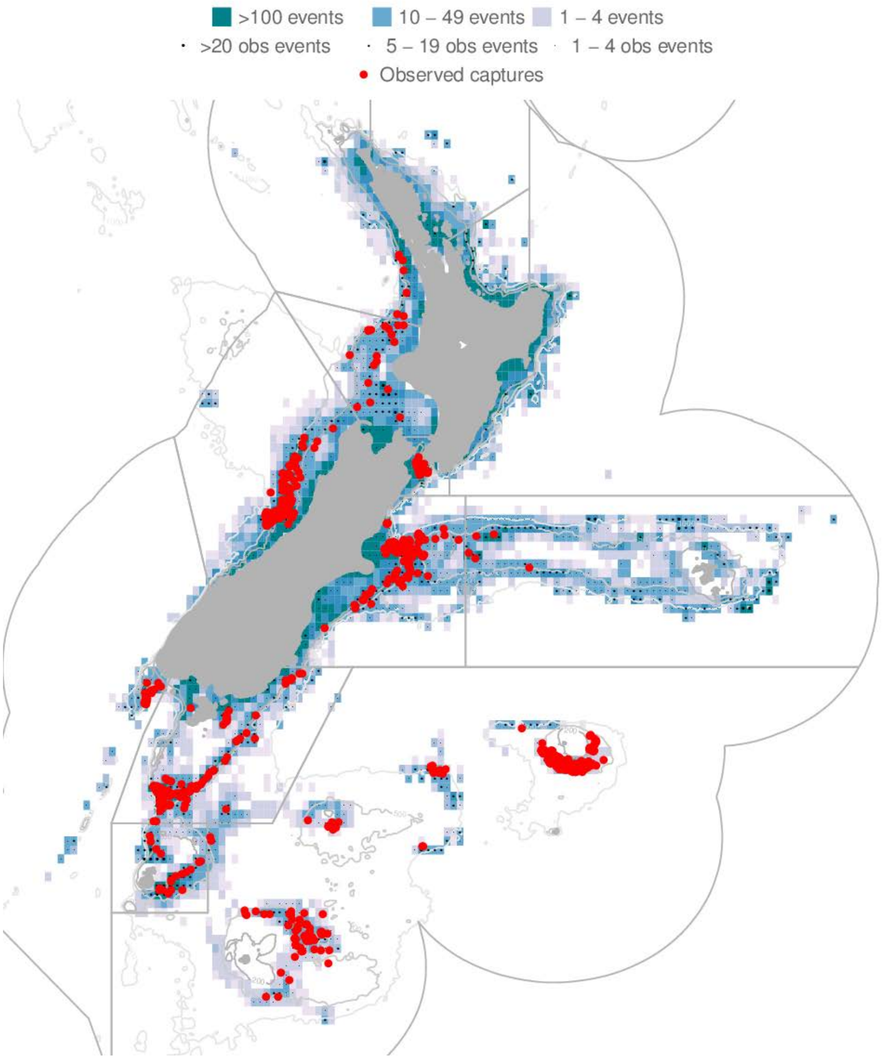


Figure 4.1: Distribution of trawl fishing effort and observed NZ fur seal captures, 2002-03 to 2012-13 (for more information see MPI data analysis at http://data.dragonfly.co.nz/psc/ data version v20140131). Fishing effort is mapped into 0.2-degree cells, coloured to represent the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing effort is shown for all tows with latitude and longitude data, where three or more vessels fished within a cell.

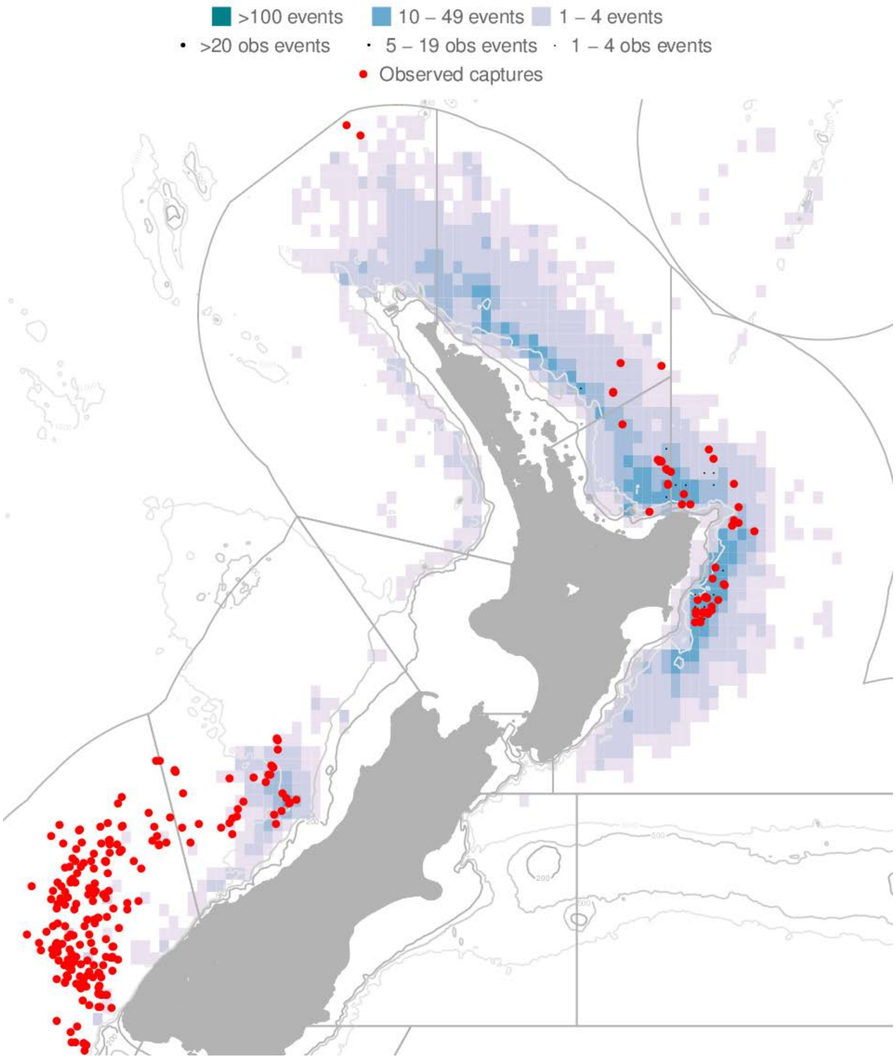


Figure 4.2: Distribution of surface longline fishing effort and observed NZ fur seal captures, 2002-03 to 2012-13 (for more information see MPI data analysis at http://data.dragonfly.co.nz/psc/ data version v20140131). Fishing effort is mapped into 0.2-degree cells, coloured to represent the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing effort is shown for sets with latitude and longitude data, where three or more vessels and three or more companies or persons fished within a cell. For these years, 89.4% of the effort is shown

4.4.1 QUANTIFYING FISHERIES INTERACTIONS

Observer data and commercial effort data have been used to characterise the incidental captures and estimate the total numbers caught (Baird & Smith 2007, Smith & Baird 2009, Thompson & Abraham 2010, Abraham & Thompson 2011). This approach is currently applied using information collected under DOC project INT2013-01 and analysed under MPI project PRO2013-01 (Thompson et al 2011, Thompson et al 2012, Abraham et al in prep.). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers of observed captures and the representativeness of the observer coverage. Initially, stratified ratio estimates were provided for the main trawl fisheries, starting in the late 1980s, after scientific observers reported 198 NZ fur seal deaths during the July to September west coast South Island spawning hoki fishery (Mattlin 1994a, 1994b). In the following years, ratio estimation was used to estimate NZ fur seal captures in the Taranaki Bight jack mackerel fisheries and Bounty Platform, Pukaki Rise, and Campbell Rise southern blue whiting fisheries, based on observed catches and stratified by area, season, and gear type (Baird 1994).

Table 4.1: Monthly distribution of NZ fur seal activity and the main trawl and longline fisheries with observed reports of NZ fur seal incidental captures.

<table>
<tr><th>NZ fur seals</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th></tr>
<tr><td>Breeding males</td><td>Dispersed at sea or at haulouts</td><td colspan="4">At breeding colony</td><td colspan="7">Dispersed at sea or at haulouts</td></tr>
<tr><td>Breeding females</td><td colspan="2">At sea</td><td colspan="2">At breeding colony</td><td colspan="8">At breeding colony and at-sea foraging and suckling</td></tr>
<tr><td>New Pups</td><td colspan="3">At sea</td><td colspan="9">At breeding colony</td></tr>
<tr><td>Non-breeders</td><td colspan="12">Dispersed at sea, at haulouts, or breeding colony periphery</td></tr>
<tr><th>Major fisheries</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th></tr>
<tr><td>Hoki trawl</td><td></td><td colspan="8">Chatham Rise and Stewart-Snares Shelf</td><td colspan="3">Cook Strait, west coast South Island, Puysegur</td></tr>
<tr><td>Squid</td><td colspan="3"></td><td colspan="2">Stewart-Snares Shelf</td><td colspan="6">Auckland Islands and Stewart-Snares shelf</td><td></td></tr>
<tr><td>Southern blue whiting</td><td colspan="2">Pukaki Rise and Campbell Rise</td><td colspan="9"></td><td>Bounty Islands</td></tr>
<tr><td>Scampi</td><td colspan="12">Mernoo Bank (Chatham Rise) and Auckland Islands</td></tr>
<tr><td>Southern bluefin tuna longline</td><td colspan="6"></td><td colspan="5">SouthWest SI</td><td></td></tr>
</table>

In the last 10 years, model-based estimates of captures have been developed for all trawl fisheries in waters south of 40° S (Baird & Smith 2007, Smith & Baird 2009, Thompson & Abraham 2010, Abraham & Thompson 2011, Thompson et al 2011, Thompson et al 2012, Abraham et al in prep.). These models use the observed and unobserved data in an hierarchical Bayesian approach that combines season and vessel-season random effects with covariates (for example, day of fishing year, time of day, tow duration, distance from shore, gear type, target) to model variation in capture rates among tows. This method compensates in part for the lack of representativeness of the observer coverage and includes the contribution from correlation in the capture rate among tows by the same vessel. The method is limited by the very large differences in the observed and non-observed proportions of data for the different vessel sizes; most observer coverage is on larger vessels that generally operate in waters deeper than 200 m. The operation of inshore vessels in terms of the location of effort, gear, and the fishing strategies used is also relatively unknown compared with the deeper water fisheries although changes to reporting requirements means that data are now improving and inshore trawl effort (not including flatfish trawl effort) is now able to be included in the modelling (Thompson et al 2012, see also description of the Trawl Catch Effort Return, TCER, in use since 2007-08, in Chapter 9 on benthic effects).

Since 2005, there has been a downward, then relatively flat trend in estimated capture rates and annual estimated NZ fur seal captures in trawl fisheries (Smith & Baird 2009, Thompson & Abraham 2010, Abraham & Thompson 2011, Thompson et al 2011, Thompson et al 2012, Abraham et al in prep., Figure 4.3). This may reflect efforts to reduce bycatch (see Section 4.4.2) combined with a reduction in fishing effort since the late 1990s. Coupled with this decrease in effort is an increase in the percentage of tows observed, especially since 2007. In 2012–13, about 15% of the 83 722 tows were observed, with a capture rate of 0.92 fur seal per 100 tows, to give an annual mean total of 398 captures (95% c.i. 236–713) (Table 4.2, Figure 4.3). Most annual captures are generally observed in Cook Strait. Note these capture rates include animals that are released alive; 13% of 1122 observed trawl captures in the 2002-03 to 2012-13 fishing years were recorded as alive by the observer.

Ratio estimation was used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods (Abraham et al 2010b). NZ fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty and off East Cape. Estimated surface longline captures range from 299 (95% c.i. 199-428) in 2002-03 to 32 (14-55) in 2006–07 (Table 4.2). These capture rates include animals that are released alive; 5% of observed surface longline captures from 2002-03 to 2012-13 (Abraham et al in prep).

Captures of NZ fur seals have also been recorded in other fisheries; 12 in setnets, 2 in bottom longline fisheries and 1 from purse seine fisheries from 2002-03 to 2012-13 (Abraham et al in prep). Captures associated with recreational fishing activities are poorly known (Abraham et al 2010a).

Table 4.2: Fishing effort and observed and estimated NZ fur seal captures in trawl and surface longline fisheries by fishing year in the New Zealand EEZ (Abraham et al in prep. and see MPI data analysis at http://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the total number of tows or hooks; the observer coverage (the percentage of tows or hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per hundred tows or per thousand hooks); the estimation method used (model or ratio); and the mean number of estimated total captures (with 95% confidence interval). For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.
Trawl fisheries							
1998-1999	153 412	4.7	190	2.62	Ratio	1 591	1 454-1 744
1999-2000	139 057	5.5	203	2.65	Ratio	1 539	1 400-1 693
2000-2001	134 243	6.8	170	1.87	Ratio	1 490	1 348-1 649
2001-2002	127 883	6	157	2.03	Ratio	1 273	1 164-1 394
2002-2003	130 174	5.3	68	0.99	Model	881	525-1 461
2003-2004	120 868	5.4	84	1.28	Model	1 066	631-1 768
2004-2005	120 438	6.4	200	2.59	Model	1 443	904-2 341
2005-2006	109 923	6	143	2.16	Model	912	563-1 515
2006-2007	103 306	7.7	73	0.92	Model	536	322-902
2007-2008	89 524	10.1	141	1.56	Model	754	473-1 306
2008-2009	87 548	11.2	72	0.73	Model	546	307-994
2009-2010	92 888	9.7	72	0.8	Model	464	265-877
2010-2011	86 090	8.6	73	0.98	Model	414	243-728
2011-2012	84 429	10.8	82	0.9	Model	428	247-768
2012-2013	83 722	14.8	114	0.92	Model	398	236-713
Surface longline fisheries							
1998-1999	6 855 124	18.9	102	0.08	Ratio	138	120-160
1999-2000	8 258 537	10.4	42	0.05	Ratio	67	54-83
2000-2001	9 698 805	10.8	43	0.04	Ratio	64	51-83
2001-2002	10 833 533	9.1	44	0.04	Ratio	75	61-93
2002-2003	10 772 188	20.4	56	0.03	Ratio	299	199-428
2003-2004	7 386 329	21.8	40	0.02	Ratio	134	90-188
2004-2005	3 679 765	21.3	20	0.03	Ratio	66	38-99
2005-2006	3 690 119	19.1	12	0.02	Ratio	47	23-79
2006-2007	3 739 912	27.8	10	0.01	Ratio	32	14-55
2007-2008	2 246 189	18.8	10	0.02	Ratio	40	19-68
2008-2009	3 115 633	30.1	22	0.02	Ratio	53	29-81
2009-2010	2 995 264	22.2	19	0.03	Ratio	77	43-121
2010-2011	3 187 879	21.2	17	0.03	Ratio	64	35-101
2011-2012	3 100 277	23.5	40	0.05	Ratio	140	92-198
2012-2013	2 862 182	19.6	21	0.04	Ratio	110	65-171

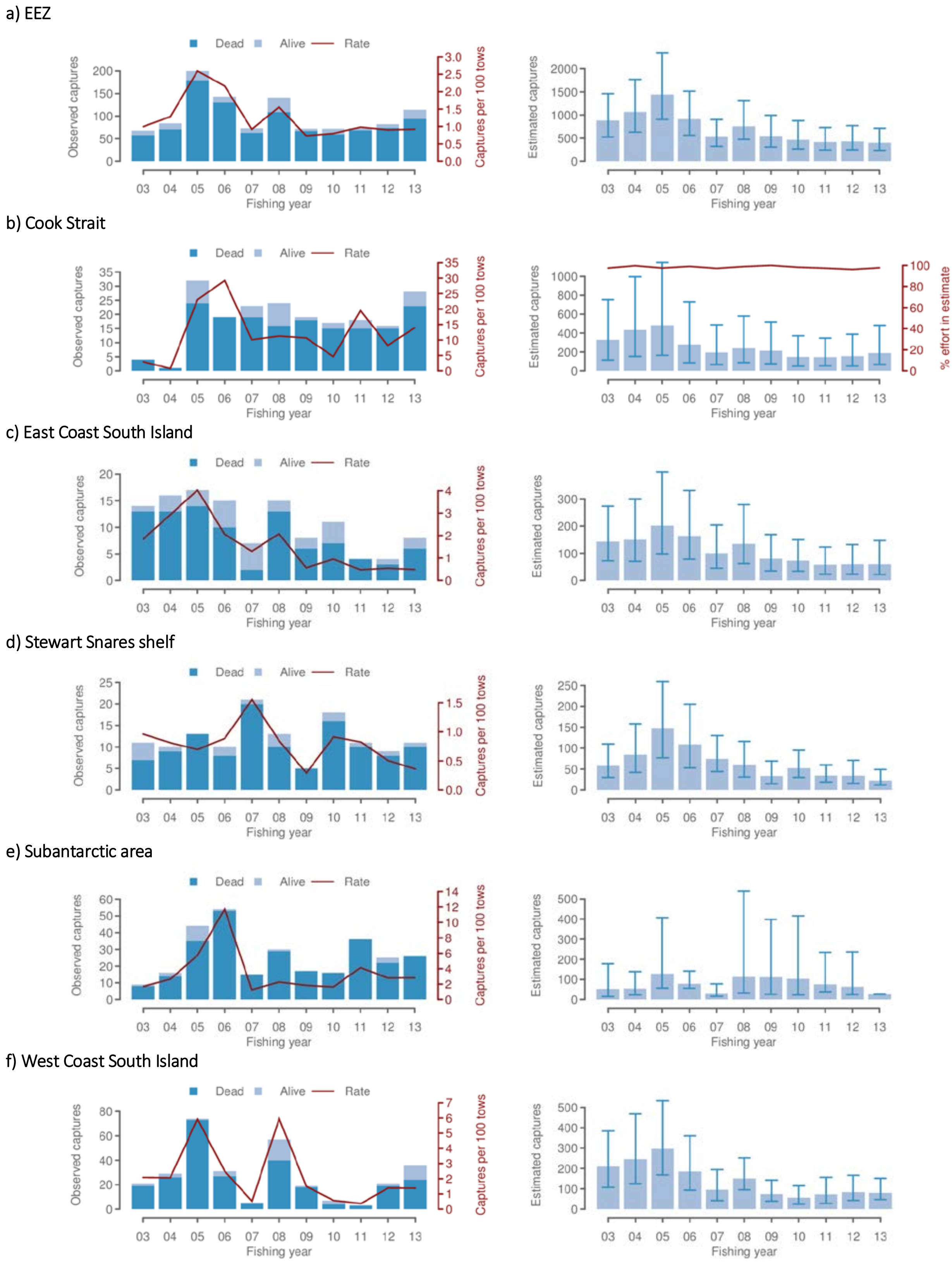


Figure 4.3: Observed captures of NZ fur seals (dead and alive) in trawl fisheries, the capture rate (captures per hundred tows) and the mean number of estimated total captures (with 95% confidence interval) by fishing year for regions with more than 50 observed captures since 2002-03: (a) New Zealand's EEZ; (b) the Cook Strait area; (c) the East Coast South Island area; (d) the Stewart Snares shelf area; and (e) the subantarctic area; and (f) the West Coast South Island area (Abraham et al in prep. and see MPI data analysis at http://data.dragonfly.co.nz/psc/ data version v20140131). Percentage effort included in the estimation is shown when it was less than 100%. For more information on the methods used to prepare the data, see Abraham and Thompson (2011).

4.4.2 MANAGING FISHERIES INTERACTIONS

The impact of fishing related captures on the NZ fur seal population is presently unknown. However, fishing interactions are considered unlikely to have adverse population-level consequences for NZ fur seals given: the scale of bycatch relative to overall NZ fur seal abundance; the apparently increasing population and range; and the level of management based on the NZ and IUCN threat status of the species. The consequences of fishing related mortality for some individual colonies may be more or less severe.

Management has focused on encouraging vessel operators to alter fishing practices to reduce captures, and monitoring captures via the observer programme. A marine mammal operating procedure (MMOP) has been developed by the deepwater sector to reduce the risk of marine mammal captures and is currently applied to trawlers greater than 28 m LOA and is supported by annual training. It includes a number of mitigation measures, such as managing offal discharge and refraining from shooting the gear when NZ fur seals are congregating around the vessel. Its major focus is to reduce the time gear is at or near the surface when it poses the greatest risk. MPI, via observers, monitors and audits vessel performance against this procedure (see the MPI National Deepwater Plan for further details). Action planned for 2013–14 included work with the deepwater industry to increase communication with Cook Strait and west coast South Island inshore skippers about fisheries and marine mammal interactions (MPI 2014). Research into methods to minimise or mitigate NZ fur seal captures in commercial fisheries has focused on fisheries in which NZ fur seals are more likely to be captured (trawl fisheries, see Clement and Associates 2009). Finding ways to mitigate captures has proved difficult because the animals are free swimming, can easily dive to the depths of the net when it is being deployed, hauled, or brought to the surface during a turn, and are known to actively and deliberately enter nets to feed. Further, any measures also need to ensure that the catch is not greatly compromised, either in terms of the amount of fish or their condition. Possible fish loss is one potential drawback of using seal exclusion devices (see Rowe 2007). Adhering to current risk mitigation methods (e.g. MMOP) will help to minimise the level of impacts, however rates may fluctuate depending on fleet deployment, NZ fur seal abundance and local feeding conditions.

4.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

The uncertainty about the size of the NZ fur seal population has restricted the potential to investigate any effects that NZ fur seal deaths through fishing may have on the population as a whole or on the viability of colonies or groups of colonies. The provenance of NZ fur seals caught during fishing is presently unknown, although proposed genetic research potentially could identify which animals belonged to a specific colony (Robertson and Gemmell 2005).

In response to the requirements for the Marine Stewardship Council certification of the hoki fishery (one target fishery contributing to NZ fur seal mortality), expert knowledge about NZ fur seals and their interactions with trawl gear (including some comparisons of annual capture estimates) have been used for an expert-based qualitative ecological risk assessment (ERAs). The results of this study have not been reviewed by the AEWG or DOC's CSP-TWG.

The impact of fisheries interactions on NZ fur seal populations (and other marine mammal populations) is being assessed in the marine mammal risk assessment project PRO2012-02. Berkenbusch et al. (2013) describe relevant marine mammal data available for risk assessment, and Abraham et al. (in prep.) present methods and results of a Delphi survey using a fully Bayesian approach to estimate consensus from multiple expert opinions. Four models were developed for each marine mammal species, for the proportion of a species within New Zealand waters, the species population size, for Rmax, and for discrete spatial distribution within New Zealand waters. Full results for NZ fur seals will be reported in this section on completion of the work.

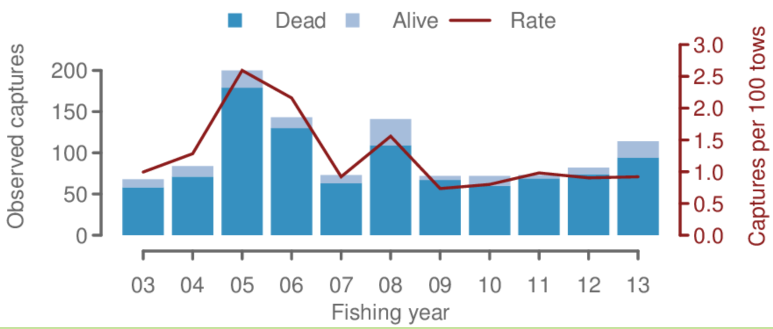
4.4.4 SOURCES OF UNCERTAINTY

Any measure of the effect of NZ fur seal mortality from commercial fisheries on NZ fur seal populations requires adequate information on the size of the populations at different colonies. Although there is reasonable information about where the main NZ fur seal breeding colonies exist, the size and dynamics of the overall populations are poorly understood. At present, the main sources of uncertainty are the lack of consistent data on: abundance by colony and in total; population demographic parameters; and at-sea distribution (which would ideally be available at the level of a colony or wider geographic area where several colonies are close together) (Baird 2011). Collation and analysis of existing data, such as that for the west coast South Island, would fill some of these gaps; there is a 20-year time series of pup production from three west coast South Island colonies, a reasonably long data series from the Otago Peninsula, and another from Kaikoura. Maximum benefit could be gained through the use of all available data, as shown by the monitoring of certain colonies of NZ fur seals in Australia to provide a measure of overall population stability (see Shaughnessy et al 1994, Goldsworthy et al 2003).

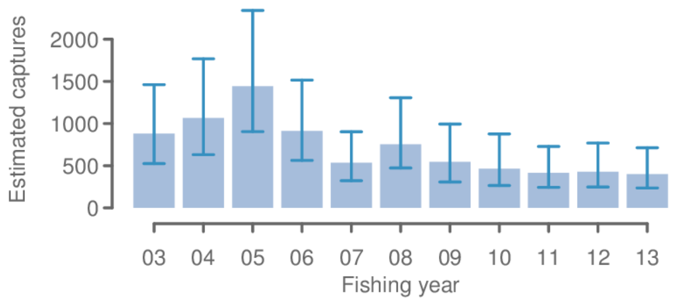
Fur seals may forage in waters near a colony or haulout, or may range widely, depending on the sex, age, and individual preferences of the animal (Baird 2011). It is not known whether the NZ fur seals around a fishing vessel are from colonies nearby. Some genetic work is proposed to test the potential to differentiate between colonies so that in the future NZ fur seals drowned by fishing gear may be identified as being from a certain colony (Robertson & Gemmell 2005).

The low to moderate levels of observer coverage in some fishery-area strata add uncertainty to the total estimated captures. However, the main source of uncertainty in the level of bycatch is the paucity of information from the inshore fishing fleets which use a variety of gears and methods. Recent increases in observer coverage enabled fur seal capture estimates to include inshore fishing effort. Further increases in coverage, particularly for inshore fisheries, would provide better data on the life stage, sex, and size of captured animals, as well as samples for fatty acid or stable isotope analysis to assess diet and to determine provenance. Information on the aspects of fishing operations that lead to capture in inshore fisheries would also be useful as input to designing mitigation measures.

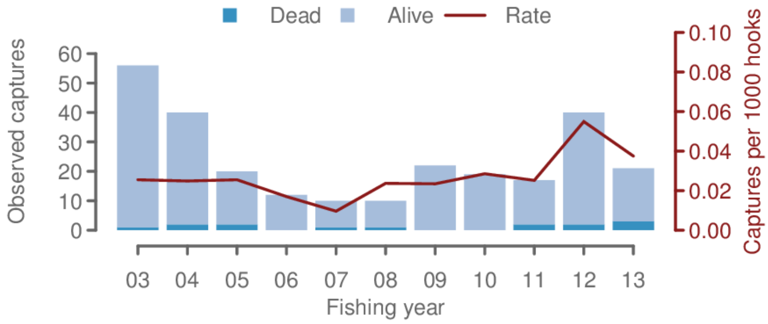
4.5 INDICATORS AND TRENDS

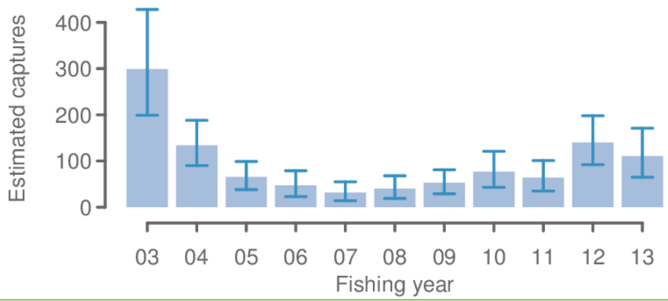
Population size	Unknown, but potentially ~100 000 in the New Zealand EEZ[23].
Population trend	Increasing at some mainland colonies but unknown for offshore island colonies. Range is thought to be increasing.
Threat status	NZ: Not Threatened, Increasing, Secure Overseas, in 2010[24]. IUCN: Least Concern, in 2008[25].
Number of interactions[26]	398 estimated captures (95% c.i.: 236–713) in trawl fisheries in 2012–13 110 estimated captures (95% c.i.: 65–171) in surface-longline fisheries in 2012–13 114 observed captures in trawl fisheries in 2012–13 21 observed captures in surface-longline fisheries in 2012–13
Trends in interactions	Trawl fisheries: 

[23] Taylor (1990), Harcourt (2001).
[24] Baker et al (2010b).
[25] Goldsworthy & Gales (2008).
[26] For more information, see: http://data.dragonfly.co.nz/psc/.



Surface longline fisheries:





4.6 REFERENCES

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. 170 pages. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Abraham, E R; Berkenbusch, K N; Richard, Y (2010a) The capture of seabirds and marine mammals in New Zealand non-commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 64. 52 p.

Abraham, E R; Neubauer, P; Berkenbusch, K; Mansfield, R; Knox, C. (in prep.) Estimating population size and distribution of marine mammals in New Zealand waters using a Delphi survey of expert knowledge. Draft New Zealand Aquatic Environment and Biodiversity Report.

Abraham, E R; Thompson, F N; Oliver, M D (2010b) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. New Zealand Aquatic Environment and Biodiversity Report No. 45. 148 p.

Abraham, E.R; Thompson, F.N; Richard, Y; Mansfield, R; (in prep) Summary of the capture of seabirds, marine mammal, and turtles in New Zealand commercial fisheries, 1998-99 to 2012-13. Draft New Zealand Aquatic Environment and Biodiversity Report.

Allum, L L; Maddigan, F W (2012) Unusual stability of diet of the New Zealand fur seal (Arctocephalus forsteri) at Banks Peninsula, New Zealand. New Zealand Journal of Marine and Freshwater Research 46: 91–96.

Baird, S J (Comp.) (1994) Nonfish species and fisheries interactions working group report. New Zealand Fisheries Assessment Working Group Report 94/1. Ministry of Fisheries. (Unpublished report held in the NIWA library, Wellington.) 54 p.

Baird, S J (2005) Review of observer comments that relate to captures of New Zealand fur seals (*Arctocephalus forsteri*) during hoki (*Macruronus novaezelandiae*) trawl fishery operations. NIWA

Client Report WLG205-43. (Report prepared for the Hoki Fishery Management Company) 27 p.

Baird, S J (2008) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in longline fisheries in New Zealand waters, 1994–95 to 2005–06. New Zealand Aquatic Environment and Biodiversity Report No. 20. 21 p.

Baird, S J (2011) New Zealand fur seals — summary of current knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 72. 50 p.

Baird, S J; Bradford, E (2000). Factors that may have influenced the capture of New Zealand fur seals (*Arctocephalus forsteri*) in the west coast South Island hoki fishery, 1991–98. NIWA Technical Report 92. 35 p.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. New Zealand Aquatic Environment and Biodiversity Report No. 14. 98 p.

Baker, B; Jensz, K; Cawthorn, M; Cunningham, R (2010a) Census of New Zealand fur seals on the west coast of New Zealand's South Island. (Report to the Deepwater Group Ltd., available at www.latitude-42.com.au.) 22 p.

Baker, C S; Chilvers, B L; Constantine, R.; DuFresne, S; Mattlin, R; van Helden, A; Hitchmough, R (2010b) Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. New Zealand Journal of Marine and Freshwater Research 44: 101–115.

Berkenbusch, K.; Abraham, E.R.; Torres, L.G. (2013). New Zealand marine mammals and commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 119. 104 p.

Best, H (2011) West Coast South Island monitoring of NZ fur seal pup numbers, 1991–2010 – a summary. Unpublished report for the Department of Conservation. 5 p.

Boren, L (2010) Diet of New Zealand fur seals (*Arctocephalus forsteri*): a summary. DOC Research & Development Series 319. Department of Conservation, Wellington. 19 p.

Boren, L; Morrissey, M; Gemmell, N J (2008) Motor vehicle collisions and the New Zealand fur seal in the Kaikoura region. Marine Mammal Science 24(1): 235–238.

Boren, L J (2005) New Zealand fur seals in the Kaikoura region: colony dynamics, maternal investment and health. A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biological Sciences at the University of Canterbury, University of Canterbury. 261 p.

Boren, L J; Morrissey, M; Muller, C G; Gemmell, N J (2006) Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. Marine Pollution Bulletin 52: 442–446.

Bradshaw, C J A; Barker, R J; Harcourt, R G; Davis, L S (2003a) Estimating survival and capture probability of fur seal pups using multistate mark-recapture models. Journal of Mammalogy 84(1): 65–80.

Bradshaw, C J A; Davis, L S; Lalas, C; Harcourt, R G (2000) Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. Journal of Zoology 252: 41–51.

Bradshaw, C J A; Harcourt, R G; Davis, L S (2003b) Male-biased sex ratios in New Zealand fur seal pups relative to environmental variation. Behavioral Ecology and Sociobiology 53(5): 297–307.

Bradshaw, C J A; Lalas, C; McConkey, S (1998) New Zealand sea lion predation on New Zealand fur seals. New Zealand Journal of Marine and Freshwater Research 32: 101–104.

Bradshaw, C J A; Thompson, C M; Davis, L S; Lalas, C (1999) Pup density related to terrestrial habitat use by New Zealand fur seals. Canadian Journal of Zoology 77(10): 1579–1586.

Carey, P W (1992) Fish prey species of the New Zealand fur seal (*Arctocephalus forsteri* Lesson). New Zealand Journal of Ecology 16(1): 41–46.

Carey, P W (1998). New Zealand fur seals (*Arctocephalus forsteri*) at the Snares Islands: a stabilised population? New Zealand Journal of Marine and Freshwater Research 32(1): 113–118.

Chilvers, B L; Wilson, K-J; Hickling, G J (1995) Suckling behaviours and growth rates of New Zealand fur seals, *Arctocephalus forsteri*, at Cape Foulwind, New Zealand. New Zealand Journal of Zoology 22: 263–270.

Clement and Associates (2009) Mitigating incidental captures of fur seals in trawl fisheries. Final Report prepared for Department of Conservation project MIT2006/09. 45 p.

Crawley, M C; Wilson, G J (1976) The natural history and behaviour of the New Zealand fur seal (*Arctocephalus forsteri*). Tuatara 22(1): 1–29.

Dickie, G S; Dawson, S M (2003) Age, growth, and reproduction in New Zealand fur seals. Marine Mammal Science 19(1): 173–185.

Dans, S L; Alonso, M K; Crespo, E A; Pedraza, S N; Garcia, N A (2003) Interactions between marine mammals and high sea fisheries in Patagonia: an integrated approach. pp. 100–115, In: Gales, N; Hindell, M; Kirkwood, R (Eds.) Marine mammals fisheries tourism and management issues. CSIRO Publishing. 446 p.

Dix, B (1993) A new record this century of a breeding colony in the North Island for the New Zealand fur seal *Arctocephalus forsteri*. Journal of the Royal Society of New Zealand 23: 1–4.

Dowell, S A; Boren, L J; Negro, S; Muller, C G; Caudron, A K; Gemmell, N J (2008) Rearing two New Zealand fur seal (*Arctocephalus forsteri*) pups to weaning. Australian Journal of Zoology 56: 33–39.

Duignan, P J (2003) Disease investigations in stranded marine mammals, 1999–2002. DOC Science Internal Series 104. Department of Conservation, Wellington. 32 p.

Duignan, P J; Jones, G W (2007) Autopsy of pinnipeds incidentally caught in commercial fisheries, 2002/03 and 2003/04. DOC Research & Development Series 280. Department of Conservation, Wellington. 41 p.

Fea, N I; Harcourt, R; Lalas, C (1999) Seasonal variation in the diet of New Zealand fur seals (*Arctocephalus forsteri*) at Otago Peninsula, New Zealand. Wildlife Research 26: 147–160.

Gales, R; Lee, A Y; Pemberton, D; Terauds, A; Irvine, A (2010) Observations of mortality of fur seals between 1998 and 2005 in Tasmania, Australia. Papers and Proceedings of the Royal Society of Tasmania 144: 29–35.

Goldsworthy, S D; Shaughnessy, P D (1994) Breeding biology and haul-out pattern of the New Zealand fur seal, *Arctocephalus forsteri*, at Cape Gantheaume, South Australia. Wildlife Research 21: 365–376 .

Goldsworthy, S D; Bulman, C; He, X; Larcombe, J; Littman, C (2003) Trophic interactions between marine mammals and Australian fisheries: an ecosystem approach, pp. 62–99. In Gales, N; Hindell, M; Kirkwood, R (Eds.), Marine mammals — fisheries, tourism and management issues. CSIRO Publishing. 446 p.

Goldsworthy, S.; Gales, N. (IUCN SSC Pinniped Specialist Group) 2008 *Arctocephalus forsteri*. The IUCN Red List of Threatened Species. Version 2014.2. <www.iucnredlist.org>. Downloaded on 30 July 2014.

Hamer, D J; Goldsworthy, S D (2006) Seal-fishery operational interactions: Identifying the environmental and operational aspects of a trawl fishery that contribute to bycatch and mortality of Australian fur seals (*Arctocephalus pusillus doriferus*). Biological Conservation 130: 517–529.

Harcourt, R G (2001) Advances in New Zealand mammalogy 1990–2000: Pinnipeds. Journal of the Royal Society of New Zealand 31(1): 135–160.

Harcourt, R G; Bradshaw, C J A; Dickson, K; Davis, L S (2002) Foraging ecology of a generalist predator, the female New Zealand fur seal. Marine Ecology Progress Series 227: 11–24.

Harcourt, R G; Schulman, A; Davis, L S; Trillmich, F (1995) Summer foraging by lactating female New Zealand fur seals (*Arctocepbalus forsteri*) off Otago Peninsula, New Zealand. Canadian Journal of Zoology 73: 678–690.

Holborrow, J (1999) The diet of New Zealand fur seals (*Arctocephalus forsteri*) in Southern New Zealand. (Unpublished MSc thesis, University of Otago, New Zealand.)

Hooper, J; Clark, J M; Charman, C; Agnew, D (2005) Sea mitigation measures on trawl vessels fishing for krill in CCAMLR Subarea 48.3. CCAMLR Science 12: 195–205.

IUCN (2014) The IUCN Red List of Threatened Species. Version 2014.2. <http://www.iucnredlist.org>. Downloaded on 24 July 2014.

Lalas, C (2008) Recolonisation of Otago, southern New Zealand, by fur seals and sea lions: unexpected patterns and consequences, 15 p. In Clarkson, B; Kurian, P; Nachowitz, T; Rennie, H (Eds.), Proceedings of the Conser-Vision Conference, University of Waikato, available at www.waikato.ac.nz/wfass/conserv-vision.

Lalas, C; Bradshaw, C J A (2001) Folklore and chimerical numbers: review of a millennium of interaction between fur seals and humans in the New Zealand region. New Zealand Journal of Marine and Freshwater Research 35(3): 477–497.

Lalas, C; Harcourt, R (1995) Pup production of the New Zealand fur seal on the Otago Peninsula, New Zealand. Journal of the Royal Society of New Zealand 25(1): 81–88.

Lalas, C.; MacDiarmid, A.B. (submitted) Rapid recolonisation of south-eastern New Zealand by New Zealand fur seals *Arctocephalus forsteri*. New Zealand Journal of Marine and Freshwater Research.

Lalas, C; Murphy, B (1998) Increase in the abundance of New Zealand fur seals at the Catlins, South Island, New Zealand. Journal of the Royal Society of New Zealand 28(2): 287–294.

Lalas, C.; Webster, T. (2014) Contrast in the importance of arrow squid as prey of male New Zealand sea lions and New Zealand fur seals at The Snares, subantarctic New Zealand. Marine Biology 161: 631–643.

Lento, G M; Mattlin, R H; Chambers, G K; Baker, C S (1994) Geographic distribution of mitochondrial cytochrome b DNA haplotypes in New Zealand fur seals (*Arctocephalus forsteri*). Canadian Journal of Zoology 72: 293–299.

Ling, J K (2002) Impact of colonial sealing on seal stocks around Australia, New Zealand and subantarctic islands between 150 and 170 degrees East. Australian Mammalogy 24: 117–126.

Mattlin, R H (1978a) Population biology, thermoregulation and site preference of the New Zealand fur seal (*Arctocephalus forsteri* (Lesson, 1828) on the Open Bay Islands, New Zealand. Unpubl. PhD Thesis, Christchurch, University of Canterbury.

Mattlin, R H (1978b) Pup mortality of the New Zealand fur seal (*Arctocephalus forsteri* Lesson). New Zealand Journal of Ecology 1: 138–144.

Mattlin, R H (1981) Pup growth of the New Zealand fur seal, *Arctocephalus forsteri,* on the Open Bay Islands, New Zealand. Journal of Zoology (London) 193: 305–314.

Mattlin, R H (1987) New Zealand fur seal, *Arctocephalus forsteri*, within the New Zealand region. In Croxall, J P; Gentry, R L Status, biology, and ecology of fur seals: Proceedings of an international symposium and workshop, Cambridge, England, 23–27 April 1984. NOAA Technical Report NMFS-51.

Mattlin, R H (1994a) Incidental catch of fur seals in the west coast South Island hoki trawl fishery, 1989–92. New Zealand Fisheries Assessment Research Document 93/19. 18 p. (Unpublished report available at NIWA library, Wellington.)

Mattlin, R H (Comp. & Ed.)(1994b) Seals and sea birds–fisheries interactions: report of a workshop, Wellington, 1992. New Zealand Fisheries Occasional Publication No. 8. 18 p. plus appendices.

Mattlin, R H; Gales, N J; Costa, D P (1998) Seasonal dive behaviour of lactating New Zealand fur seals (*Arctocephalus forsteri*). Canadian Journal of Zoology 76(2): 350–360.

Mellina, E; Cawthorn, M (2009). New Zealand fur seal (*Arctocephalus forsteri*) population assessment in Fiordland Sounds. Draft Report. Presented to AEWG July 7 2009, Wellington, New Zealand. 31 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Meynier L, Chilvers BL, Muller C, Virgili A, McGill R, Bury S., Willis T, Morel PCH 2013. Combining bio-logging with stable isotope and fatty acid analyses to assess the foraging habits of New Zealand fur seals, west coast, New Zealand. Oral presentation. Proceedings of the 20th Biennial Conference on the Biology of Marine Mammals, December 2013, Dunedin, NZ.

Miller, E H (1975) Body and organ measurements of fur seals, *Arctocephalus forsteri* (Lesson), from New Zealand. Journal of Mammalogy 56(2): 511–513.

Moore, J E; Wallace, B P; Lewison, R L; Žydelis, R; Cox, T M; Crowder, L B (2009) A review of marine mammal, sea turtle and seabird bycatch in USA fisheries and the role of policy in shaping management. Marine Policy33: 435–451.

Mormede, S; Baird, S J; Smith, M H (2008) Factors that may influence the probability of fur seal capture in selected New Zealand fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 19. 42 p.

MP1 (2014) Annual Operational Plan for Deepwater Fisheries for 2013/14. MPI Technical Paper No. 2013/52. 66 p. Available at:http://www.mpi.govt.nz/news-resources/publications.aspx

Norman, F I (2000) Preliminary investigation of the bycatch of marine birds and mammals in inshore commercial Fisheries, Victoria, Australia. Biological Conservation 92:217–226.

Read, A J; Drinker, P; Northridge, S (2006) Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20(1): 163–169.

Richard, Y; Abraham, E R; Filippi, D (2011) Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for research projects IPA2009-19 and IPA2009-20. (Unpublished report held by Ministry for Primary Industries, Wellington.). 66 pages.

Richards, R (1994) "The upland seal" of the Antipodes and Macquarie Islands: a historian's perspective. Journal of The Royal Society of New Zealand 24:289–295.

Robertson, B C; Gemmell, N J (2005) Microsatellite DNA markers for the study of population structure in the New Zealand fur seal *Arctocephalus forsteri*. DOC Science Internal Series 196. Department of Conservation, Wellington. 18 p.

Rowe, S J (2007) A review of methodologies for mitigating incidental catch of protected marine mammals. DOC Research and Development Series 283. 47 p. Science and Technical Publishing . DOC Wellington.

Rowe, S J (2009) Conservation Services Programme observer report: 1 July 2004 to 30 June 2007. DOC Marine Conservation Services Series 1. Department of Conservation, Wellington. 93 p.

Shaughnessy, P D (1999) The action plan for Australian seals. Environment Australia. 62 p.

Shaughnessy, P D; Davenport, S R (1996) Underwater videographic observations and incidental mortality of fur seals around fishing equipment in south-eastern Australia. Marine and Freshwater Research 47: 553–556.

Shaughnessy, P D; Gales, N J; Dennis, T E; Goldsworthy, S D (1994) Distribution and abundance of New Zealand fur seals, *Arctocephalus forsteri*, in South Australia and Western Australia. Wildlife Research 21(6): 667–695.

Shaughnessy, P D; Payne, A I L (1979) Incidental mortality of Cape fur seals during trawl fishing activities in South African waters. Fisheries Bulletin, South Africa 12: 20–25.

Smith, I W G (1989) Maori impact on the marine megafauna: pre-European distributions of New Zealand sea mammals, pp. 76–108. In Sutton, D.G. (Ed.) “Saying so doesn’t make it so”, papers in honour of B. Foss Leach. New Zealand Archaeological Association, Dunedin.

Smith, I W G (2005) Retreat and resilience: fur seals and human settlement in New Zealand, pp. 6–18. In Monks, G. (Ed.), “The Exploitation and Cultural Importance of Sea Mammals”. Oxbow Books, Oxford. 173 p.

Smith, I W G (2011) Estimating the magnitude of pre-European Maori marine harvest in two New Zealand study areas. New Zealand Aquatic Environment and Biodiversity Report No. 82.

Smith, M H; Baird, S J (2009) Model-based estimation of New Zealand fur seal (*Arctocephalus forsteri*) incidental captures and strike rates for trawl fishing in New Zealand waters for the years 1994–95 to 2005–06. New Zealand Aquatic Environment and Biodiversity Report No. 40. 90 p.

Sorensen, J H (1969) New Zealand seals with special reference to the fur seal. Fisheries Technical Report No. 39. N.Z. Marine Department. 35 p.

Suisted, R; Neale, D M (2004) Department of Conservation Marine Mammal Action Plan for 2005–2010. Department of Conservation: Wellington.

Taylor, R H (1990) Records of subantarctic fur seals in New Zealand (Note). New Zealand Journal of Marine and Freshwater Research 24: 499–502.

Taylor, R H (1996) Distribution, abundance and pup production of the New Zealand fur seal (*Arctocephalus forsteri* Lesson) at the Bounty Islands. Science for Conservation No. 32. 14 p.

Taylor, R H; Barton, K J; Wilson, P R; Thomas, B W; Karl, B J (1995) Population status and breeding of New Zealand fur seals (*Arctocephalus forsteri*) in the Nelson-northern Marlborough region. New Zealand Journal of Marine and Freshwater Research 29(2): 223–234.

Thompson, F N; Abraham, E R (2010) Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002–03 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 61. 37 p.

Thompson, F N; Abraham, E R; Berkenbusch, K (2011). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Draft Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by the Ministry for Primary Industries, Wellington). 80 p.

Thompson, F N; Abraham, E R; Berkenbusch, K (2012) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by the Ministry for Primary Industries, Wellington). 90 p.

Townsend, A J; de Lange, P J; Duffy, C A J; Miskelly, C M; Molloy, J; Norton, D A (2007) New Zealand Threat Classification System manual. Department of Conservation, Wellington. 35 p.

Troy, S K; Mattlin, R; Shaughnessy, P D; Davie, P S (1999) Morphology, age and survival of adult male New Zealand fur seals, *Arctocephalus forsteri*, in South Australia, Wildlife Research 26: 21–34.

Wade, P R (1998) Calculating limits to the allowable human caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14: 1–37.

Willis, T J; Triossi, F; Meynier, L (2008) Diet of fur seals *Arctocephalus forsteri* at Tonga Island, Abel Tasman National Park. NIWA Client

Report: NEL2008-011 12 p. prepared for the Department of Conservation and available at http://www.doc.govt.nz/upload/documents/conservation/marine-and-coastal/marine-protected-areas/tonga-island-seal-diet.pdf.

Wilson, G J (1981) Distribution and abundance of the New Zealand fur seal, *Arctocephalus forsteri*. Fisheries Research Division Occasional Publication No. 20. 39 p.

5 HECTOR'S DOLPHIN (*CEPHALORHYNCHUS HECTORI HECTORI*) AND MĀUI DOLPHIN (*C. H. MAUI*)

Scope of chapter	This chapter outlines the biology of Hector's dolphin (*Cephalorhynchus hectori hectori*) and Māui dolphin (*C. h. maui*), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	Areas with significant fisheries interactions include waters over or close to the continental shelf surrounding the South Island and the west coast of the North Island.
Key issues	Improving estimates of incidental capture in set net and trawl fisheries, and assessing the potential for populations to sustain the present levels of incidental capture.
Emerging issues	Improving data and information sources for future assessments of residual risk.
MPI Research (current)	PRO2009-01C *Abundance, distribution and productivity of Hector's (and Maui's) dolphins* (ECSI survey); PRO2012-02 *Assess the risk posed to marine mammal populations from New Zealand fisheries*; PRO2013-01 *Estimating the nature & extent of incidental captures of seabirds, marine mammals & turtles in New Zealand commercial fisheries*; PRO2013-06 *Abundance & distribution of WCSI Hector's dolphins*; PRO2013-08 *Reanalysis of aerial line transect surveys where best practice analysis was not used*; PRO2013-09 *Population viability of Maui's dolphins*.
NZ Government Research (current)	DOC Marine Conservation Services Programme (CSP): MIT2012-03 *Review of mitigation techniques in set net fisheries;* INT2013-01 *To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities*; INT2013-03 *To determine which marine mammal, turtle and protected fish species are captured in fisheries and their mode of capture*; INT2013-04 *To review the data collected by fisheries observers in relation to understanding the interaction with protected species, and refine efficient protocols for future data collection*; Additional conservancy-level work including aerial and boat surveys in Taranaki, genetic sampling and necropsies of recovered animals.
Other Research[27]	Otago University: Long term study of Hector's dolphins at Banks Peninsula, including distribution and abundance, survival rates, reproductive rates, movements, feeding ecology. Auckland University: Population monitoring of Maui's dolphins and population genetics of Hector's and Maui's dolphins. Massey University: Necropsy of recovered Hector's / Maui's dolphins.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts
Related chapters/issues	See the New Zealand sea lion and New Zealand fur seal chapters.

Note: Only minor edits have been made to this chapter since AEBAR 2013.

[27] Du Fresne et al (2012) recently compiled a bibliography of all Hector's and Maui's dolphin research completed since 2003 (available online: http://www.doc.govt.nz/documents/science-and-technical/drds332entire.pdf)

5.1 CONTEXT

Hector's and Māui dolphin[28] (*Cephalorhynchus hectori*), comprising the South Island sub-species referred to as Hector's dolphin (*C. h. hectori*) and the North Island sub-species known as Māui dolphin (*C. h. maui*), is endemic to the coastal waters of New Zealand. Like most other small cetaceans, the species is at risk of fisheries related mortality (e.g. Read et al 2006; Reeves et al 2013; Geijer & Read 2013).

Hector's and Maui's dolphin was gazetted as a "threatened species" by the Minister of Conservation in 1999 and is defined as a "protected species" according to part 1, section 2(1) of the Fisheries Act 1996 and section 2(1) of the Marine Mammals Protection Act (MMPA) 1978. Management of fisheries impacts on Hector's and Māui dolphins is legislated under both these acts. The MMPA (1978) allows for the approval of a population management plan for any protected species, within which a maximum allowable level of fishing-related mortality may be imposed. For threatened species, this level "should allow the species to achieve non-threatened status as soon as reasonably practicable, and in any event within a period not exceeding 20 years" (MMPA 1978, p. 11). If a population management plan has been approved, the Fisheries Act (1996) requires that all reasonable steps be taken to ensure that the maximum allowable level of fishing-related mortality is not exceeded, and the Minister may take other measures necessary to further avoid, remedy, or mitigate any adverse effects of fishing on the relevant protected species. In the absence of a population management plan, "the Minister may, after consultation with the Minister of Conservation, take such measures as he or she considers are necessary to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species, and such measures may include setting a limit on fishing-related mortality" (Fisheries Act 1996, p. 66).

The latest DOC Marine Mammal Action Plan[29] (DOC MMPA; Suisted & Neale 2004) stated that actions required include:

- *"Prepare species plans for both Hector's and Maui's dolphins"*
- *"Consider preparation of Population Management Plans (PMP) for Hector's and Maui's dolphins in accordance with the legal process and the species plans."*

However, to date no population management plan (PMP) has been produced for Hector's or Māui dolphin and no maximum allowable level of fishing-related mortality has been set. A draft threat management plan (TMP) for Hector's and Māui dolphin was developed jointly by the Department of Conservation (DOC) and the Ministry of Fisheries (MFish) in 2007. The TMP is not a statutory document, but a management plan identifying human-induced threats to Hector's and Māui dolphin populations and outlining strategies to mitigate those threats. The stated goals of the TMP (DOC & MFish 2007) are:

- *"To ensure the long-term viability of Hector's and Maui's dolphins is not threatened by human activities; and*
- *"To further reduce impacts of human activities as far as possible, taking into account advances in technology and knowledge, and financial, social and cultural implications."*

These goals were re-stated in the Review of the Māui dolphin TMP consultation paper published in 2012 (MPI & DOC 2012). The review of the Māui portion of the TMP provided a comprehensive overview of information relating to the biology, distribution, threats to, and management of Māui dolphins. To inform the review of the Māui dolphin TMP, a spatially-explicit, semi-quantitative risk assessment was conducted using an expert panel, to identify, analyse and evaluate all threats to Māui dolphins (Currey et al 2012). The process involved expert panellists mapping dolphin distribution, identifying and characterising threats, scoring the likely impact of each threat, and subsequent quantitative analysis to estimate risk posed by threats. The results of this process are described in the relevant sections below.

[28] In this document, 'Hector's dolphin(s)' refers to the South Island subspecies (*Cephalorhynchus hectori hectori*), while 'Maui's dolphin(s)' refers to the North Island subspecies (*C. hectori maui*). 'Hector's and Maui's dolphin(s)' refers to both subspecies collectively (*C. hectori*). This approach is taken to avoid confusion and enable distinction between the South Island subspecies and the species as a whole.

[29] DOC has confirmed that the Marine Mammal Action Plan for 2005–2010 still reflects DOC's priorities for marine mammal conservation.

5.2 BIOLOGY

5.2.1 TAXONOMY

Hector's and Māui dolphin is one of four species in the genus *Cephalorhynchus*, which are all restricted to cool, temperate, coastal waters in the southern hemisphere. On the basis of morphological differences, and genetic information which indicated reproductive isolation, Hector's and Māui dolphin was divided into two sub-species; Hector's dolphin around the South Island (41 □S to 47 □S) and Māui dolphin on the west coast of the North Island (36°S to 40°S; Baker et al 2002). The reproductive isolation of the Māui subspecies is supported by a more recent genetic analysis with a larger sample size (Hamner et al 2012a) despite genetic analyses having located four Hector's dolphins off the WCNI (Hamner et al 2014).

5.2.2 DISTRIBUTION

Hector's dolphins are most frequently sighted on the west coast of the South Island (WCSI) between Jackson Bay and Kahurangi Point (Bräger & Schneider 1998, Rayment et al 2011a), on the east coast (ECSI) between the Marlborough Sounds and Otago Peninsula (Dawson et al 2004, MacKenzie & Clement 2014) and on the south coast (SCSI) between Toetoes Bay and Porpoise Bay and in Te Waewae Bay (Bejder & Dawson 2001, Dawson et al 2004). Current population densities are lower in the intervening stretches of coast, e.g. Fiordland (Bräger & Schneider 1998), Golden Bay (Slooten et al 2001) and the south Otago coast (Jim Fyfe, personal communication), resulting in a fragmented distribution. There is significant genetic differentiation among the west, east and south coast populations, with little or no gene flow connecting them (Pichler et al 1998; Pichler 2002; Hamner et al 2012a). The observed levels of genetic divergence over such small distances are unusual among cetaceans, especially considering the absence of geographical barriers (Pichler et al 1998). These genetic differences are thought to result from individuals having small home ranges and high philopatry (Pichler et al 1998, Bräger et al 2002, Rayment et al 2009b). For example, the mean lifetime alongshore home range of the 20 most frequently sighted dolphins at Banks Peninsula was 49.7 km (SE = 5.29; ranging from 13.60 km to 101.43 km for individual dolphins) for the period 1985 to 2006 (Rayment et al 2009b).

Satellite tagging of three Hector's dolphins off the Banks Peninsula in 2004 indicated maximum distances between locations of 50.9 to 66.5 km over deployments lasting from four to seven months (Stone et al 2005). For photo identified dolphins, Rayment et al (2009a) reported distances between extreme sightings for 53 dolphins ranging from 9.34 km to 107.38 km for the period 1985 – 2006.

Genetic testing of dolphins off the WCNI since 2001 has identified a small number of Hector's dolphins located within the contemporary distribution of Māui dolphin in the WCNI area as far north as the Manukau Harbour. These results raise the possibility of at least occasional long distance dispersal by Hector's dolphins (Hamner et al 2012b). Although some of these dolphins were found in association with Māui dolphins there is currently no evidence of interbreeding (Hamner et al 2014). Some of the Hector's dolphins sampled on the WCNI could not be unambiguously assigned to one of the three Hector's dolphin populations leading Hamner et al (2014) to raise the possibility that they may represent a hitherto unsampled population of Hector's dolphins or indicate interbreeding between the ESCI and WCSI populations.

Māui dolphins are most frequently sighted between Maunganui Bluff and New Plymouth (Slooten et al 2005; Du Fresne 2010; Hamner et al 2012a, b). Research surveys since 2003 have sighted Māui dolphins between Kaipara Harbour and Kawhia (Slooten et al 2005, Du Fresne 2010; Hamner et al 2012a, b). Historical samples from strandings and museum specimens have allowed genetic identification of Māui dolphins on the WCNI from Dargaville to Wellington (DOC Sightings Database 2013; DOC Incident Database 2013, Hamner, pers. comm.); however there are doubts as to the provenance of a record of a Māui dolphin attributed to the Bay of Islands (Hamner, pers. comm.).

There are reported public sightings of Hector's and Māui dolphins from all around the North Island coast, including the Bay of Islands, Hauraki Gulf, Coromandel Peninsula, Hawkes Bay, Wairarapa and Kapiti Coast (Baker 1978, Cawthorn 1988, Russell 1999, DOC Incident Database 2013). Pichler & Baker (2000) reported genetic analysis of samples of Hector's and Māui dolphins dating back to 1870 and suggest that abundance has declined and geographic range has contracted over the past 140 years. It has also been suggested that Māui dolphin's range has contracted off the west coast of the North Island in recent history coincident with a decline in abundance (MPI & DOC 2012).

Small scale movements by Māui dolphins over up to 80 km of coastline have been revealed by repeated genetic sampling of the same individuals (mean distance between the two most extreme locations for the six individuals sampled at least three times = 35.5 km; SE = 4.03 km; Oremus et al 2012).

Hector's and Māui densities are highest close to the coast throughout the year. Bräger et al (2003) used resource selection models to show that Hector's dolphins have a preference for shallow, turbid waters. During systematic aerial surveys on the South Island west coast (Rayment et al 2011a), east coast (MacKenzie & Clement 2014, Figure 5.2 and Figure 5.3), at Banks Peninsula (Rayment et al 2010), in Cloudy and Clifford Bays (DuFresne & Mattlin 2009) and on the North Island west coast (Slooten et al 2005) most sightings were in water depths less than 100 m (e.g. Figure 5.2 and Figure 5.3). Occasional sightings are made beyond the 100 m isobath (e.g. DuFresne & Mattlin 2009, MacKenzie & Clement 2014). Varying bathymetry among these locations meant that all sightings were within 6 n.mi. offshore of the South Island west coast (Rayment et al 2011a), yet extended at least out to 20 n.mi. from the coast at Banks Peninsula (MacKenzie & Clement 2014). In both these areas, distance offshore best explained dolphin distribution, possibly due to declining prey availability with increasing distance from the coast (Rayment et al 2010, 2011a). At Banks Peninsula, there was a significant seasonal difference in distribution, with a greater proportion of dolphins close to shore in summer than winter (Rayment et al 2010, MacKenzie & Clement 2014), a conclusion consistent with nearshore boat-based surveys (e.g. Dawson & Slooten 1988, Bräger 1998) and passive acoustic monitoring (Rayment et al 2009a). However, the furthest offshore sighting distances were similar in summer and winter (Rayment et al 2010, MacKenzie & Clement 2014). From analysis of passive acoustic data, Dawson et al (2013a) suggested that dolphins use of an inner harbour site in Akaroa Harbour was greater than expected in winter, and that habitat selection was affected by time of day and state of the tide. No such seasonal difference in dolphin distribution was detected during aerial surveys on the South Island west coast (Rayment et al 2011a).

The highest density of Māui dolphins occurs inshore (within 4 n.mi. of the coast) between Manukau Harbour and Port Waikato (Slooten et al 2005, MPI & DOC 2012, Oremus et al 2012). Sightings are occasionally made beyond 4 n.mi. from the coast, extending at least to 7 n.mi. offshore (Du Fresne 2010, Thompson & Richard 2012). Sightings of Māui dolphins have been made in three North Island harbours (Kaipara, Manukau and Raglan; see review in Slooten et al 2005). Passive acoustic monitoring of these three harbours, in addition to Kawhia Harbour, revealed a low-level of episodic use of Kaipara and Manukau Harbours (Rayment et al 2011b).

A map of Māui dolphin distribution[30] was developed as part of the Māui dolphin risk assessment (Currey et al 2012). The distribution was generated via generalised additive modelling (Thompson & Richard 2012) of systematic survey data (Ferreira & Roberts 2003, Slooten et al 2005, 2006, Scali 2006, Rayment & du Fresne 2007, Childerhouse et al 2008, Stanley 2009, Hamner et al 2012a) and modification to incorporate expert panel feedback regarding the alongshore, offshore and inshore extent (Figure 5.1; see Currey et al 2012 for further details).

5.2.3 FORAGING ECOLOGY

Miller et al (2013) investigated the diet of Hector's and Māui dolphins through the examination of diagnostic prey remains in the stomachs of 63 incidentally captured and beach-cast animals. They concluded that Hector's dolphins

[30] The map of Maui's dolphin distribution was produced using data that included sightings of unknown sub-species identity (e.g. from aerial surveys). Hector's dolphins have been detected off the North Island West Coast. However, they comprised just 4 of the 91 animals genetically identified within the area of mapped distribution since 2001 (two living females, one dead female, one dead male; Hamner et al 2012a, 2013). The two living Hector's dolphins were found in association with Maui's dolphins and three of four dolphins were found in or near Manukau Harbour, close to the core of Maui's dolphin distribution (Figure 5.1). Given that the proportion of Hector's dolphins is likely to be small and there was no evidence to suggest that their inclusion would bias the distribution, the risk assessment proceeded with this map on the basis that it provided the best estimate of Maui's dolphin distribution available.

take a wide variety of prey throughout the water column (in total 29 taxa were recorded), but that the diet is dominated by a few mid-water and demersal species, particularly red cod (*Pseudophycis bachus*), ahuru (*Auchenoceros punctatus*), arrow squid (*Notodarus* sp.), sprat (*Sprattus* sp.), sole (*Peltorhamphus* sp.) and stargazer (*Crapatulus* sp.). Prey items ranged from an estimated 0.5–60.8 cm in length, but the majority were less than 10 cm in length, indicating that the juveniles of some species were targeted (Miller et al 2013). The diets of dolphins from the South Island west and east coasts were significantly different, due largely to the importance of javelinfish (*Lepidorhynchus denticulatus*) on the west coast, and a greater consumption of demersal prey species on the east coast (Miller et al 2013). Only two samples were derived from the west coast of the North Island, containing only red cod, ahuru, sole and flounder (Rhomboselea sp.; Miller et al 2013). The stomachs of the six smallest dolphins in the sample (standard length under 90 cm) contained only milk, while the next largest (99 cm standard length) contained milk and remains of arrow squid (Miller et al 2013). Milk was not found in the stomachs of any dolphins longer than 107 cm (Miller et al 2013).

Hector's dolphins have been observed foraging in association with demersal trawlers at Banks Peninsula, presumably targeting the fish disturbed but not captured by the trawl net (Rayment & Webster 2009). Dolphins are occasionally seen foraging near the sea surface on small fish including sprat, pilchard (*Sardinops neopilchardus*) and yellow-eyed mullet (Aldrichetta forsteri; Miller et al 2013), sometimes in association with white-fronted terns (Sterna striata; Brager 1998). The seasonal changes in distribution of Hector's dolphins at Banks Peninsula described above are presumed to be in response to seasonal movements of their prey species (Rayment et al 2010), many of which migrate into shallower nearshore waters in the summer months (Paul 2000).

5.2.4 REPRODUCTIVE BIOLOGY

Incidentally captured and stranded Hector's dolphins have provided information on the life history and reproductive parameters of the species. Males reach sexual maturity between six and nine years of age, and females have their first calf between seven and nine years old (Slooten 1991). Examination of the ultrastructure of the teeth from these necropsied animals revealed that females live to at least 19 years (n = 33) and males (n = 27) to at least 20 (Slooten 1991). Photo-ID studies have provided additional data and revealed that the calving interval is two to four years (Slooten 1990) and that longevity is at least 22 years (Rayment et al 2009b; Webster et al 2009). Gormley (2009) extended these analyses, estimating mean female fecundity of Hector's dolphins off Banks Peninsula at 0.205 female offspring per capita per annum (SD = 0.050) and mean age at first reproduction at 7.5 years (SD = 0.42).

Calves are typically born during spring and early summer, with neonatal length estimated to be 60–75 cm (Slooten & Dawson 1994). Calves stay with their mothers for at least one year, more usually two, and the mother does not appear to conceive again until the calf is independent (Slooten & Dawson 1994). Application of the growth models produced by Webster et al (2010) to the diet data obtained by Miller et al (2013) suggests that weaning occurs between one and two years of age. Growth is rapid and asymptotic length is reached in 5–6 years (Webster et al 2010). Sexually mature adults usually fall within the range 119–145 cm total length and at maturity females are approximately 10 cm longer than males (Slooten & Dawson 1994; Webster et al 2010). In a sample of 66 female and 100 male known age Hector's dolphins, the maximum total length measurements were 145 cm and 132 cm respectively (Webster et al 2010). Māui dolphins are significantly longer than Hector's dolphins, with a maximum recorded total length of 162 cm (Russell 1999).

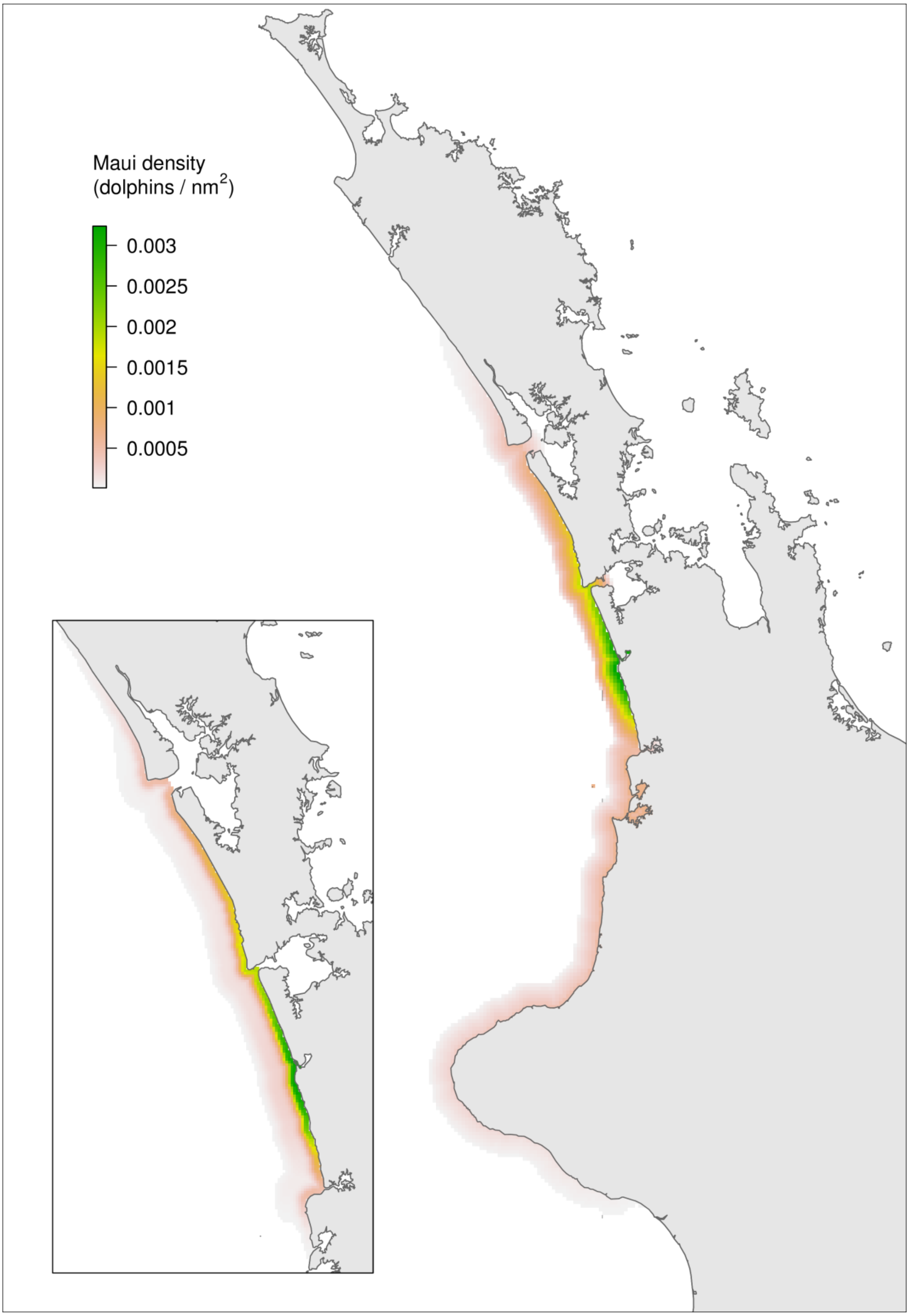


Figure 5.1: Māui dolphin distribution modelled from systematic survey data collected between 2000 and 2012 and modified to incorporate expert panel feedback (Currey et al 2012). The inset depicts the modelled distribution prior to modification (Thompson & Richard 2012).

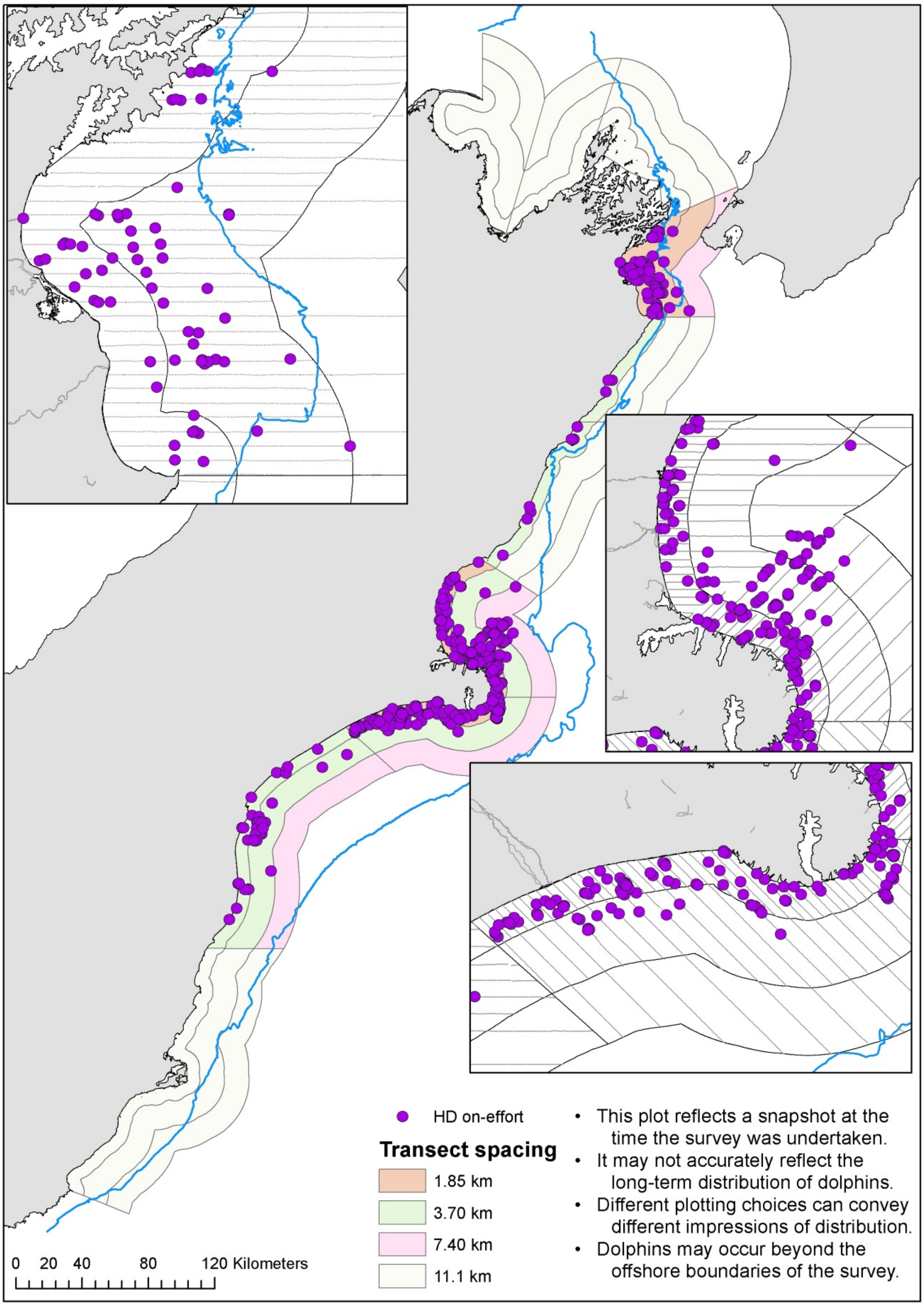


Figure 5.2: The distribution of all on-effort sightings of Hector's dolphins during the summer survey of the ECSI between 28 January and 13 March 2013. Reproduced from MacKenzie & Clement (2014).

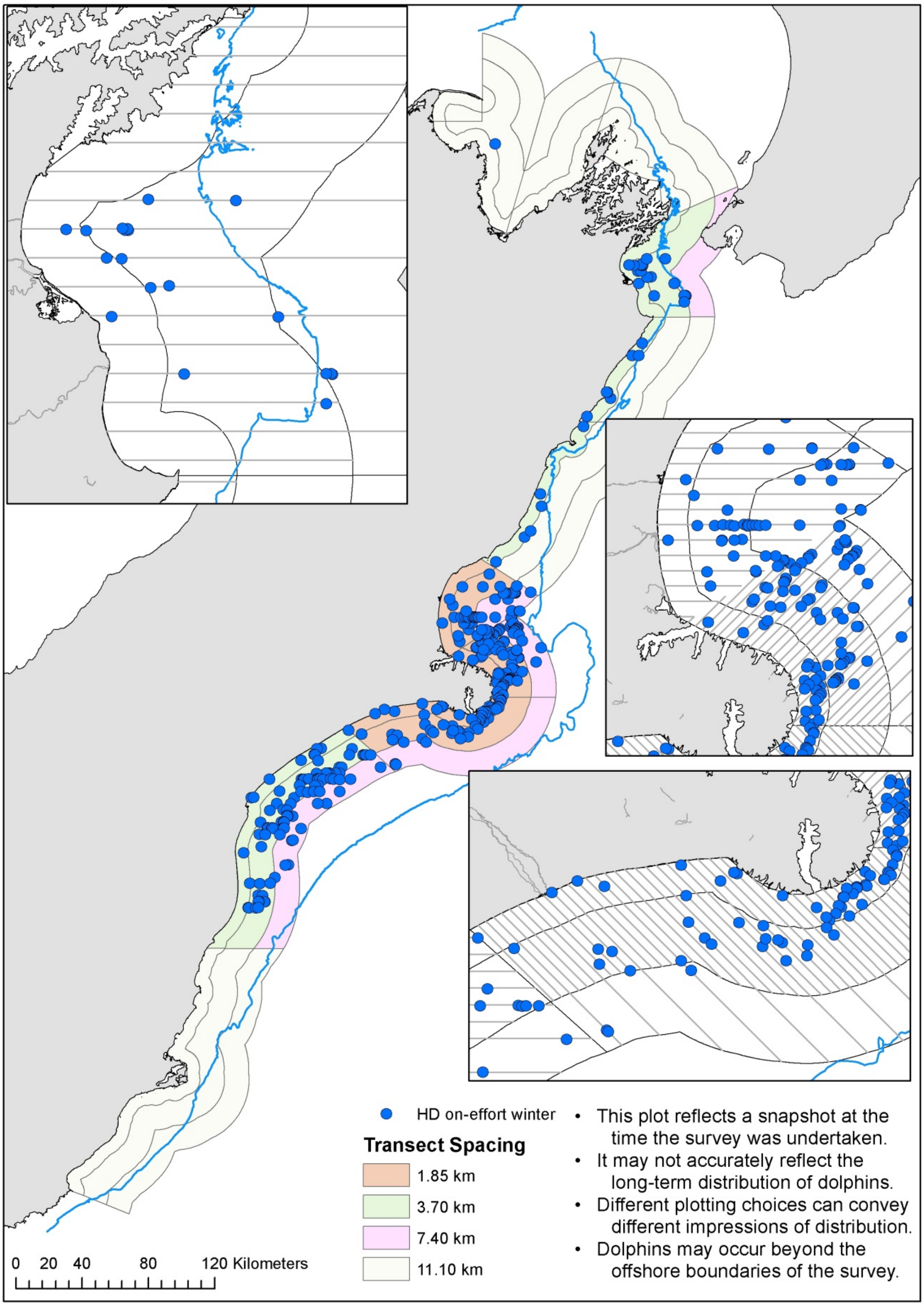


Figure 5.3: The distribution of all on-effort sightings of Hector's dolphins during the winter survey of the ECSI between 1 July and 18 August 2013. Reproduced from MacKenzie & Clement (2014).

Hector's and Māui dolphins are typically found in small groups of 1–14 individuals (Slooten et al 2006, Rayment et al 2010, 2011b, Oremus et al 2012). Mean group sizes appear to be larger when estimated from boat based surveys (e.g. Webster et al 2009, Oremus et al 2012) compared with aerial surveys (e.g. Slooten et al 2006, Rayment et al 2010) possibly due to the species' boat-positive behaviour (e.g. Dawson et al 2004). Webster et al (2009) found that Hector's dolphin groups were highly segregated by sex, with 91% of groups of up to five individuals being all male or all female. Using molecular sexing techniques, Oremus et al (2012) found no evidence of sexual segregation in groups of fewer than eight Māui dolphins. The social organisation of Hector's dolphin groups is characterised by fluid association patterns, with little stability over periods longer than a few days (Slooten et al 1993). Together with observations of sexual behaviour (Slooten 1990) and the relatively large testis size of males (Slooten 1991), this suggests that Hector's dolphins have a promiscuous mating system, in which males seek encounters with multiple females rather than attempting to monopolise them (Slooten et al 1993).

These life-history characteristics mean that Hector's dolphins, like many other small cetaceans (Perrin & Reilly 1984), have a low intrinsic population growth rate. Using matrix population models, asymptotic population growth rate for Hector's dolphins was estimated to be –4.2 to +4.9% per year for survivorship schedules based on other mammals (Slooten & Lad 1991). The authors considered that a growth rate of 1.8% was a plausible "best case" scenario for Hector's dolphin (Slooten & Lad 1991). Estimates of the intrinsic rate of increase from matrix models are sensitive to the particular parameters chosen (Slooten & Lad 1991, Gormley et al 2012, Baker et al 2013).

5.2.5 POPULATION BIOLOGY

The earliest survey-based abundance estimate for Hector's and Māui dolphin (3408 animals with a suggested range of 3000 to 4000) was obtained via small boat-based strip transects surveys (Dawson & Slooten 1988, Table 5.1). These surveys were primarily focused on assessing alongshore distribution rather than abundance. Consequently survey effort was concentrated within 800 m of shore and calibrated with a limited number of 5 n.mi. offshore transects. Nationwide line transect surveys of Hector's and Māui dolphin were carried out between 1997 and 2004 (Dawson et al 2004, Slooten et al 2004, 2006). These resulted in a population estimate for Hector's dolphin around the South Island and offshore to 4 n.mi. of 7270 (CV = 16%; Slooten et al 2004) and for Māui dolphin of 111 (CV = 44%; Slooten et al 2006; Table 5.1). Further aerial surveys focused on assessing seasonal and annual variation in distribution around Banks Peninsula (Rayment et al 2010) and in distribution and abundance in Cloudy and Clifford Bays (DuFresne & Mattlin 2009)[31]. There have also been a number of photo-ID mark-recapture estimates focused on sub-populations of Hector's dolphin (Bejder & Dawson 2001, Gormley et al 2005, Turek et al 2013; Table 5.1) and genotype mark-recapture estimates of abundance for Māui dolphin and Hector's dolphins in Cloudy Bay (Hamner et al 2012b, 2013, Baker et al 2013,Table 5.1). The genetic mark-recapture data yielded estimates of average annual population change for Māui dolphin of -0.13 (i.e. a 13% decrease p.a.; 95% CI = -0.40 to +0.14) for the period 2001 – 2007 (Baker et al 2013), and -0.03 (95% CI = -0.11 to +0.06) for the period 2001 – 2011 (Hamner et al 2012b). Population trends have also been inferred for Māui dolphins via other methods, including linear regression of the natural logarithm of abundance estimates obtained using a variety of survey methods over the period 1985 to 2011 (–0.032; 90% CI = –0.057 to –0.006 for aerial and boat surveys; –0.037; 90% CI = –0.042 to –0.032 for boat surveys alone; Wade et al 2012). Analysis of the Māui dolphin risk assessment expert panel's mortality scores yielded an estimated rate of population decline of 7.6% per annum (95% CI = 13.8% decline to 0.1% increase; Currey et al 2012). Across methods, estimates of Māui dolphin population trends indicate a high probability that the population is declining, with mean or median estimates suggesting a rate of decline at or above 3% per annum (Currey et al 2012, Hamner et al 2012b, Wade et al 2012, Baker et al 2013).

Recently, MPI-funded survey programmes (PRO2009-01A, PRO2009-01B, PRO2009-01C) were conducted to assess abundance and distribution of the SCSI and ECSI populations of Hector's dolphin (Clement et al 2011, MacKenzie et al 2012, MacKenzie & Clement 2014).The SCSI programme involved two aerial surveys undertaken during March 2010 and August 2010 between Puysegur

[31] There is uncertainty as to how sightings in the area viewed by more than one observer were treated in the analysis. This will be investigated under project PRO2013-08.

Point and Nugget Point and out to the 100 m depth contour (PRO2009-01A, Clement et al 2011)[32]. Seven dolphin groups were sighted during summer/autumn surveys and ten groups were observed in winter. Sightings data pooled across seasons were analysed using mark-recapture distance sampling (MRDS) with helicopter-based dive cycle observations used to correct for availability bias. SCSI Hector's dolphin abundance was estimated to be 628 dolphins (CV = 38.9%, 95% CI = 301–1,311, Clement et al 2011).

The ECSI program involved an initial design phase (PRO2009-01B, MacKenzie et al 2012) followed by two aerial surveys conducted over summer 2012-13 and winter 2013 between Farewell Spit and Nugget Point and offshore to 20 n.mi. (covering about 42 677 km2; PRO2009-01C; MacKenzie & Clement 2014). A total of 354 dolphin groups were sighted in the summer, along 7156 km of transect lines, and 328 dolphin groups were sighted in the winter, along 7276 km of transect lines (Figures 5.2 and 5.3). Sightings data were analysed using MRDS and density surface modelling techniques to yield estimates of density and total abundance. The estimates of ECSI Hector's dolphin abundance were 9130 dolphins (CV = 19%, 95% CI = 6342–13144) in summer 2012-13 and 7456 dolphins (CV = 18%, 95% CI = 5224–10 641) in winter 2013 (MacKenzie & Clement 2014). These estimates were obtained via model averaging four sets of MRDS results for each season; from two different data sets using different truncation distances and two methods of estimating availability (helicopter-based dive cycle and survey aircraft circle-backs). These estimates do not include harbours and bays that were outside of the survey region. This work has been subject to international peer review.

Hector's dolphin is one of very few dolphin species for which estimates of survival are available. For long lived species, a long time-series of data is required to robustly estimate survival. The long term photo-ID study at Banks Peninsula has facilitated several survival rate estimates since its inception in 1984 (Slooten et al 1992, Cameron et al 1999, Du Fresne 2004, Gormley et al 2012). The most recent analysis utilises the most data and is therefore arguably the most powerful. Survival rate was estimated as 0.863 (95% CI = 0.647 – 0.971) for the period 1986–1988, prior to the designation of the Banks Peninsula Marine Mammal Sanctuary, and 0.917 (95% CI = 0.802 – 0.984) from 1989–2006 after the designation (Gormley et al 2012). Given the reproductive parameters detailed above, these survival rate estimates equate to a mean estimated population growth rate of 0.939 (95% CI = 0.779 – 1.025) pre-sanctuary and 0.995 (95% CI = 0.927 – 1.048) post-sanctuary (Gormley et al 2012). In the post-sanctuary scenario, most of the uncertainty in the population growth estimate is due to uncertainty in the estimate of fecundity (Gormley et al 2012).

Annual survival of Māui dolphin has been estimated from the genotype mark-recapture data (Hamner et al 2012b, Baker et al 2013). The most precise estimates come from the longest data series, 2001 – 2011, yielding survival rates of 0.83 from a Pradel model (95% CI = 0.75 – 0.90) and 0.84 from a POPAN model (95% CI = 0.75 – 0.90\, Hamner et al 2012b).

Fisheries mortality is known to be a serious threat to Hector's and Māui dolphins (DOC & MFish 2007, MPI & DOC 2012, see below). There is no evidence to suggest that any of the other known or potential threats to Hector's and Māui dolphin cause mortalities on the order of tens or hundreds of individuals per year. There has been one confirmed death due to boat strike since 1921, a Hector's dolphin calf in Akaroa harbour in 1999 (Stone & Yoshinaga 2000, DOC Incident Database 2013).

Other known sources of mortality include predation by sharks (e.g. Cawthorn 1988), disease (e.g. Roe et al 2013) and separation of calves from their mothers (DOC Incident Database 2013), possibly exacerbated by extreme weather conditions (DOC & MFish 2007, MPI & DOC 2012).

The presence of tourist vessels has been demonstrated to cause behavioural changes (Bejder et al 1999, Martinez et al 2012). There are potential negative effects due to bioaccumulation of organochlorines and heavy metals (reviewed by Slooten & Dawson 1994). Stockin et al (2010) reported elevated levels of PCBs and organochlorine pesticides in the tissues of Hector's and Māui dolphins but noted that no PCB concentrations were over the threshold considered to have immunological and reproductive effects. Additionally, both sub-species face pressures placed on coastal habitat through activities such as aquaculture, seabed mining, dredging and tidal energy

[32] There is uncertainty as to how sightings in the area viewed by more than one observer were treated in the analysis. This will be investigated under project PRO2013-08.

installations (DOC & MFish 2007, Currey et al 2012, MPI & DOC 2012).

A comprehensive list of the threats posed to Māui dolphins was produced as part of the spatially-explicit, semi-quantitative risk assessment (Currey et al 2012). The expert panel was asked to identify, analyse and evaluate all potential threats to Māui dolphins. Working from a previously established list of 47 potential threats to Hector's dolphins from the Hector's and Māui dolphin TMP (DOC & MFish 2007), the expert panel assessed 23 threats potentially relevant to Māui dolphins (i.e., present within their established distribution) in terms of whether these were likely to affect population trends within the next five years (Table 5.2). For each of these threats, the expert panel provided estimates of the number of Māui dolphin mortalities per year (Table 5.3).

Table 5.1: Abundance estimates for Hector's and Māui dolphin. N = estimated population size. * applies to individuals more than 1 yr of age and includes two individuals genetically identified as Hector's dolphins. [Continued on next page]

Sampling period	Sub-species	Survey area	Survey method	Analysis method	N	CV	95% CI	Reference
1984–1985	Hector's and Māui dolphin	North and South Islands	Small boat based strip-transect	Distance sampling	3408		3000 – 4000 (range)	Dawson & Slooten 1988
1989–1997	Hector's dolphin	Banks Peninsula	Photo-ID	Mark-recapture	1119	0.21	744 – 1682	Gormley et al 2005
1995–1997	Hector's dolphin	Porpoise Bay	Photo-ID	Mark-recapture	48		44 – 55	Bejder & Dawson 2001
1997–1998	Hector's dolphin	Motunau – Timaru (0 – 4 n.mi.)	Boat based line-transect	Distance sampling	1198	0.27	848 – 1693	Dawson et al 2004
1998–1999	Hector's dolphin	Timaru – Long Point (0 – 4 n.mi.)	Boat based line-transect	Distance sampling	399	0.26	279 – 570	Dawson et al 2004
1999–2000	Hector's dolphin	Farewell Spit – Motunau (0 – 4 n.mi.)	Boat based line-transect	Distance sampling	285	0.39	137 – 590	Dawson et al 2004
2000–2001	Hector's dolphin	Farewell Spit – Milford Sound (0 – 4 n.mi.)	Aerial line-transect	Distance sampling	5388	0.21	3613 – 8034	Slooten et al 2004
2001–2007	Māui dolphin	Kaipara Harbour – Tirua Point	Biopsy	Mark-recapture	59		19 – 181	Baker et al 2013
2004	Māui dolphin	Maunganui Bluff – Pariokariwa Point (0 – 4 n.mi.)	Aerial line-transect	Distance sampling	111	0.44	48 – 252	Slooten et al 2006
2004–2005	Hector's dolphin	Te Waewae Bay	Photo-ID	Mark-recapture	251 (autumn)	0.162	183 – 343	Green et al 2007
					403 (summer)	0.121	280 – 488	
2006–2009	Hector's dolphin	Cloudy and Clifford Bays (100 m contour)	Aerial line-transect	Distance sampling	951 (summer)	0.26	573 – 1577	DuFresne & Mattlin 2009
					927 (autumn)	0.30	520 – 1651	
					315 (winter)	0.31	173 – 575	
					188 (spring)	0.33	100 – 355	
2010	Hector's dolphin	Puysegur Point - Nugget Point (100 m contour)	Aerial line-transect	Distance sampling	628	0.39	301 – 1311	Clement et al 2011
2010–2011	Māui dolphin	Kaipara Harbour – New Plymouth	Biopsy	Mark-recapture	57*		49 – 71	Hamner et al 2012b

Table 5.1 [Continued]:

2010–2011	Hector's dolphin	Taiaroa Head – Cornish Head (Otago)	Photo-ID	Mark-recapture	42	0.41	19 – 92	Turek et al 2013
2011–2012	Hector's dolphin	Cloudy Bay	Biopsy	Mark-recapture	272	0.12	236 – 323	Hamner et al 2013
2012–2013	Hector's dolphin	Farewell Spit - Nugget Point (0 – 20 n.mi.)	Aerial line-transect	Mark-recapture distance sampling	9130 (summer)	0.19	6342 – 13144	MacKenzie & Clement 2014
					7456 (winter)	0.18	5224 – 10641	

The expert panel's assessment of mortalities can be treated as testable hypotheses (Currey et al 2012) and evaluated using new information. Roe et al 's (2013) finding that 2 of 3 Māui dolphins tested in the period 2007 to 2011 had died as a result of *Toxoplasma gondii* infection, possibly as a result of run off from terrestrial sources, indicates that the panel results (Table 5.3) may have underestimated mortality from this source. Roe et al (2013) note that toxoplasmosis may have other effects beyond direct mortality and could be an important cause of neonatal loss.

The panel process resulted in estimated numbers of Māui dolphin mortalities from commercial set net fisheries of 2.33 (95% CI: 0.02–4.26) per annum, with spatial disaggregation of the estimates indicating that Māui dolphins are exposed to the greatest level of risk from set net fisheries in the area of the northern Taranaki coastline out to 7 n.mi. offshore, and at the entrance to the Manukau Harbour. Subsequent interim measures restricted set net fishing within 2 n.mi. of the Taranaki coast and required full observer coverage of set net fishing to 7 n.mi. No Māui dolphins have been captured or sighted by observers in the Taranaki set net fishery to date.

5.2.6 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

Threat classification is an established approach for identifying species at risk of extinction (IUCN 2013). The risk of extinction for Hector's and Māui dolphin has been assessed under two threat classification systems: the New Zealand Threat Classification System (Townsend et al 2008) and the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2013).

The IUCN classifies Māui dolphin as Critically Endangered under criteria A4c,d and C2a(ii)[33] due to an ongoing and projected decline of greater than 80% over three generations, and there being fewer than 250 mature individuals remaining (Reeves et al 2013a). Critically Endangered is the most threatened status before "Extinct in the Wild". Hector's dolphin is classified by the IUCN as Endangered under criterion A4d[34] due to an ongoing and projected decline of greater than 50% over three generations (Reeves et al 2013b).

Under the New Zealand Threat Classification System (Baker et al 2010), Māui dolphin is classified as Nationally

[33] A taxon is listed as 'Critically Endangered' if it is considered to be facing an extremely high risk of extinction in the wild. A4c,d refers to a reduction in population size (A), based on an observed, estimated, inferred, projected or suspected reduction of ≥ 80% over any 10 year or three generation period (whichever is longer up to a maximum of 100 years (3); with the reduction being based on a decline in area of occupancy, extent of occurrence and/or quality of habitat (c); or actual or potential levels of exploitation (d; IUCN 2010). C2a(ii) refers to a population size estimated to number fewer than 250 mature individuals (C); with a continuing decline, observed, projected, or inferred, in numbers of mature individuals (2); and a population structure (a) with at least 90% of mature individuals in one subpopulation (ii; IUCN 2013).

[34] A taxon is listed as 'Endangered' if it is considered to be facing a very high risk of extinction in the wild. A4d refers to a reduction in population size (A), based on an observed, estimated, inferred, projected or suspected reduction of ≥ 80% over any 10 year or three generation period (whichever is longer up to a maximum of 100 years (3); with the reduction being based on actual or potential levels of exploitation (d, IUCN 2013).

Critical, the most threatened status, under criterion A(1), with the qualifier Conservation Dependent (CD)[35] and Hector's dolphin as Nationally Endangered, the second most threatened status, under criterion C(1/1), with the qualifier Conservation Dependent (CD)[36].

5.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

Coastal cetaceans are impacted by incidental capture in fisheries throughout the world (Read et al 2006, Read 2008, Reeves et al 2003). Read et al (2006) estimated that global incidental captures of cetaceans exceeded 270 000 p.a. in the mid-1990s and that more than 95% of incidental captures occurred in set nets. Hector's and Māui dolphins are endemic to New Zealand and hence discussion of fisheries interactions for the species is detailed below under state of knowledge in New Zealand.

5.4 STATE OF KNOWLEDGE IN NEW ZEALAND

It is widely accepted that incidental mortality in coastal fisheries, notably set nets and to a lesser extent trawls, is the most significant threat to Hector's and Māui dolphins (MFish & DOC 2007, Slooten & Dawson 2010, Currey et al 2012, see Table 5.3). Hector's and Māui dolphins have been caught in inshore commercial and recreational set net fisheries since at least the early 1970s (Taylor 1992). Incidental mortalities have been documented throughout the species' range (Table 5.4). Beach cast carcasses are frequently reported by members of the public, with the greatest number of reports coming from the east coast of the South Island (DOC Incident Database 2013, Table 5.4). The numbers reported in the DOC Incident database are not representative of the total magnitude or relative scale of incidental capture (DOC Incident Database 2013, Slooten 2013) because carcasses may not be reported by fishers, may not wash ashore, may not be recovered or may not show evidence of interaction with fishing gear. Carcass reporting is also likely to be correlated with proximity to major population centres and thoroughfares. The information in the incident data base (Table 5.4) provides only a biased indication of incidental captures. It is clear from this information however that incidental captures occur in all areas where Hector's and Māui dolphins are found. Observer programmes, and potentially video monitoring, are the only robust way to quantify incidental captures (see below).

Incidental capture most frequently occurs in commercial set nets targeting rig (*Mustelus lenticulatus*), elephant fish (Callorhynchus milli) and school shark (*Galeorhinus australis*, Dawson 1991, Baird & Bradford 2000), and in recreational nets set for flounder (*Rhomboselea* sp.) and moki (*Latridopsis ciliaris*, Dawson 1991).

Nineteen individual Hector's dolphins were reported caught in trawl fisheries between 1921 and 2008 (Table 5.4, DOC Incident Database 2013). The first report of incidental capture in the commercial trawl fishery dates back to 1973 (Baker 1978).

[35] A taxon is listed as 'Nationally Critical' under criterion A(1) when evidence indicates that there are fewer than 250 mature individuals, regardless of population trend and regardless of whether the population size is natural or unnatural (Townsend et al 2008).

[36] A taxon is 'Nationally Endangered' under criterion C(1/1)when evidence indicates that the total population size is 1000–5000 mature individuals and there is an ongoing or predicted decline of 50–70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer (Townsend et al 2008).

Table 5.2: Characterisation of threats evaluated as relevant to Māui dolphins and likely to affect population trends within the next five years. Reproduced from Currey et al (2012).

Threat class	Threat	Mechanism	Type	Population component(s) affected
Fishing	Commercial trawl	Incidental capture, cryptic mortality	Direct	Juvenile or adult survival
	Commercial set net	Incidental capture, cryptic mortality	Direct	Juvenile or adult survival
	Recreational set net	Incidental capture, cryptic mortality	Direct	Juvenile or adult survival
	Recreational driftnet	Incidental capture, cryptic mortality	Direct	Juvenile or adult survival
	Customary set net	Incidental capture, cryptic mortality	Direct	Juvenile or adult survival
	Trophic effects	Competition for prey, changes in abundance of prey and predator species	Indirect	Fecundity, juvenile or adult survival
	Vessel noise: displacement, sonar	Displacement from habitat, masking biologically important behaviour	Indirect	Fecundity, juvenile or adult survival
Vessel traffic	Boat strike	Physical injury/mortality	Direct	Juvenile or adult survival
	Disturbance	Displacement from habitat, masking biologically important behaviour	Indirect	Fecundity, juvenile or adult survival
Pollution	Agricultural run-off	Compromising dolphin health, habitat degradation, trophic effects	Indirect	Fecundity, juvenile or adult survival
	Industrial run-off	Compromising dolphin health, habitat degradation, trophic effects	Indirect	Fecundity, juvenile or adult survival
	Plastics	Compromising dolphin health, ingestion and entanglement	Both	Fecundity, juvenile or adult survival
	Oil spills	Compromising dolphin health, ingestion (direct and prey) and inhalation	Both	Fecundity, juvenile or adult survival
	Trophic effects	Changes in abundance of prey and predator species	Indirect	Fecundity, juvenile or adult survival
	Sewage and stormwater	Compromising dolphin health, habitat degradation, trophic effects	Indirect	Fecundity, juvenile or adult survival
Disease	Natural	Compromising dolphin health	Both	Fecundity, juvenile or adult survival
	Stress-induced	Compromising dolphin health	Both	Fecundity, juvenile or adult survival
	Domestic animal vectors	Compromising dolphin health	Both	Fecundity, juvenile or adult survival
Small population effects	Stochastic and Allee effects	Increased susceptibility to other threats	Indirect	Fecundity, juvenile or adult survival
Mining and oil activities	Noise (non-trauma)	Displacement from habitat, masking biologically important behaviour	Indirect	Fecundity, juvenile or adult survival
	Noise (trauma)	Compromising dolphin health	Direct	Fecundity, juvenile or adult survival
	Pollution (discharge)	Compromising dolphin health	Indirect	Fecundity, juvenile or adult survival
	Habitat degradation	Displacement from habitat, reduced foraging efficiency, trophic effects	Indirect	Fecundity, juvenile or adult survival

Table 5.3: Estimated number of Māui dolphin mortalities per year, the risk ratio of estimated mortalities to PBR and the likelihood of exceeding PBR for each threat, as scored by the expert panel. Individual threat scores were bootstrap resampled from distributions specified by the panel members and aggregated to generate medians and 95% confidence intervals. Modified from Currey et al (2012).

Threat	Estimated mortalities		Risk ratio		Likelihood of exceeding PBR
	Median	95% CI	Median	95% CI	Median percentage
Fishing	4.97	0.28–8.04	71.5	3.7–143.6	100.0
Commercial set net fishing	2.33	0.02–4.26	33.8	0.3–74.3	88.9
Commercial trawl fishing	1.13	0.01–2.87	16.7	0.1–48.5	88.9
Recreational/customary set net fishing	0.88	0.02–3.14	12.8	0.3–50.9	88.7
Recreational driftnet fishing	0.05	0.01–0.71	0.7	0.1–10.9	41.3
Trophic effects of fishing	0.01	<0.01–0.08	0.1	<0.1–1.2	4.7
Vessel noise/disturbance from fishing	<0.01	<0.01–0.10	<0.1	<0.1–1.6	9.0
Mining and oil activities	0.10	0.01–0.46	1.5	0.1–7.4	61.3
Habitat degradation from mining and oil activities	0.03	<0.01–0.17	0.4	<0.1–2.7	26.4
Noise (non-trauma) from mining and oil activities	0.03	<0.01–0.23	0.5	<0.1–3.6	28.6
Noise (trauma) from mining and oil activities	0.01	<0.01–0.13	0.2	<0.1–2.0	8.8
Pollution (discharge) from mining and oil activities	<0.01	<0.01–0.13	0.1	<0.1–2.2	13.4
Vessel traffic	0.07	<0.01–0.19	1.0	0.1–3.1	47.8
Boat strike from all vessels	0.03	<0.01–0.10	0.5	<0.1–1.6	17.9
Vessel noise/disturbance from other vessels	0.02	<0.01–0.12	0.3	<0.1–1.9	14.4
Pollution	0.05	<0.01–0.36	0.8	<0.1–5.9	40.2
Oil spills	0.02	<0.01–0.15	0.4	<0.1–2.4	20.4
Agricultural run-off	<0.01	<0.01–0.12	<0.1	<0.1–1.9	9.6
Industrial run-off	<0.01	<0.01–0.11	<0.1	<0.1–1.7	7.6
Sewage and stormwater	<0.01	<0.01–0.11	<0.1	<0.1–1.6	7.3
Trophic effects of pollution	<0.01	<0.01–0.06	<0.1	<0.1–0.9	2.1
Plastics	<0.01	<0.01–0.01	<0.1	<0.1–0.1	<0.1
Disease	<0.01	<0.01–0.36	<0.1	<0.1–5.5	29.5
Stress-induced diseases	<0.01	<0.01–0.35	<0.1	<0.1–5.2	20.7
Domestic animal diseases	<0.01	<0.01–0.07	<0.1	<0.1–1.1	3.9
Total	**5.27**	**0.97–8.39**	**75.5**	**12.4–150.7**	**100.0**

There have been three known incidents of Hector's dolphins becoming entangled in buoy lines of pots set for crayfish (*Jasus edwardsii*), all from Kaikoura (DOC & MFish 2007, DOC Incident Database 2013). Since the collation of the data presented in Table 5.4, there have been seven additional incidents of known incidental capture in commercial set nets (five from the ECSI, one each from WCSI and WCNI) and one incident of known incidental capture in an unknown net from the WCSI. These additional data are valid as of August 2013 (DOC Incident Database 2013).

There are discrepancies between the data presented in the DOC Incident Database (2013) and elsewhere in the published literature. Dawson (1991) collated reports of known incidental captures in Canterbury between 1984 and 1988 based on interviews with fishers. The minimum estimate of incidental captures in commercial set nets was 200 and in amateur nets was 24 (Dawson 1991), both of which are appreciably higher than the numbers presented in Table 5.4. These interview estimates were reviewed by Voller (1992) who reported a total of 112 entanglements in commercial nets from Timaru to Motanau in the period 1984 – 1988 and attributed the difference from Dawson's results to the assumptions made about information provided by three individuals. There are a number of reasons why the people who were interviewed multiple times may have provided different information regarding incidental captures.

Table 5.4: Fishing related cause of death of Hector's and Māui dolphins from 1921 to 2008 by region as listed in the DOC Incident Database (2013). ECSI = East Coast South Island, WCSI = West Coast South Island, SCSI = South Coast South Island, WCNI = West Coast North Island. See footnotes for explanation of probability categories as detailed in the database.

	Cause of death	ECSI	WCSI	SCSI	WCNI	Unknown population
Known entanglement[37]	Commercial setnetset net	41	2	0	0	2
	Recreational setnetset net	12	9	0	0	0
	Unknown setnetset net	15	6	0	2	1
	Trawl net	15	4	0	0	0
Probable entanglement[38]	Commercial setnetset net	0	0	0	0	0
	Recreational setnetset net	0	0	0	0	0
	Unknown setnetset net	1	4	0	0	0
	Unknown net	8	4	1	1	0
Possible entanglement[39]	Commercial setnetset net	0	0	0	0	0
	Recreational setnetset net	1	0	0	0	0
	Unknown setnetset net	16	10	0	0	0
	Unknown net	16	7	1	2	0

Table 5.5: Summary of observed inshore set net and trawl events, and Hector's and Māui dolphin captures, 1997–2012 (see also Baird & Bradford 2000, Blezard 2002, Fairfax 2002, Rowe 2009, 2010, Ramm 2010, 2012a, 2012b). Observed fishing effort, measured in kilometres of net set, or number of trawl tows. Fishing effort numbers are taken from linked fisher reports where possible. The inshore trawl effort is defined as being vessels less than 28 metres, targeting flat fish (FLA, LSO, ESO, SFL, YBF, FLO, GFL, TUR, BFL, PAD) or inshore species (TAR, SNA, GUR, RCO, TRE, JDO, STA, ELE, LEA, QSC, MOK, SCH, SPO, BCO, RSK, HPB, LDO). FMAs include areas within and outside Hector's and Māui dolphin distribution (within: 3, 5, 7, 8 & 9; outside: 1, 2 & 10).

Fishing year	Set net					Inshore trawl			
	Areas (FMAs)	Total effort (sets)	Total effort (kms)	Observed effort (%)	Observed captures	Areas (FMAs)	Effort (tows)	Observed effort (%)	Observed captures
1997–98	3	214	260	0.87	8	3, 5, 7, 10	403	0.5	1
1998–99						2	15	0.02	0
1999–00						2, 3, 9,	24	0.04	0
2000–01	3	535	24	0.08	0	2, 3	47	0.08	0
2001–02						1, 3, 9	25	0.04	0
2002–03						1	1	0	0
2003–04						3	4	0.01	0
2004–05						3	2	0	0
2005–06	3, 5, 7, 8	458	139	0.57	0	2, 7, 9	49	0.08	0
2006–07	3, 5, 7, 8	413	167	0.69	1	1, 3, 5, 7, 8, 9	260	0.46	0
2007–08	3, 5, 7, 8, 9	821	295	1.4	1	1, 3, 7, 8, 9	102	0.22	0
2008–09	3, 5, 7, 9	1829	504	2.41	1	1, 3, 5, 7, 8, 9	1682	3.46	0
2009–10	1, 3, 5, 7	1927	580	2.61	2	1, 3, 5, 7	788	1.47	0
2010–11	2, 3	514	174	0.81	0	1, 2, 5, 7, 8	744	1.52	0
2011–12	7, 8, 9	161	75	0.37	0	1, 3, 7	328	0.67	0

[37] Animal was known (from incident report) to have been entangled and died.

[38] As read from pathology report, or presence of net marks on body and a mention of this in incident report.

[39] As read from pathology report, or presence of net marks on body and a mention of this in incident report.

5.4.1 QUANTIFYING FISHERIES INTERACTIONS

Prior to 2012, the only observer programme with sufficient coverage to yield a robust estimate of the rate of incidental capture of Hector's dolphins in inshore commercial set nets (Baird & Bradford 2000) was an observer programme in Statistical Areas 018, 020 and 022 (FMA 3) on the east coast of the South Island in the 1997-98 fishing year which observed 214 inshore set net events, targeting shark species and elephant fish. Eight Hector's dolphins were caught in five sets, of which two were released alive. Capture rates were most precise in area 022, where six of the catches were reported, following observer coverage of 39% (Baird & Bradford 2000). Capture rate was estimated at 0.064 dolphins per set (CV = 43%) in area 022 and 0.037 dolphins per set (CV = 39%) in areas 020 and 022 combined (Baird & Bradford 2000). A total of 16 dolphins (CV = 43%) were estimated caught in area 022 with 18 dolphins (CV = 38%)[40] estimated caught in areas 020 and 022 combined (Baird & Bradford 2000). The authors stress that the preceding estimates are of dolphins caught, and not necessarily of mortalities (Baird & Bradford 2000). Note also that these estimates are from statistical areas containing the Banks Peninsula Marine Mammal Sanctuary, which at that time effectively prohibited commercial set netting between Sumner Head and the Rakaia River out to 4 n.mi. from the coast (Dawson & Slooten 1993).

The spatial distribution of inshore set net and trawl fishery effort is presented in Figure 5.4. The level of observation of inshore set net fisheries since 1998 has been low (Table 5.5). Slooten & Davies (2012) used the observed set net data from 2009-10 to estimate total captures on the ECSI of 23 dolphins (CV = 0.21). This was the first published capture estimate since extensive protection measures to mitigate Hector's dolphin risk were introduced in 2008 (see below). While this analysis has not been reviewed by the AEWG, a similar analysis extrapolating a capture rate estimated around Kaikoura across the ECSI was previously presented to an AEWG and rejected given the unrepresentative nature of the observer coverage.

[40] This was reported as either 16 or 18 dolphins in the cited reference, but has been confirmed as 18 dolphins by correspondence with the author (S. Baird pers.comm.).

In the 2012-13 year, the inshore set-net fishery operating in Statistical Areas 022 and 024 was observed by human observers and electronic monitoring. During that time, at least two Hector's dolphins were captured, with one released alive. The percentage of observer coverage in this fishery and estimated captures will be estimated under PRO2013-01.

Hector's dolphin captures in trawl nets include an individual caught in a trawl targeting red cod (*Pseudophycis bacchus*) in area 022 in 1997–98 (Starr & Langley 2000) and the capture of three Hector's dolphins in a trawl in Cloudy Bay in 2006 (DOC & MFish 2007). Baird & Bradford (2000) noted that the lack of information on the depth and position of commercial trawl effort and low observer coverage precluded any estimation of the total number of Hector's dolphins caught in trawl nets. While there have been ongoing attempts to increase the level of observer coverage in inshore trawl fisheries, it still remains low (Table 5.5). A simple extrapolation using capture rate and total fishing effort suggests that the number of dolphins caught in trawl fisheries could be as high as the number caught in set nets (Slooten & Davies 2012).

In addition to data gathered by human observers, electronic monitoring of inshore set net and trawl fisheries has been trialled (McElderry et al 2007). The trial monitored 89 set net events and 24 trawls off the Canterbury coast in the 2003–04 fishing year. Two Hector's dolphin captures were recorded in the set nets (McElderry et al 2007), reflecting a similar catch rate to previous estimates. Observers and electronic monitoring were deployed in the Timaru set net fishery in 2012–13 and observers were deployed again in 2013–14.

Until recently, no attempt to quantify total captures of Māui dolphins in set nets or trawls using population-specific observer data had been made. However, the likely magnitude of fishing impacts on Māui dolphin over the coming five years was estimated in a risk assessment involving a panel of nine domestic and international experts (Currey et al 2012). The panel attributed 95.5% of the mortality risk to fishing-related activities and 4.5% to non-fishing related threats, with captures in commercial set nets assessed as posing the greatest risk (Table 5.3; Currey et al 2012). The risk assessment was conducted before the introduction of interim measures off the west coast of the North Island in 2012 but, since the introduction of interim measures, commercial set net vessels have been required to carry an MPI observer when operating off the Taranaki coastline from 2 to 7 n.mi. offshore between Pariokariwa Point and Hawera (i.e. outside the existing set net closure area). There have been no observed captures and no observations of dolphins in this area over this period.

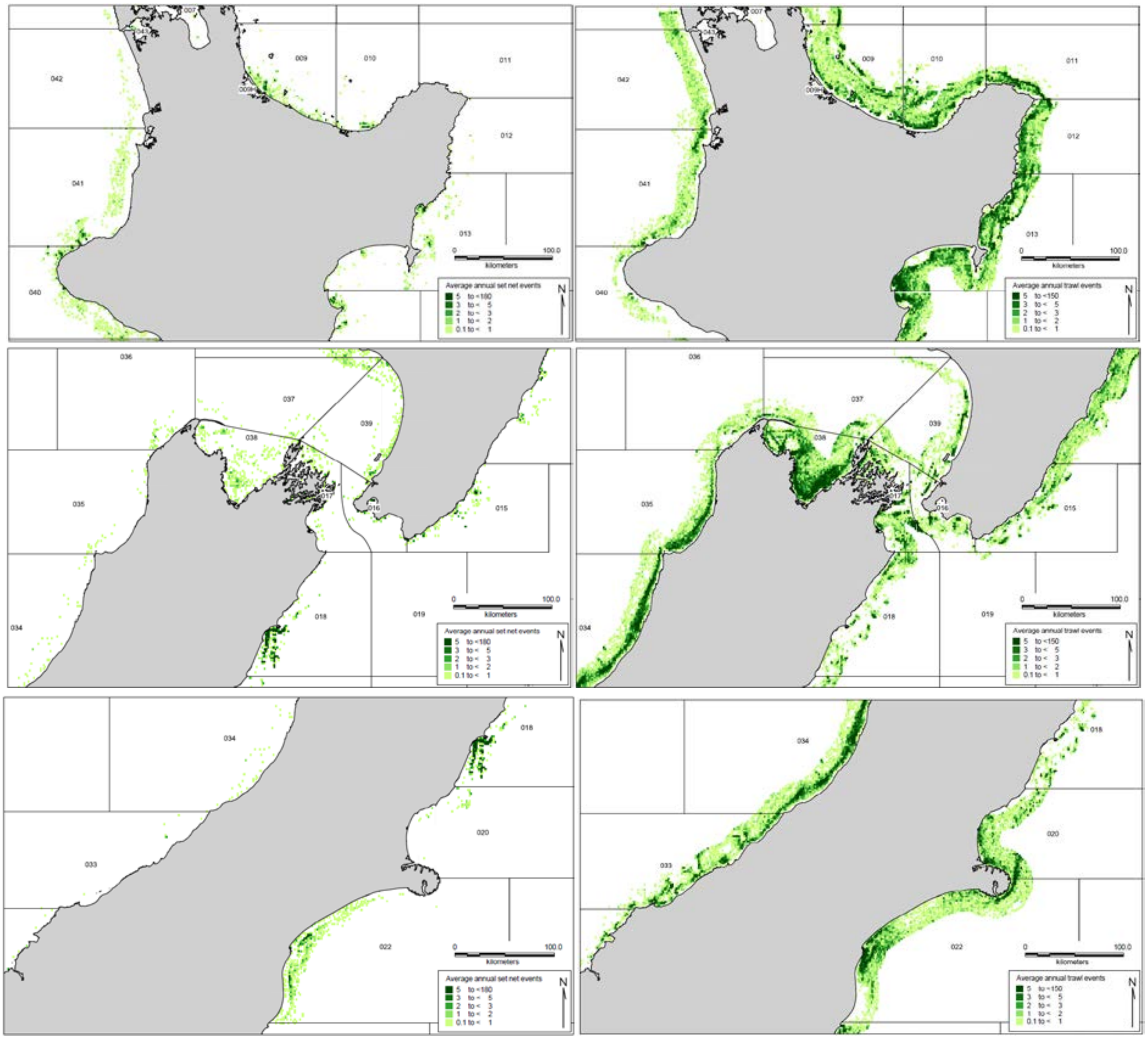


Figure 5.4: The distribution of set net (left) and trawl (right) fishing events 2007–08 to 2009–10 (from www.fish.govt.nz/en-nz/Commercial/About+the+Fishing+Industry/Maps+of+Commercial+Inshore+Fishing+Activity/) to show the general spatial pattern of fishing activity. The annual average number of events (start positions) is shown for each 1 n.mi. grid cell for events reporting coordinates (about 33% of set netting events, almost 100% of trawl events). Black lines show general statistical areas. Fishing returns are subject to occasional errors in method codes and coordinates; where possible, these errors have been corrected.

5.4.2 MANAGING FISHERIES INTERACTIONS

Broadly, there are three potential solutions to managing incidental captures: gear modifications, mortality limits and spatial closures (Dawson & Slooten 2005). Gear modifications aimed at reducing cetacean captures include changing the way that fishing gear is deployed to reduce the risk of entanglement (e.g. Hembree & Harwood 1987) or adding acoustic alarms (pingers) to make its presence more obvious (Dawson et al 2013b). Setting mortality limits involves determining a level of mortality that is sustainable (e.g. Wade 1998), and closing the fishery when it is reached. Both these approaches have been used as Hector's dolphin management tools. Canterbury fishermen voluntarily used pingers under a Code of Practice (Southeast Finfish Management Company 2000), and an annual mortality limit of three Hector's dolphins was established for the Canterbury gillnet fishery (Hodgson 2002). Although the effectiveness of pingers has been demonstrated in some experimental trials for other small cetaceans (e.g. Kraus et al 1997, Trippel et al 1999; Bordino et al 2002, see review in Dawson et al 2013b), cetaceans can become habituated to the presence of pingers (Cox et al 2001) and fishers do not necessarily deploy them correctly in real fisheries (Cox et al 2007; Dawson et al 2013b). Further, a trial reporting that 10 kHz pingers were avoided by Hector's dolphins (Stone et al 1997) was analytically flawed and hence its conclusion is not correct (Dawson & Lusseau 2005). While setting mortality limits is an effective solution in some fisheries, it requires sufficient observer coverage to provide credible data on how many dolphins are caught, and hence when the fishery should be closed. Baird & Bradford (2000), who analysed the data from the Canterbury observer programme, estimated that the level of observer coverage would need to be 56–83% (depending on the fisheries area) to achieve a CV of 30% on the capture estimate, and 74–100% to achieve a CV of less than 20%. The third solution, creation of spatial closures where harmful activities are restricted or regulated, is the only management approach for which there has been an apparent associated improvement in a vital rate for Hector's and Māui dolphins. Gormley et al (2012) estimated a 90% probability of increased annual survival rate following the designation of the Banks Peninsula Marine Mammal Sanctuary (see below).

The first spatial closure implemented to mitigate the risk of Hector's dolphin incidental capture was designated at Banks Peninsula in 1988 (Dawson & Slooten 1993). Commercial set netting was effectively prohibited out to 4 n.mi. from the coast and recreational set netting was subject to seasonal restrictions (Dawson & Slooten 1993). A second was designated off the WCNI in 2003. All set nets were prohibited to 4 n.mi. offshore (DOC & MFish 2007). In 2008, a more extensive package of spatial closures was implemented by the Minister of Fisheries (see review by Slooten 2013), providing some protection in most of the areas where Hector's and Māui are found and largely superseding the two existing discrete closures. The set net restrictions on the WCNI were extended to 7 n.mi. offshore between Maunganui Bluff and Pariokariwa Point (including the entrances to the Kaipara, Manukau and Raglan Harbours and the entrance to the Waikato River), most set netting was prohibited within 4 n.mi. of the coast on the ECSI and SCSI, and recreational set netting was banned on the WCSI within 2 n.mi. of the coast and commercial set netting was subject to a seasonal restriction (Figure 5.5). Trawling was banned on the WCNI to 2 n.mi. offshore between Maunganui Bluff and Pariokariwa Point and 4 n.mi. offshore between Manukau Harbour and Port Waikato, and restricted within 2 n.mi. offshore on the ECSI and SCSI[41] (Figure 5.6). In 2012, the set net restrictions on the WCNI were extended further south, banning commercial and recreational set netting to 2 n.mi. offshore from Pariokariwa Point to Hawera and requiring an MPI observer on any commercial set net vessel operating between 2 and 7 n.mi. (Figure 5.5).

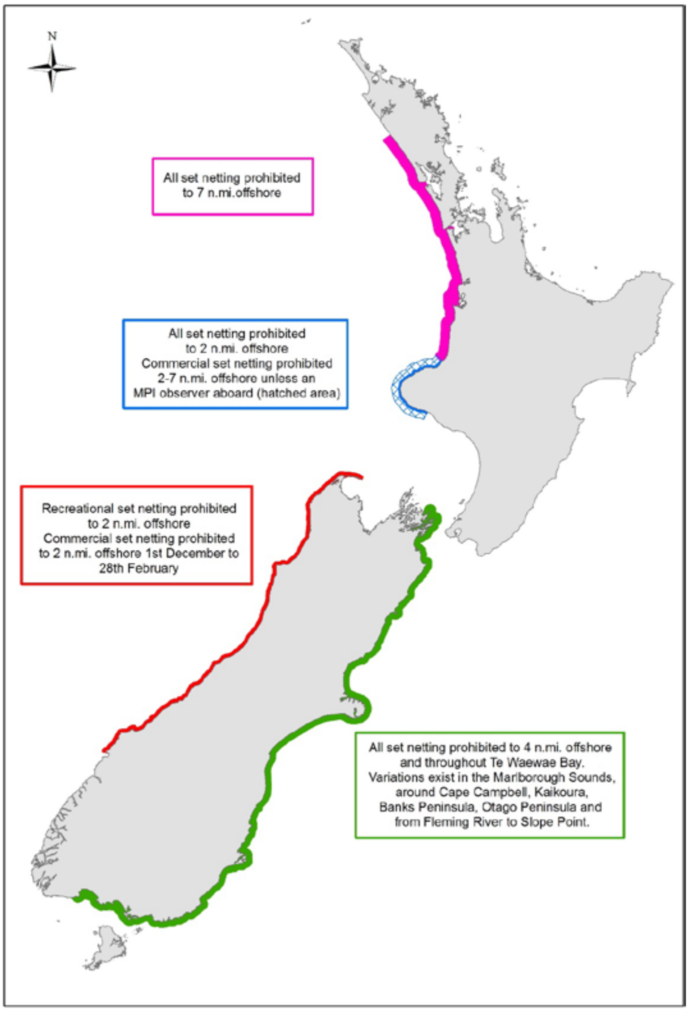


Figure 5.5: Summary of restrictions on commercial and amateur set netting. For a full description of the restrictions, for example in NIWC harbours and variations on ECSI and SCSI, see http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins.

[41] Detailed descriptions of the restrictions can be found at http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins

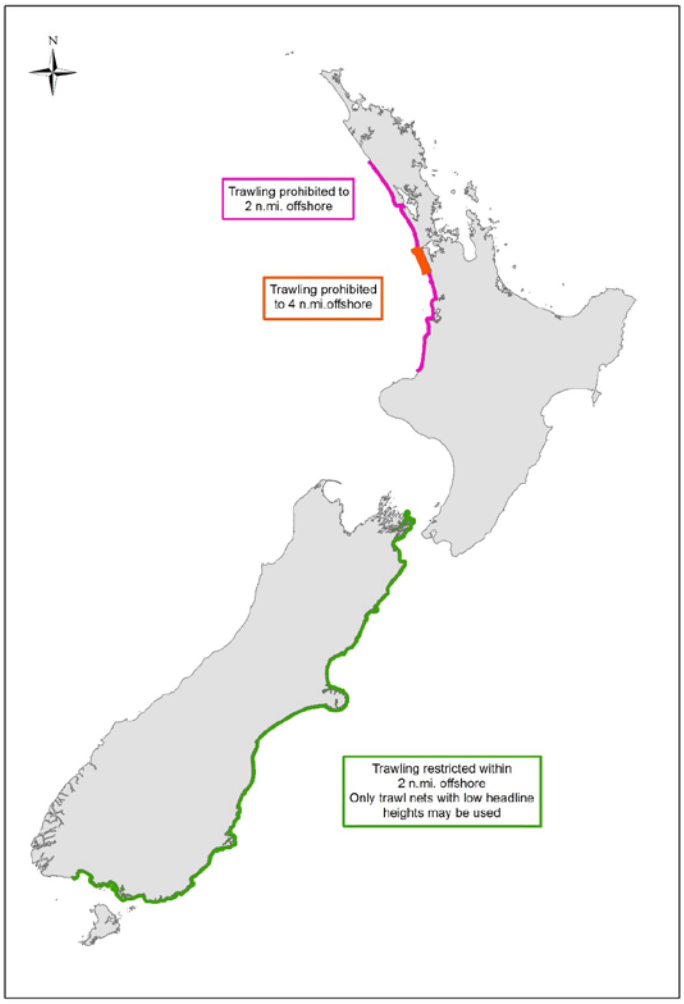


Figure 5.6: Summary of restrictions on trawling. For a full description of the restrictions see http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins.

Assessing the degree of coverage of Hector's and Māui dolphin distribution afforded by spatial management measures is not straightforward as dolphin distributions are dynamic. Aerial surveys can be used to provide a broad-scale indication of dolphin distribution; however they only provide a static picture, strictly relevant to the time of the survey. Notwithstanding this limitation, it is possible to gain an indication of the proportion of a population that was within or outside a particular area at the time of an aerial survey from the proportion of on-effort sightings that were made inside or outside the area. For example, Rayment et al (2010, Figure 5.7) conducted aerial surveys of Hector's dolphins at Banks Peninsula from the coast to 15 n.mi. offshore over three summers and winters. A significantly larger proportion of the population was sighted inside the 4 n.mi. set net restriction in summer (mean = 81%, SE = 3.60) than in winter (mean = 44%, SE = 3.60). Similar seasonal differences in distribution were observed during the recent ECSI aerial surveys (MacKenzie & Clement 2014, Figure 5.8). In the Banks Peninsula (BP) stratum, 45% of the local summer population and 26% of the local winter population were within the set net fisheries restriction zones. In the Clifford and Cloudy Bay (CCB) stratum, 47% of the local summer population and 14% of the local winter population were within the set net fisheries restriction zones Although a sizeable proportion of the sightings occurred within areas closed to set net fishing during both surveys (Rayment et al 2010, MacKenzie & Clement 2014), many sightings in summer and most sightings in winter occurred outside these areas.

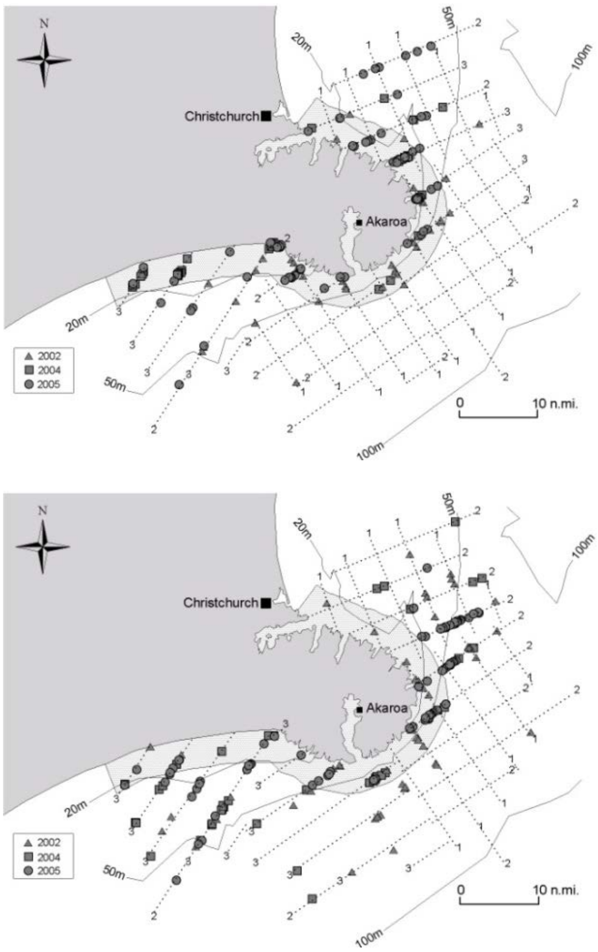


Figure 5.7: Transects and Hector's dolphin sightings on (top) three summer surveys, and (bottom) three winter surveys around Banks Peninsula. Numbers at the end of transect lines are the number of years each line was surveyed. Reproduced from Rayment et al (2010).

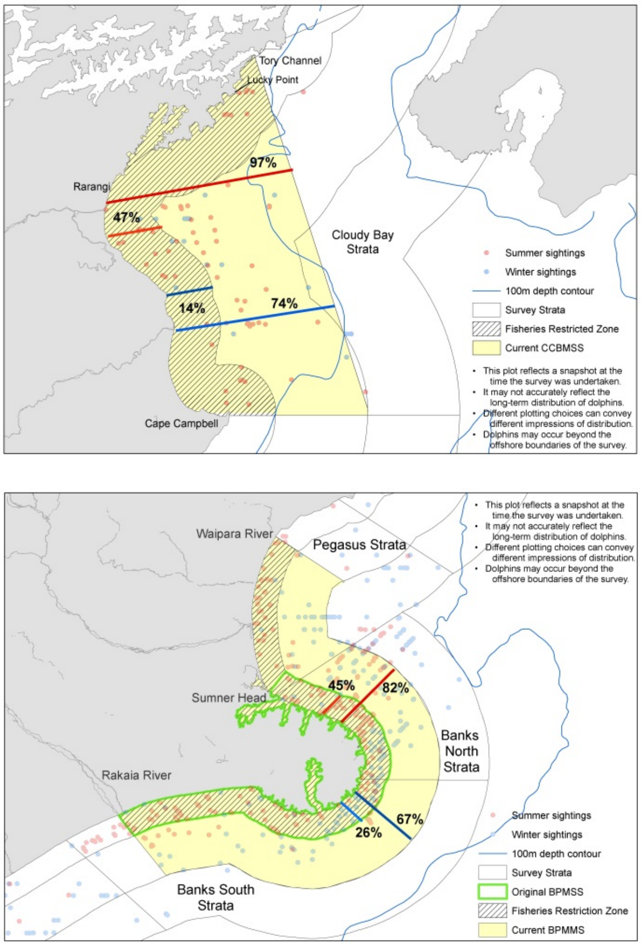


Figure 5.8: The location of summer (red) and winter (blue) survey sightings in relation to fisheries restriction zones and marine mammal sanctuary (MMS) boundaries around Clifford and Cloudy Bays (CCB, top) and Banks Peninsula (BP, bottom). Lines and associated percentages represent proportion of the local population found within 4 n.mi. and 12 n.mi. in summer (red) and winter (blue). Reproduced from MacKenzie & Clement (2014).

5.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

A number of modelling exercises have aimed to assess the effect of various proposed management approaches on the future population trajectory of Hector's and Māui dolphins. Most of this work has been published in science journals (Martien et al 1999, Burkhart & Slooten 2003, Slooten 2007a, Slooten & Dawson 2010) using their respective peer-review processes, but Davies et al's (2008) analysis was reviewed by the AEWG and published as a research report.

The various models share some necessary similarities given the available information:

- Each assumes a particular form of population model and uses this to project dolphin numbers forward and backward from a single population estimate;
- None of the models used the most recent survey estimates of abundance and distribution in SCSI and ECSI;
- A single estimate of dolphin capture rate from the ECSI is applied to historical fishing effort and assumed future fishing effort to estimate fishing related dolphin mortalities for all four populations.

Martien et al (1999) employed a simple logistic ("Schaefer") population model and projected numbers back to 1970, and forward 200 years, from the 1985 abundance estimate published by Dawson & Slooten (1988). Three separate populations were modelled (WCNI, WCSI and a population that included both ECSI and SCSI populations). Using Dawson's (1991) estimates of mortality from the ECSI area, the back calculation suggested a total of 7077 dolphins across the three populations in 1970, if maximum population growth rate was 4.4%, and 7957 if maximum population growth rate was 1.8% per annum. Martien et al (1999) considered that the 1985 estimate of abundance was likely to be a slight underestimate (because transects to assess offshore distribution extended only 5 n.mi. offshore), but suggested that any resulting bias in the estimate of the level of the population as a proportion of carrying capacity was likely to be small. The ESCI population was projected to increase for all combinations of parameters except when the maximum growth rate was set to 1.8%.

Davies & Gilbert (2003) conducted a risk assessment for Māui dolphins using a spatially and temporally stratified, age-structured, Bayesian population model for ECSI Hector's dolphins, a population thought to have similar biological and productivity characteristics to Māui dolphin. Estimated population productivity was highly uncertain and largely driven by the priors. Strong assumptions were needed to translate the ECSI model to a model for Māui dolphin and to model population distribution and abundance off the WCNI. Davies & Gilbert found the probability of population decline to be high (50 to 90%) assuming the distribution and intensity of fishing effort pertaining at the time, but the predicted performance of alternative management strategies was sensitive to assumptions about movement, adult survival rate, and set net catchability. In February 2003 the Ministry of Fisheries introduced closures off WCNI to reduce the risk to Māui dolphins.

Burkhart & Slooten (2003) developed a stochastic version of the logistic model to include a wider range of parameters, variation in fishing effort and population growth, and smaller population units (16 closed populations). Using the same survey and mortality estimates as Martien et al (1999) yielded similar estimates of the total 1970 population size, but disaggregation of the population into smaller units allowed a conclusion that only the Banks Peninsula sub-population was likely to increase.

Slooten (2007a) used the stochastic version of the logistic model, the 1998–2003 series of abundance estimates, and catch rates from a 1998 observer programme and concluded a markedly higher estimate of 29 316 individuals in 1970 (CV = 0.26). Slooten's (2007a) projections under status quo management suggested that populations in many areas, including Banks Peninsula, would decrease, but that the WCNI population would increase. Middleton et al (2007) criticised the high level of confidence ascribed by Slooten (2007a) to her model results without acknowledging that (i) these were dependent on particular model assumptions and (ii) failed to consider other relevant data. In response, Slooten (2007b) gave more detail of her modelling choices, suggested that they were unlikely to lead to overestimation of the impact of fishing, and pointed to similarities between her results and those of other work that was close to being finalised at the time (Davies et al 2008).

The modelling conducted by Davies et al (2008) built on the work by Davies & Gilbert (2003) and comprised a Bayesian age-structured population model for the Banks Peninsula (BP) subpopulation and 100-yr projection simulations for all four subpopulations under different assumed management regimes. The BP population model was structured by age, area, and seasonally to account for the behaviour of the dolphins and the fishery, had a density-dependent calving rate (maximum one calf per female every 2 years). It was fitted to an absolute abundance estimate from the 1998–2000 surveys of the South Island east coast, a time series of relative abundance indices for 1990 to 1996 from mark-recapture analyses of dolphin re-sightings around Banks Peninsula, an estimate of average annual adult survival rate 1985–2002, information on the age at first reproduction, the age composition of entangled dolphins, the catch of dolphins recorded by relevant observers, and the amount and distribution of relevant commercial set net fishing since 1970. Sensitivity to key assumptions was explored by fitting models based on alternative assumptions and by omitting some data sets.

Because so few data were available on the dolphin population and bycatch, Davies et al (2008) required informative priors to fit their BP model. Even so, the posterior distributions of most parameters were broad and were sensitive to key assumptions, suggesting great uncertainty in our understanding of historical dolphin population dynamics and current population status. Estimates of potential population growth rate ranged from close to zero to the upper bound of what is biologically feasible. The stochastic 100-year projections for each subpopulation entail additional uncertainty, only some of which could be captured in the simulations.

The AEWG agreed that:

- The outcomes of different management strategies could not be predicted with any certainty and, for all subpopulations and management strategies modelled, future population increases and decreases were both plausible.
- Taking the modelling results at face value, all three subpopulations of Hector's dolphin were more likely to decline than increase under set net fishing effort pertaining at the time, and the decline could be substantial. Conversely, under all alternative strategies simulated, all three subpopulations of Hector's dolphins were more likely to increase than decrease.
- The results for ECSI, including BP, were likely to be more reliable.
- The predicted rates of increase or decrease of all subpopulations were sensitive to the assumed level of productivity.
- For Māui dolphins, the management regime at that time included substantial protection, and the likelihood of continued decline depended strongly on the assumed level of productivity.
- The available data had been used in the best possible way and had been found not to be sufficient to support a definitive analysis. However, the modelling provided helpful guidance

on areas where new information should be collected to reduce our uncertainty.

- If the risk analysis was to be communicated to managers, it should be with appropriate caveats around its shortcomings and uncertainty.

The AEWG could not agree whether it was reasonable to adopt all the assumptions required but, consistent with the Terms of Reference, the Chair of the AEWG decided that the modelling could provide qualitative guidance to managers as a risk assessment. He added that the predicted rates of change for all Hector's and Māui subpopulations were sensitive to the assumed level of productivity but, except at the lowest level of productivity, the differences between the predicted outcomes of strategies other than status quo were modest. He noted that, at the lowest assumed level of productivity, projections suggested that the small SCSI subpopulation was more likely to decrease than increase under all simulated management measures other than zero fishing mortality, and that population was also quite likely to be affected by depensation (increasingly low population productivity as abundance decreases, also called an Allee effect).

The stochastic logistic model was used by Slooten & Dawson (2010) to assess the effect of management options developed for the Hector's and Māui Dolphin Threat Management Plan (although the options evaluated differed from the final proposals). The input data were similar to those of Slooten (2007a, b). Slooten & Dawson's (2010) population estimates for 1970 (their figure 1) were similar to those reported by Slooten (2007a), but showed some regional differences. Both Slooten (2007a) and Slooten & Dawson (2010) suggested that the WCNI population would increase under management pertaining at the time, whereas the other three populations would decline. Slooten & Dawson (2010) further suggested that their option B (similar to the 2008 measures) would lead to the ECSI and SCSI populations increasing on average, whereas the WCSI population would continue to decline.

Slooten & Davies (2012) published a new estimate of 23 captures from the ECSI population between May 2009 and April 2010 based on observer records (although their description of the methods suggests that their reported CV of 21% is greatly underestimated). They used this and an estimate of 110–150 dolphins caught annually around the South Island before 2008, including 35 to 50 dolphins caught off the ECSI (Davies et al 2008) to update the two most recent modelling approaches (Davies et al 2008 and Slooten & Dawson 2010). Slooten & Davies (2012) found the consistent predictions from all population models used to date surprising, given the substantial differences in their structural assumptions. They noted that all population models indicated that substantial declines had occurred and were likely to continue, and concluded that this consistency should add confidence to the predictions about the consequences of the different management options. In addition, they also cited a number of reasons why the conclusions might be optimistic, notably that most only include incidental captures in commercial set nets, as the other forms of fisheries-related mortality have yet to be quantified (Davies et al 2008, Slooten & Dawson 2010, Slooten & Davies 2012).

The likely magnitude of human induced impacts on Māui dolphin was estimated in a risk assessment workshop (Currey et al 2012). Population projections based on the estimated total mortalities indicated a 95.7% likelihood that the population would decline if the threats remain at the levels assessed to pertain before the introduction of the 2012 interim measures (Currey et al 2012). The estimated human induced mortalities equate to a level of impact 75.5 times (95% CI = 12.4 to 150.7 times; Currey et al 2012) higher than the estimated PBR (one dolphin every 10 to 23 years, Wade et al 2012).

The impact of fisheries interactions on Hector's and Māui dolphin populations (and other marine mammal populations) will be assessed in the marine mammal risk assessment project PRO2012-02. The goal of this project is to assess the risk posed to marine mammal populations by New Zealand fisheries by applying a similar approach to the recent seabird risk assessment (Richard & Abraham. 2013a; b). In this approach, risk is defined as the ratio of total estimated annual potential fatalities in fisheries to an estimate of PBR. The draft literature review for this project has been reviewed by the AEWG and the results of the risk assessment should be available in 2015.

5.4.4 SOURCES OF UNCERTAINTY

None of the population modelling exercises presented here has considered the most recent estimates of abundance and descriptions of distribution for the SCSI and ECSI populations.

The uncertainties and assumptions in the modelling by Davies et al (2008), Slooten & Dawson (2010), and Slooten & Davies (2012) were reviewed in detail by Slooten & Davies (2012). The models incorporate uncertainties in parameter distributions and hence population estimates are presented with their estimated levels of precision. The population viability analyses incorporated a distribution for population growth rate based on a wide range of values for maximum growth rate in Hector's dolphin (e.g. Slooten et al 2000) and the Bayesian population models included a fully integrated parameter estimation of fisheries-related mortality and reproductive rate (Slooten & Davies 2012). Slooten & Dawson (2010) showed via sensitivity analysis that the probability of recovery to half the maximum population size was robust to uncertainty in the catch rate (± 0.25 times the assumed catch rate of 0.037 dolphins per set) used in the PVAs.

The AEWG discussed outstanding areas of uncertainty and concluded that the following areas represented important uncertainties in assessing the impacts of fishing on Hector's and Māui dolphins.

CAPTURE ESTIMATES AND CAPTURE RATE

Increased observer coverage, using either observers or electronic monitoring, for set net and inshore trawl fisheries is needed to ensure representative estimates of captures and capture rate. Observer effort needs to cover a sufficiently high proportion of fishing effort so as to enable the detection of rare events (particularly important for Māui dolphin), to minimise the risk of non-representative coverage, and to provide adequate estimation precision to enable the assessment of trends in capture rate in space and time.

CRYPTIC MORTALITY

The level of cryptic mortality associated with fisheries interactions is unknown for Hector's and Māui dolphins, but may be non-trivial if estimates for other small cetaceans are any indication (e.g. 58% of captured porpoises falling out of a net before reaching the deck; Kindt-Larsen et al 2012). Quantifying cryptic mortality will reduce uncertainty associated with future risk assessments for Hector's and Māui dolphins.

DEMOGRAPHIC PARAMETERS

All the various risk analyses rely, at least in part, on demographic data obtained from one part of one population (i.e. Banks Peninsula). This necessitates assumptions as to how these data, and the resulting parameter estimates, apply outside the Banks Peninsula region. Obtaining additional demographic data from other region(s) could enable any difference between regions to be detected and reflected in future risk analyses. However, robust estimation of demographic parameters will require long-term (more than 10 years) of data collection to produce a time series of photographic or genetic individual identifications.

POPULATION ESTIMATES FOR THE WCSI POPULATION

Recent estimates of abundance are available for all populations of Hector's and Māui dolphins other than WCSI (Clement et al 2011, Hamner et al 2012b, MacKenzie & Clement 2014). Abundance was last estimated for the WCSI population in 2000–2001 (Slooten et al 2004). An updated abundance estimate for the WCSI population will be obtained under project PRO2013-06.

POPULATION CONNECTIVITY AND MOVEMENT

Ongoing photo-ID research (e.g. Bräger et al 2002, Rayment et al 2009b) and genetic recaptures (Oremus et al 2012, Hamner et al 2012a, b, 2014) will improve estimates of movements and dispersal (Rayment et al 2009b, Hamner et al 2012a, b, Pichler 2002). For example, Hamner et al (2014) suggested that failure to protect the habitat between the North and South Island will reduce the likelihood of dispersal, possibly to the detriment of Māui dolphin.

OTHER THREATS (NON-FISHING-RELATED, INDIRECT, SUB-LETHAL, CUMULATIVE)

Uncertainty exists over the magnitude of impacts faced by Hector's and Māui dolphins due to mining and hydrocarbon extraction, tourism, vessel traffic, anthropogenic noise, pollution, aquaculture and research activities (DOC & MFish 2007, Currey et al 2012, MPI & DOC 2012). Even if the impacts in isolation are sub-lethal, it is unknown whether the effects are cumulative, how they might affect factors such as breeding success, and whether they interact with the direct and indirect threats due to fishing (DOC & MFish 2007, Currey et al 2012). Roe et al (2013) identified infection with *Toxoplasma gondii* as a factor potentially contributing to the population decline of Hector's and Māui dolphins, and recommend further investigation of the source and route of entry of pathogens into the coastal environment.

5.4.5 POTENTIAL INDIRECT THREATS

Miller et al (2013) note that red cod is targeted by the inshore trawl fishery and its abundance is highly variable, particularly around Banks Peninsula. Given that red cod contribute most in terms of mass to the diet of Hector's dolphins on the ECSI, Miller et al (2013) suggest that further research is required to investigate the effect on Hector's dolphin populations.

5.5 INDICATORS AND TRENDS

Population size	Māui dolphins: 55 (95% CI = 48–69) in 2010–2011. ECSI Hector's dolphins: 9130 (CV = 19%; 95% CI = 6342–13 144) in summer 2012-13 and 7456 (CV = 18%; 95% CI = 5224–10 641) in winter 2013. WCSI Hector's dolphins: 5388(CV = 21%; 95% CI = 3613–8034) in 2000-01. SCSI Hector's dolphins: 628 (CV = 38.9%; 95% CI = 301–1311) in 2011.
Population trend	Māui dolphins: Declining. Consistent evidence from multiple methods. ECSI Hector's dolphins: Probably declining. Inconsistent evidence from abundance estimates, risk analyses and demographic estimates of population growth rate. WCSI Hector's dolphins: Probably declining, assuming ECSI estimates of capture rate and productivity are applied to this area via risk analyses. There has been a substantial reduction in commercial set net effort on the WCSI since 2008 which may have resulted in a reduction in captures. SCSI Hector's dolphins: Unknown. Inconsistent evidence from abundance estimates and risk analyses.
Threat status	Māui dolphins: NZ: Nationally Critical, Criterion A(1), Conservation Dependent in 2010 IUCN: Critically Endangered, Criteria A4c,d and C2a(ii) in 2013 Hector's dolphins: NZ: Nationally Endangered, Criterion C(1/1), Conservation Dependent in 2010 IUCN: Endangered, Criterion A4d in 2013
Number of interactions[42]	Māui dolphins: <1 per annum (Davies et al 2008), 4.97 per annum (95% CI: 0.28–8.04; Currey et al 2012) ECSI Hector's dolphins: 35 to 50 per annum (Davies et al 2008) WCSI Hector's dolphins: 70 to 100 per annum (Davies et al 2008) SCSI Hector's dolphins: about 2 per annum (Davies et al 2008)
Trends in interactions	Possible reduction from 35 to 50 per annum (Davies et al 2008) to about 23 for ECSI (Slooten & Davies 2012). No estimates for other areas.

[42] For more information, see: http://data.dragonfly.co.nz/psc/.

5.6 REFERENCES

Baird, S J; Bradford, E (2000) Estimation of Hector's dolphin bycatch from inshore fisheries, 1997/98 fishing year. Department of Conservation, Wellington. 28 p.

Baker, A N (1978) The status of Hector's dolphin *Cephalorhynchus hectori* (van Beneden) in New Zealand waters. Reports of the International Whaling Commission 28: 331 – 334.

Baker, A N; Smith, A N H; Pichler, F B (2002) Geographical variation in Hector's dolphin: recognition of a new subspecies of *Cephalorhynchus hectori*. Journal of the Royal Society of New Zealand 32: 713 – 717.

Baker, C S; Chilvers, B L; Constantine, R; Du Fresne, S; Mattlin, R; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals, 2009. New Zealand Journal of Marine and Freshwater Research 44: 101 – 115.

Baker, C S; Hamner, R M; Cooke, J; Heimeier, D; Vant, M; Steel, D; Constantine, R (2013) Low abundance and probable decline of the critically endangered Maui's dolphin estimated by genotype capture-recapture. Animal Conservation 16: 224 – 233.

Bejder, L; Dawson, S (2001) Abundance, residency and habitat utilisation of Hector's dolphin (*Cephalorhynchus hectori*) in Porpoise Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research 35: 277 – 287.

Bejder, L; Dawson, S M; Harraway, J A (1999) Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. Marine Mammal Science 15: 738 – 750.

Blezard, R H (2002) Observations of set net and inshore trawl fishing operations in the South Canterbury Bight, 2001. DOC Internal Science Series 85. Department of Conservation, Wellington, New Zealand.

Bordino, P; Kraus, S; Albareda, D; Fazio, A; Palmerio, A; Mendez, M; Botta, S (2002) Reducing incidental mortality of franciscana dolphin *Pontoporia blainvillei* with acoustic warning devices attached to fishing nets. Marine Mammal Science 18: 833 – 842.

Bräger, S (1998) Behavioural ecology and population structure of Hector's dolphin (*Cephalorhynchus hectori*). Unpublished PhD thesis, University of Otago, Dunedin, New Zealand. 168 p.

Bräger, S; Dawson, S M; Slooten E; Smith, S; Stone, G S; Yoshinaga, A (2002) Site fidelity and along-shore range in Hector's dolphin, an endangered marine dolphin from New Zealand. Biological Conservation 108: 281 – 287.

Bräger, S; Harraway, J; Manly, B F J (2003) Habitat selection in a coastal dolphin species (*Cephalorhynchus hectori*). Marine Biology 143: 233–244.

Bräger, S; Schneider, K (1998) Nearshore distribution and abundance of dolphins along the West Coast of the South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 32: 105 – 112.

Burkhart, S M; Slooten, E (2003) Population viability analysis for Hector's dolphin (*Cephalorhynchus hectori*): a stochastic population model for local populations. New Zealand Journal of Marine and Freshwater Research 37: 553 – 566.

Cameron, C; Barker, R; Fletcher, D; Slooten, E; Dawson, S M (1999) Modelling survival of Hector's dolphins around Banks Peninsula, New Zealand. Journal of Agricultural, Biological and Environmental Statistics 4: 126–135.

Cawthorn, M W (1988) Recent observations of Hector's dolphin, *Cephalorhynchus hectori*, in New Zealand. Reports of the International Whaling Commission Special Issue 9: 303 – 314.

Childerhouse, S; Rayment, W; Webster, T; Scali, S; du Fresne, S D (2008) Offshore aerial survey of Maui's dolphin distribution 2008. Auckland Conservancy, Department of Conservation (unpublished). 6 p.

Clement, D; Mattlin, R; Torres, L (2011) Abundance, distribution and productivity of Hector's (and Maui's) dolphins. Final Research Report, project PRO2009-01A. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cox, T M; Lewison, R L; Zydelis, R; Crowder, L B; Safina, C; Read, A J (2007) Comparing effectiveness of experimental and implemented bycatch reduction measures: the ideal and the real. Conservation Biology 21: 1155 – 1164.

Cox, T M; Read, A J; Solow, A; Tregenza, N (2001) Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? Journal of Cetacean Research and Management 3: 81 – 86.

Currey, R J C; Boren, L; Sharp, B; Peterson, D (2012) A risk assessment of threats to Maui's dolphins. Ministry for Primary Industries and Department of Conservation, Wellington. 51 p.

Davies, N M; Bian, R; Starr, P; Lallemand, P; Gilbert, D J; McKenzie, J R (2008) Risk analysis of Maui's dolphin and Hector's dolphin subpopulations to commercial set net fishing using a temporal-spatial age-structured model. Ministry of Fisheries, Wellington, New Zealand. 113 p.

Davies, N M; Gilbert, D J (2003) A risk analysis of an endangered dolphin subspecies using a temporal-spatial age-structured model. Final Research Report for Ministry of Fisheries Research Projects MOF2002/03D, Objectives 1, 2, & 3. (Unpublished report held by Ministry for Primary Industries.) 42 p.

Dawson, S; Fletcher, D; Slooten, E (2013a) Habitat use and conservation of an Endangered dolphin. Endangered Species Research 21: 45–54.

Dawson, S; Northridge, S; Waples, D; Read, A J (2013b) To ping or not to ping: the use of active acoustic devices in mitigating interactions between small cetaceans and gillnet fisheries. Endangered Species Research 19: 201–221.

Dawson, S M (1991) Incidental catch of Hector's dolphin in inshore gillnets. Marine Mammal Science 7: 283 – 295.

Dawson, S M; Lusseau, D (2005) Pseudoreplication problems in studies of dolphin and porpoise reaction to pingers. Marine Mammal Science 21: 175 – 176.

Dawson, S M; Slooten, E (1988) Hector's Dolphin *Cephalorhynchus hectori*: Distribution and abundance. Reports of the. International Whaling Commission Special Issue 9: 315 – 324.

Dawson, S M; Slooten, E (1993) Conservation of Hector's dolphins: The case and process which led to the establishment of the Banks Peninsula Marine Mammal Sanctuary. Aquatic Conservation: Marine and Freshwater Ecosystems 3: 207 – 221.

Dawson, S M; Slooten, E (2005) Management of gillnet bycatch of cetaceans in New Zealand. Journal of Cetacean Research and Management 7 (1): 59 – 64.

Dawson, S M; Slooten, E; DuFresne, S D; Wade, P; Clement, D M (2004) Small-boat surveys for coastal dolphins: Line-transect surveys of Hector's dolphins (*Cephalorhynchus hectori*). Fishery Bulletin 102: 441 – 451.

DOC and MFish (Department of Conservation and Ministry of Fisheries) (2007) Hector's and Maui's Dolphin Threat Management Plan: Draft for Public Consultation. Ministry of Fisheries and Department of Conservation. 298 p.

DOC Hector's and Maui's dolphin incident database. (2013) Available at: www.doc.govt.nz/conservation/native-animals/marine-mammals/dolphins/hectors-dolphin/docs-work/hectors-and-mauis-dolphin-incident-database/ downloaded 16-9-13.

DOC. (2013) Consultation on a proposed variation to the West Coast North Island Marine Mammal Sanctuary to prohibit commercial and recreational set net fishing between two and seven nautical miles offshore between Pariokariwa Point and the Waiwhakaiho River, Taranaki. Department of Conservation. 44 p.

Du Fresne, S (2004) Conservation biology of Hector's dolphin. PhD thesis, University of Otago, Dunedin, New Zealand. 166 p.

Du Fresne, S (2010) Distribution of Maui's dolphin (*Cephalorhynchus hectori maui*) 2000 – 2009. DOC Research & Development Series 322. Department of Conservation, Wellington, New Zealand.

Du Fresne, S; Burns, D; Gates, E (2012) An updated, annotated bibliography for Hector's (*Cephalorhynchus hectori hectori*) and Maui's (*C. hectori maui*) dolphins. DOC Research and Development Series 332. Department of Conservation, Wellington. 43 p.

Du Fresne, S; Mattlin, R (2009) Distribution and Abundance of Hector's Dolphin (*Cephalorhynchus hectori*) in Clifford and Cloudy Bays (Final report for NIWA project CBF07401). Marine Wildlife Research Ltd.

Fairfax, D (2002) Observations of inshore trawl fishing operations in Pegasus Bay and the Canterbury Bight, 2002. DOC Internal Science Series 86. Department of Conservation, Wellington, New Zealand.

Ferreira, S M; Roberts, C C (2003) Distribution and abundance of Maui's dolphins (*Cephalorhynchus hectori maui*) along the North Island west coast, New Zealand. DOC Science Internal Series 93. 19 p.

Geijer, C K; Read, A J (2013) Mitigation of marine mammal bycatch in U.S. fisheries since 1994. Biological Conservation 159: 54 – 60.

Gormley, A M (2009) Population modelling of Hector's dolphin. Unpublished PhD thesis. University of Otago, Dunedin, New Zealand. 217 p.

Gormley, A M; Dawson, S M; Slooten, E; Bräger, S (2005) Capture-recapture estimates of Hector's dolphin abundance at Banks Peninsula, New Zealand. Marine Mammal Science 21: 204 – 216.

Gormley, A M; Slooten, E; Dawson, S M; Barker, R J; Rayment, W; Du Fresne, S; Bräger, S (2012) First evidence that marine protected areas can work for marine mammals. Journal of Applied Ecology 49: 474–480.

Green, E; Charteris, C; Rodda, J (2007) Te Waewae Bay Hector's dolphins: abundance, distribution and threats. Southland Conservancy, Department of Conservation, Invercargill. 54 p.

Hamner, R M; Constantine, R; Mattlin, R; Waples, R; Baker, C S (2013) Genotype capture-recapture estimates of abundance and effective population size of Hector's dolphins in Cloudy Bay, New Zealand. SC/65a/SM07. 65th meeting of the International Whaling Commission Scientific Committee, Jeju, South Korea.

Hamner, R M; Constantine, R; Oremus, M; Stanley, M; Brown, P; Baker, C S (2014) Long range genetic movement by Hector's dolphins provides potential genetic enhancement for critically endangered Maui's dolphin. Marine Mammal Science 30: 139–153.

Hamner, R M; Oremus, M; Stanley, M.; Brown, P; Constantine, R; Baker, C S (2012b) Estimating the abundance and effective population size of Maui's dolphins using microsatellite genotypes in 2010–11, with retrospective matching to 2001–2007. Department of Conservation, Auckland, New Zealand. 48 p.

Hamner, R M; Pichler, F B; Heimeier, D; Constantine, R; Baker, C S (2012a) Genetic differentiation and limited gene flow among fragmented populations of New Zealand endemic Hector's and Maui's dolphins. Conservation Genetics 13: 987 – 1002.

Hembree, D; Harwood, M B (1987) Pelagic gillnet modification trials in northern Australian seas. Reports of the International Whaling Commission 37: 369 – 373.

Hodgson, P (2002) South Island Hector's dolphin decisions. Ministry of Fisheries, PO Box 1020, Wellington, New Zealand. 13 p.

IUCN (2013) The IUCN Red List of Threatened Species. Version 2013.1. <http://www.iucnredlist.org>. Downloaded on 07 October 2013.

Kindt-Larsen, L; Dalskov, J; Stage, B; Larsen, F (2012) Observing incidental harbour porpoise *Phocoena phocoena* bycatch by remote electronic monitoring. Endangered Species Research 19: 75–83.

Kraus, S D; Read, A J; Solow, A; Baldwin, K; Spradlin, T; Anderson, E; Williamson, J (1997) Acoustic alarms reduce porpoise mortality. Nature 388: 525.

MacKenzie, D; Clement, D (2014) Abundance and Distribution of ECSI Hector's dolphin. New Zealand Aquatic Environment and Biodiversity Report No. 123.

MacKenzie, D I; Clement, D; Mattlin, R (2012) Abundance, distribution and productivity of Hector's (and Maui's) dolphins (Final Research Report for project PRO2009-01B). (Unpublished report held by Ministry for Primary Industries, Wellington.)

Martien, K K; Taylor, B L; Slooten, E; Dawson, S M (1999) A sensitivity analysis to guide research and management for Hector's dolphin. Biological Conservation 90: 183 – 191.

Martinez, E; Orams, M; Pawley, M; Stockin, K (2012) The use of auditory stimulants during swim encounters with Hector's dolphins in Akaroa harbour, New Zealand. Marine Mammal Science 28: E295-E315.

McElderry, H; McCullough, D; Schrader, J; Illingworth, J (2007) Pilot study to test the effectiveness of electronic monitoring in Canterbury fisheries. DOC Research and Development Series 264. Department of Conservation, Wellington. 27 pp.

Middleton, D A J; Starr, P J; Gilbert, D J (2007) Modelling the impact of fisheries bycatch on Hector's dolphin: comment on Slooten (2007). Endangered Species Research 3: 331 – 334.

Miller, E; Lalas, C; Dawson, S; Ratz, H; Slooten, E (2013) Hector's dolphin diet: the species, sizes and relative importance of prey eaten by *Cephalorhynchus hectori*, investigated using stomach content analysis. Marine Mammal Science 29:606–628. doi: 10.1111/j.1748-7692.2012.00594.x

MPI & DOC (Ministry for Primary Industries and Department of Conservation) (2012) Review of the Maui's dolphin threat management plan. MPI & DOC Joint Discussion Paper No: 2012/18.

Oremus, M; Hamner, R M; Stanley, M; Brown, P; Baker, C S; Constantine, R (2012) Distribution, group characteristics and movements of the Critically Endangered Maui's dolphin *Cephalorhynchus hectori maui*. Endangered Species Research 19: 1 – 10.

Paul, L (2000) New Zealand Fishes: identification, natural history and fisheries. Reed Publishing, Auckland, New Zealand.

Perrin, W F; Reilly, S B (1984) Reproductive parameters of dolphins and small whales of the family Delphinidae. Reports of the International Whaling Commission Special Issue 6: 97 – 133.

Pichler, F B (2002) Genetic assessment of population boundaries and genetic exchange in Hector's dolphin. DoC Science Internal Series 44. Department of Conservation, Wellington. 37 p.

Pichler, F B; Baker, C S (2000) Loss of genetic diversity in the endemic Hector's dolphin due to fisheries related mortality. Proceedings of the Royal Society B 267: 97 – 102.

Pichler, F B; Dawson, S M; Slooten, E; Baker, C S (1998) Geographic isolation of Hector's dolphin populations described by mitochondrial DNA sequences. Conservation Biology 12: 676 – 682.

Ramm, K (2010) Conservation Services Programme Observer Report: 1 July 2008 to 30 June 2009. Final Draft. Department of Conservation, Wellington, New Zealand. 121 p.

Ramm, K (2012a) Conservation Services Programme Observer Report: 1 July 2009 to 30 June 2010. Final Report. Department of Conservation, Wellington, New Zealand. 130 p.

Ramm, K (2012b) Conservation Services Programme Observer Report: 1 July 2010 to 30 June 2011. Final Report. Department of Conservation, Wellington, New Zealand. 126 p.

Rayment, W; Clement, D; Dawson, S; Slooten, E; Secchi, E (2011a) Distribution of Hector's dolphin (*Cephalorhynchus hectori*) off the west coast, South Island, New Zealand, with implications for the management of bycatch. Marine Mammal Science 27: 398 – 420.

Rayment, W; Dawson, S; Scali, S; Slooten, E (2011b) Listening for a needle in a haystack: passive acoustic detection of dolphins at very low densities. Endangered Species Research 14: 149 – 156.

Rayment, W; Dawson, S; Slooten, E (2010) Seasonal changes in distribution of Hector's dolphin at Banks Peninsula, New Zealand: implications for protected area design. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 106–116.

Rayment, W; Dawson, S; Slooten, E (2009a) Use of T-PODs for acoustic monitoring of Cephalorhynchus dolphins: a case study with Hector's dolphins in a marine protected area. Endangered Species Research 10: 333–339.

Rayment, W; Dawson, S; Slooten, E; Bräger, S; Du Fresne, S; Webster, T. (2009b) Kernel density estimates of alongshore home range of Hector's dolphins at Banks Peninsula, New Zealand. Marine Mammal Science 25: 537–556.

Rayment, W; du Fresne, S D (2007) Offshore aerial survey of Maui's dolphin distribution 2007. Auckland Conservancy, Department of Conservation (unpublished). 6 p.

Rayment, W; Webster, T (2009) Observation of Hector's dolphins associating with inshore fishing trawlers at Banks Peninsula, New Zealand. New Zealand Journal of Marine and Freshwater Research 43: 911 – 916.

Read, A J (2008) The looming crisis: interactions between marine mammals and fisheries. Journal of Mammalogy 89: 541–548.

Read, A J; Drinker, P; Northridge, S (2006) Bycatch of marine mammals in US and global fisheries. Conservation Biology 20: 163 – 169.

Reeves, R R; Dawson, S M; Jefferson, T A; Karczmarski, L; Laidre, K; O'Corry-Crowe, G; Rojas-Bracho, L; Secchi, E R; Slooten, E; Smith, B D; Wang, J Y; Zhou, K (2013a) *Cephalorhynchus hectori* ssp. maui. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 29 September 2013.

Reeves, R R; Dawson, S M; Jefferson, T A; Karczmarski, L; Laidre, K; O'Corry-Crowe, G; Rojas-Bracho, L; Secchi, E R; Slooten, E; Smith, B D; Wang, J Y; Zhou, K (2013b) *Cephalorhynchus hectori*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 27 September 2013.

Reeves, R R; Smith, B D; Crespo, E A; Notarbartolo di Sciara, G (compilers). (2003) Dolphins, Whales and Porpoises: 2002–2010 Conservation Action Plan for the World's Cetaceans. IUCN/SSC Cetacean Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. ix + 139pp.

Richard, Y; Abraham, E R (2013a) Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30 p.

Richard, Y; Abraham, E R (2013b) Risk of commercial fisheries to New Zealand seabird populations, 2006–07 to 2010–11. New Zealand Aquatic Environment and Biodiversity Report No. 109. 58 p.

Roe, W D; Howe, L; Baker, E; Burrows, L; Hunter, S (2013) An atypical genotype of *Toxoplasma gondii* as a cause of mortality in Hector's dolphins. Veterinary Parasitology 192: 67 – 74.

Rowe, S J (2009) Conservations Services Programme observer report, 01 July 2004 to 30 June 2007. DOC Marine Conservation Services Series 1. Department of Conservation, Wellington, New Zealand. 94 p.

Rowe, S J (2010) Conservations Services Programme observer report, 01 July 2007 to 30 June 2008. DOC Marine Conservation Services Series 4. Department of Conservation, Wellington, New Zealand. 98 p.

Russell, K (1999) The North Island Hector's dolphin: a species in need of conservation. Unpublished MSc thesis. University of Auckland, New Zealand.

Scali, S (2006) Use of harbours by the critically endangered species Maui's dolphin (*Cephalorhynchus hectori maui*). Auckland Conservancy, Department of Conversation (unpublished). 28 p.

Slooten, E (1990) Population biology, social organisation and behaviour of Hector's dolphin. PhD thesis, University of Canterbury, New Zealand.

Slooten, E (1991) Age, growth and reproduction in Hector's dolphins. Canadian Journal of Zoology 69: 1689 – 1700.

Slooten, E (2007a) Conservation management in the face of uncertainty: effectiveness of four options for managing Hector's dolphin bycatch. Endangered Species Research 3: 169 – 179.

Slooten, E (2007b) Criticism is unfounded: reply to Middleton et al. (2007). Endangered Species Research 3: 335 – 339.

Slooten, E (2013) Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin. Endangered Species Research 20: 121–130.

Slooten, E; Davies, N (2012) Hector's dolphin risk assessments: old and new analyses show consistent results. Journal of the Royal Society of New Zealand 42: 49–60.

Slooten, E; Dawson, S (2010) Assessing the effectiveness of conservation management decisions: likely effects of new protection measures for Hector's dolphin. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 334–347.

Slooten, E; Dawson, S M (1994) Hector's dolphin *Cephalorhynchus hectori*. Pp. 311–333 in: Handbook of Marine Mammals. Volume V (Delphinidae and Phocoenidae) (S.H. Ridgway and R. Harrison eds). Academic Press. New York.

Slooten, E; Dawson, S; Du Fresne, S (2001) Report on interactions between Hector's dolphins (*Cephalorhynchus hectori*) and a Golden Bay mussel farm. Unpublished report for Environment Canterbury 2001, no 11. 8 p.

Slooten, E; Dawson, S M; Lad, F (1992) Survival rates of photographically identified Hector's dolphins from 1984 to 1988. Marine Mammal Science 8: 327 – 343.

Slooten, E; Dawson, S M; Rayment, W J (2004) Aerial surveys for coastal dolphins: abundance of Hector's dolphins off the South Island West Coast, New Zealand. Marine Mammal Science 20:477–490.

Slooten, E; Dawson, S M; Rayment, W J; Childerhouse, S J (2005) Distribution of Maui's dolphin, *Cepahalorhynchus hectori maui*. New Zealand Fisheries Assessment Report 2005/28. 22 p.

Slooten, E; Dawson, S M; Rayment, W; Childerhouse, S (2006) A new abundance estimate for Maui's dolphin: What does it mean for managing this critically endangered species? Biological Conservation 128: 576 – 581.

Slooten, E; Dawson, S M; Whitehead, H (1993) Associations among photographically identified Hector's dolphins. Canadian Journal of Zoology 71: 2311 – 2318.

Slooten, E; Fletcher, D; Taylor, B (2000) Accounting for uncertainty in risk assessment: case study of Hector's dolphin mortality due to gillnet entanglement. Conservation Biology 14: 1264–1270.

Slooten, E; Lad, F (1991) Population biology and conservation of Hector's dolphins. Canadian Journal of Zoology 69: 1701 – 1707.

Southeast Finfish Management Company (2000) Voluntary code of practice – commercial net setters. SE Finfish Management Ltd, PO Box 43, Lyttelton, NZ. 22 p.

Stanley, M (2009) Maui's winter offshore aerial survey June/July 2009. Auckland Conservancy, Department of Conservation (unpublished). 10 p.

Starr, P; Langley, A (2000) Inshore Fishery Observer Programme for Hector's dolphins in Pegasus Bay, Canterbury Bight, 1997/1998. Published client report on contract 3020, funded by Conservation Services Levy. Department of Conservation, Wellington. 28 p.

Stockin, K A; Law, R; Roe, W; Meynier, L; Martinez, E; Duignan, P; Bridgen, P; Jones, B (2010) PCBs and organochlorine pesticides in Hector's and Maui's dolphins. Marine Pollution Bulletin 60: 834 – 842.

Stone, G; Hutt, A; Duignan, P; Teilmann, J; Cooper, R; Geschke, K; Yoshinaga, A; Russell, K; Baker, A; Suisted, R; Baker, S; Brown, J; Jones, G; Higgins, D (2005) Hector's Dolphin (*Cephalorhynchus hectori hectori*) Satellite Tagging, Health and Genetic Assessment. Final Report. New England Aquarium, Boston, USA.

Stone, G; Kraus, S; Hutt, A; Martin, S; Yoshinaga, A; Joy, L (1997) Reducing by-catch: can acoustic pingers keep Hector's dolphins out of fishing nets. Marine Technological Society Journal 31: 3 – 7.

Stone, G S; Yoshinaga, A (2000) Hector's dolphin (*Cephalorhynchus hectori*) calf mortalities may indicate new risks from boat traffic and habituation. Pacific Conservation Biology 6: 162 – 170.

Suisted, R; Neale, D (2004) Department of Conservation Marine Mammal Action Plan for 2005 – 2010. Department of Conservation, Wellington, New Zealand. 89 p.

Taylor, P R (1992) Incidental catch of non-fish species in set nets in New Zealand waters. New Zealand Fisheries Assessment Research document 92/21. (Unpublished document available at NIWA library, Wellington.)

Thompson, F N; Richard Y (2012) Maui's dolphin distribution and fishing effort. pp. 33–49 In: Currey, R J C; Boren, L J; Sharp, B R; Peterson, D. A risk assessment of threats to Maui's dolphins. Ministry for Primary Industries and Department of Conservation, Wellington. 51 p.

Townsend, A J; de Lange, P J; Duffy, C A J; Miskelly, C M; Molloy, J; Norton, D A (2008) New Zealand Threat Classification System manual. Department of Conservation, Wellington. 35 p.

Trippel, E A; Strong, M B; Terhune, J M; Conway, J D (1999) Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56:113 – 123.

Turek, J; Slooten, E; Dawson, S; Rayment, W; Turek, D (2013) Distribution and abundance of Hector's dolphins off Otago, New Zealand. New Zealand Journal of Marine and Freshwater Research 47: 181–191.

Voller, R (1992) Entanglements of Hector's dolphins in set nets between Motunau and Timaru. Ministry of Agriculture and Fisheries. 21p.

Wade, P R (1998) Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14: 1 – 37.

Wade, P R; Hamner, R M; Constantine, R; Baker, C S (2012) The Potential Biological Removal (PBR) and probability of decline for Maui's dolphin. pp. 28–32 In: Currey, R J C; Boren, L J; Sharp, B R; Peterson, D. A risk assessment of threats to Maui's dolphins. Ministry for Primary Industries and Department of Conservation, Wellington. 51 p.

Webster, T A; Dawson, S M; Slooten, E (2009) Evidence of sex segregation in Hector's dolphin. Aquatic Mammals 35: 212 – 219.

Webster, T A; Dawson, S M; Slooten, E (2010) A simple laser photogrammetry technique for measuring Hector's dolphins in the field. Marine Mammal Science 26: 296 – 308.

6 NEW ZEALAND SEABIRDS

Scope of chapter	This chapter focuses on estimates of captures and risk assessments conducted for seabirds that breed in New Zealand waters. Also included are descriptions of the nature of fishing interactions, the management context and approach, trends in key indicators and major sources of uncertainty. It does not include detail on the biology or response of individual seabird species other than those four taxa for which quantitative population modelling has been conducted.
Area	New Zealand EEZ and Territorial Sea (noting that many seabirds are highly migratory and spend prolonged periods outside the NZ EEZ; on the high seas these effects are considered by CCSBT, WCPFC, CCAMLR, SPRFMO, etc. and NZ capture estimates are reported to those bodies).
Focal localities	Interactions with fisheries occur in many parts of the EEZ and TS as well as on the high seas and in the EEZs of other nations.
Key issues	Quantitative and semi-quantitative risk assessments can be improved through better estimates of: incidental captures in fisheries that are poorly or un-observed; species identity, especially of birds released alive; cryptic mortality rates; survival of birds released alive; and the ability of seabird populations to sustain given levels of bycatch, especially given fisheries interactions and captures outside the New Zealand EEZ and in non-commercial fisheries. Consolidating qualitative and (semi) quantitative risk assessments is a key challenge.
Emerging issues	Assessing total fisheries impacts (i.e., including non-commercial and out-of-zone) and fisheries impacts in the context of other factors influencing seabird survival and reproduction, including other anthropogenic effects. Mortality caused by superstructure strikes.
MPI Research (current)	PRO2013-01 *Estimating incidental captures of protected species*; PRO2012-07 *Cryptic mortality of seabirds in trawl and longline fisheries*; PRO2012-10 *Level 3 risk assessment for Antipodean albatross*; PRO2013-13 *Global seabird risk assessment for NZ species*; PRO2013-17 *Repeat level-3 risk assessment for southern Buller's albatross*; SEA2013-06 *Distribution of black petrel;* PRO2014-05 *Reducing uncertainty in biological components of the risk assessments for at-risk seabird species;* PRO2014-06 *Update of level-2 seabird risk assessment.*
NZ Government Research (current)	DOC Conservation Services Programme (CSP) projects: INT2014-01 *Observing commercial fisheries*, INT2013-02 *Identification of seabirds captured in New Zealand fisheries*, INT2013-03 *Identification of marine mammals, turtles and protected fish captured in New Zealand fisheries*, POP2014-02 *Seabird population research 2014-15*, POP2014-03 *Protected fish population research*, MIT2014-01 *Protected species bycatch newsletter*, MIT2014-02 *Improvement of tori line performance in small vessel longline fisheries*, MIT2014-03 *Seabird liaison officer*, POP2014-02 *Seabird population research 2014-15*
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
Related chapters/issues	National Plan of Action (2013) to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries (MPI 2013)

Note: This chapter has been updated for the AEBAR 2014.

6.1 CONTEXT

Seabird names and taxonomy in this document generally follow that adopted by the Ornithological Society of New Zealand (OSNZ 2010) except where a different classification has been agreed by the parties to the Agreement for the Conservation of Albatrosses and Petrels, ACAP, or the New Zealand Threat Classification Scheme (NZTCS) classifies multiple taxa within a single OSNZ species (Table 6.1). The key differences to the OSNZ (2010) species-level classification are for: white-capped albatross (OSNZ cites a subspecies *Thalassarche cauta steadi* whereas full species status is used here following

ACAP); blue penguins (OSNZ cites a single species, little penguin *Eudyptula minor*, whereas multiple sub-species are used here to reflect NZTCS); and white-fronted tern (OSNZ cite a single species *Sterna striata*, whereas multiple sub-species are used here to reflect NZTCS). Southern and northern Buller's albatrosses are treated as separate taxa here, although ACAP lists a single species "Buller's albatross". The taxonomy and common names adopted here will, therefore, differ in some instances from those used in legislation or other documents.

There are probably more than 10 000 bird species worldwide, but fewer than 400 are classified as seabirds (being specialised marine foragers). All but seven seabird taxa in New Zealand are absolutely protected under s.3 of the Wildlife Act 1953, meaning that it is an offence to hunt or kill them. Southern black-backed gull, *Larus dominicanus*, is the only species that is not protected. Black shag, *Phalacrocorax carbo*, and subantarctic skua, *Catharacta antarctica lonnbergi*, are partially protected, and sooty shearwater, *Puffinus griseus*, grey-faced petrel, *Pterodroma macroptera*, little shag, *Phalacrocorax melanoleucos brevirostris*, and pied shag, *Phalacrocorax varius*, may be hunted or killed subject to Minister's notification. Of the 85 seabird taxa that breed in New Zealand waters, 47 are considered threatened (by far the largest number in the world). For albatrosses and petrels, a key threat is injury or death in fishing operations, although the Wildlife Act provides defences if the accidental or incidental death or injury took place in the course of fishing pursuant to a permit, licence, authority, or approval issued, granted, or given under the Fisheries Act 1996, as long as the interaction is reported. Commercial fishers are required to complete a Non-Fish and Protected Species Catch Return (NFPSCR, s11E of the Fisheries (Reporting) Regulations 2001).

The Minister of Conservation may approve a Population Management Plan (PMP) for one or more species under s.14F of the Wildlife Act and a PMP can include a maximum allowable level of fishing-related mortality for a species (MALFiRM). Such a limit would apply to New Zealand fisheries waters and would be for the purpose of enabling a threatened species to achieve a non-threatened status as soon as reasonably practicable, and in any event within a period not exceeding 20 years, or, in the case of non-threatened species, neither cause a net reduction in the size of the population nor seriously threaten the reproductive capacity of the species (s.14G). No PMPs are in place for seabirds but, in the absence of a PMP, the Minister for Primary Industries may, after consultation with the Minister of Conservation, take such measures as they consider necessary to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species (s.15(2) of the Fisheries Act 1996).

Relevant, high level guidance from the 2005 statement of General Policy under the Conservation Act 1987 and Wildlife Act 1953 includes the following stated policies:

4.4 (f) Marine protected species should be managed for their long-term viability and recovery throughout their natural range.

4.4 (g) Where unprotected marine species are identified as threatened, consideration will be given to amending the Wildlife Act 1953 schedules to declare such species absolutely protected.

4.4 (j) Human interactions with marine mammals and other marine protected species should be managed to avoid or minimise adverse effects on populations and individuals.

4.4 (l) The Department should work with other agencies and interests to protect marine species.

New Zealand is a signatory to a number of international conventions and agreements to provide for the management of threats to seabirds, including:

- the United Nations Convention on the Law of the Sea (UNCLOS);
- the United Nations Fish Stocks Agreement (insofar as it relates to the conservation of non-target, associated and dependent species);
- the Convention on Biological Diversity (CBD);
- the Convention on Migratory Species (CMS);
- the Food and Agriculture Organisation's (FAO) International Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries (IPOA);
- the FAO Code of Conduct for Responsible Fisheries and the interpretive Best Practice Technical Guidelines;
- the Agreement on the Conservation of Albatrosses and Petrels (ACAP)
- Western & Central Pacific Fisheries Commission (WCPFC)

- Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean (SPRFMO).

The ACAP agreement requires that parties achieve and maintain a favourable conservation status for selected albatross and petrel taxa. Under the IPOA-seabirds, New Zealand developed a National Plan of Action (NPOA) to reduce the incidental catch of seabirds in New Zealand fisheries in 2004 (MFish & DOC 2004) and recently revised NPOA-seabirds (MPI 2013) (http://www.fish.govt.nz/en-nz/Environmental/Seabirds/default.htm). The scopes of the 2004 and 2013 NPOA are broader than the original IPOA to facilitate a co-ordinated and long-term approach to reducing the impact of fishing activity on seabirds. The 2013 NPOA covers all New Zealand fisheries and has a long-term objective that *"New Zealand seabirds thrive without pressure from fishing related mortalities, New Zealand fishers avoid or mitigate against seabird captures and New Zealand fisheries are globally recognised as seabird friendly."* There are high-level subsidiary objectives related to practical aspects, biological risk, research and development, and international issues. Implementation is largely through MPI fisheries plans (see below). More detail is included in Section 6.4.3, *Managing fisheries interactions*.

Management of fishing-related mortality of seabirds is consistent with Fisheries 2030 Objective 6: Manage impacts of fishing and aquaculture. Further, the management actions follow Strategic Action 6.2: *Set and monitor environmental standards, including for threatened and protected species and seabed impacts.*

All National Fisheries Plans except that for freshwater fisheries are relevant to the management of fishing-related mortality of seabirds.

Under the National Deepwater Plan, the objective most relevant for management of seabirds is Management Objective 2.5: *Manage deepwater and middle-depth fisheries to avoid or minimise adverse effects on the long-term viability of endangered, threatened and protected species.*

Management objective 7 of the National Fisheries Plan for Highly Migratory Species (HMS) is to *"Implement an ecosystem approach to fisheries management, taking into account associated and dependent species"*. This comprises four components: *Avoid, remedy, or mitigate the adverse effects of fishing on associated and dependent species, including through maintaining food-chain relationships; Minimise unwanted bycatch and maximise survival of incidental catches of protected species in HMS fisheries, using a risk management approach; Increase the level and quality of information available on the capture of protected species; and Recognise the intrinsic values of HMS and their ecosystems, comprising predators, prey, and protected species.*

The Environment Objective is the same for all groups of fisheries in the draft National Fisheries Plan for Inshore Finfish and the draft National Fisheries Plan for Inshore Shellfish, to *"Minimise adverse effects of fishing on the aquatic environment, including on biological diversity"*. The draft National Fisheries Plan for Freshwater has the same objective but is unlikely to be relevant to management of fishing-related mortality of seabirds.

Table 6.1: List of New Zealand seabird taxa, excluding occasional visitors and vagrants, according to the Ornithological Society of New Zealand (OSNZ 2010) unless otherwise indicated (all taxa under the New Zealand Threat Classification System are listed, ACAP taxonomy generally takes precedence). IUCN and New Zealand (DOC) classifications are shown (http://www.iucnredlist.org/ and Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf).

Common name	Scientific name	DOC category	IUCN category
Wandering albatross	*Diomedea exulans*	Non-Resident Native: Migrant	Vulnerable
Antipodean albatross	*Diomedea antipodensis antipodensis*	Threatened: Nationally Critical	#Vulnerable
Gibson's albatross	*Diomedea antipodensis gibsonii*	Threatened: Nationally Critical	#Vulnerable
Southern royal albatross	*Diomedea epomophora*	At Risk: Naturally Uncommon	Vulnerable
Northern royal albatross	*Diomedea sanfordi*	At Risk: Naturally Uncommon	Endangered
Black-browed albatross	*Thalassarche melanophris*	Non-Resident Native: Coloniser	#Endangered
Campbell black-browed albatross	*Thalassarche impavida*	At Risk: Naturally Uncommon	#Endangered
Southern Buller's albatross	*Thalassarche bulleri*	At Risk: Naturally Uncommon	#Near Threatened

Table 6.1 (Continued).

Common name	Scientific name	DOC category	IUCN category
Northern Buller's albatross	*Thalassarche bulleri platei.*	At Risk: Naturally Uncommon	#Near Threatened
White-capped albatross	*Thalassarche steadi**	At Risk: Declining	Near Threatened
Salvin's albatross	*Thalassarche salvini*	Threatened: Nationally Critical	Vulnerable
Chatham Island albatross	*Thalassarche eremita*	At Risk: Naturally Uncommon	Vulnerable
Indian yellow-nosed albatross	*Thalassarche carteri*	Non-Resident Native: Coloniser	Endangered
Grey-headed albatross	*Thalassarche chrysostoma*	Threatened: Nationally Vulnerable	Vulnerable
Light mantled sooty albatross	*Phoebetria palpebrata*	At Risk: Declining	Near Threatened
Flesh-footed shearwater	*Puffinus carneipes*	Threatened: Nationally Vulnerable	Least Concern
Wedge-tailed shearwater	*Puffinus pacificus*	At Risk: Relict	Least Concern
Buller's shearwater	*Puffinus bulleri*	At Risk: Naturally Uncommon	Vulnerable
Sooty shearwater	*Puffinus griseus*	At Risk: Declining	Near Threatened
Short-tailed shearwater	*Puffinus tenuirostris*	Non-Resident Native: Migrant	Least Concern
Fluttering shearwater	*Puffinus gavia*	At Risk: Relict	Least Concern
Hutton's shearwater	*Puffinus huttoni*	At Risk: Declining	Endangered
Kermadec little shearwater	*Puffinus assimilis kermadecensis*	At Risk: Relict	#Least Concern
North Island little shearwater	*Puffinus assimilis haurakiensis*	At Risk: Declining	#Least Concern
Subantarctic little shearwater	*Puffinus elegans*	At Risk: Naturally Uncommon	#Least Concern
Northern diving petrel	*Pelecanoides urinatrix urinatrix*	At Risk: Relict	#Least Concern
Southern diving petrel	*Pelecanoides urinatrix chathamensis*	At Risk: Relict	#Least Concern
Subantarctic diving petrel	*Pelecanoides urinatrix exsul*	Non-Resident Native: Coloniser	#Least Concern
South Georgian diving petrel	*Pelecanoides georgicus* †	Threatened: Nationally Critical	Least Concern
Grey petrel	*Procellaria cinerea*	At Risk: Naturally Uncommon	Near Threatened
Black petrel	*Procellaria parkinsoni*	Threatened: Nationally Vulnerable	Vulnerable
Westland petrel	*Procellaria westlandica*	At Risk: Naturally Uncommon	Vulnerable
White-chinned petrel	*Procellaria aequinoctialis*	At Risk: Declining	Vulnerable
Kerguelen petrel	*Lugensa brevirostris*	Non-Resident Native: Migrant	Least Concern
Southern Cape petrel	*Daption capense capense*	Non-Resident Native: Migrant	#Least Concern
Snares Cape petrel	*Daption capense australe*	At Risk: Naturally Uncommon	#Least Concern
Antarctic fulmar	*Fulmarus glacialoides*	Non-Resident Native: Migrant	Least Concern
Southern giant petrel	*Macronectes giganteus*	Non-Resident Native: Migrant	Least Concern
Northern giant petrel	*Macronectes halli*	At Risk: Naturally Uncommon	Least Concern
Fairy prion	*Pachyptila turtur*	At Risk: Relict	Least Concern
Chatham fulmar prion	*Pachyptila crassirostris crassirostris*	At Risk: Naturally Uncommon	#Least Concern
Lesser fulmar prion	*Pachyptila crassirostris flemingi*	At Risk: Naturally Uncommon	#Least Concern
Thin-billed prion	*Pachyptila belcheri*	Non-Resident Native: Migrant	Least Concern
Antarctic prion	*Pachyptila desolata*	At Risk: Naturally Uncommon	Least Concern
Salvin's prion	*Pachyptila salvini*	Non-Resident Native: Migrant	–
Broad-billed prion	*Pachyptila vittata*	At Risk: Relict	Least Concern
Blue petrel	*Halobaena caerulea*	Non-Resident Native: Migrant	Least Concern
Pycroft's petrel	*Pterodroma pycrofti*	At Risk: Declining	Vulnerable
Cook's petrel	*Pterodroma cookii*	At Risk: Relict	Vulnerable
Black-winged petrel	*Pterodroma nigripennis*	Not Threatened	Least Concern
Chatham petrel	*Pterodroma axillaris*	Threatened	Endangered
Mottled petrel	*Pterodroma inexpectata*	At Risk: Relict	Near Threatened
White-naped petrel	*Pterodroma cervicalis*	At Risk: Relict	Vulnerable

Table 6.1 [Continued]:

Common name	Scientific name	DOC category	IUCN category
Kermadec petrel	*Pterodroma neglecta*	At Risk: Relict	Least Concern
Grey-faced petrel	*Pterodroma macroptera gouldi*	Not Threatened	Least Concern
Chatham Island taiko	*Pterodroma magentae*	Threatened: Nationally Critical	Critically
White-headed petrel	*Pterodroma lessonii*	Not Threatened	Least Concern
Soft-plumaged petrel	*Pterodroma mollis*	Non-Resident Native: Coloniser	Least Concern
Wilson's storm petrel	*Oceanites oceanicus*	Non-Resident Native: Migrant	Least Concern
Kermadec storm petrel	*Pelagodroma albiclunis*	Threatened: Nationally Critical	–
New Zealand storm petrel	*Pealeornis maoriana*	Threatened: Nationally	Critically
Grey-backed storm petrel	*Garrodia nereis*	At Risk: Relict	Least Concern
New Zealand white-faced storm	*Pelagodroma marina maoriana*	At Risk: Relict	#Least Concern
Black-bellied storm petrel	*Fregetta tropica*	Not Threatened	Least Concern
White-bellied storm petrel	*Fregetta grallaria grallaria*	Threatened: Nationally	Least Concern
Yellow-eyed penguin	*Megadyptes antipodes*	Threatened: Nationally Vulnerable	Endangered
Northern blue penguin**	*Eudyptula minor iredalei***	At Risk: Declining	#Least Concern
Southern blue penguin**	*Eudyptula minor minor***	At Risk: Declining	#Least Concern
Chatham Island blue penguin**	*Eudyptula minor*	At Risk: Naturally Uncommon	#Least Concern
White-flippered blue penguin**	*Eudyptula minor albosignata***	Threatened: Nationally Vulnerable	#Least Concern
Eastern rockhopper penguin	*Eudyptes filholi*	Threatened: Nationally Critical	#Vulnerable
Fiordland crested penguin	*Eudyptes pachyrhynchus*	Threatened: Nationally	Vulnerable
Snares crested penguin	*Eudyptes robustus*	At Risk: Naturally Uncommon	Vulnerable
Erect-crested penguin	*Eudyptes sclateri*	At Risk: Declining	Endangered

* OSNZ (2010) classify New Zealand white-capped albatross as a subspecies *Thalassarche cauta steadi*. Full species status is used here following ACAP.

** OSNZ (2010) classify a single species, little penguin *Eudyptula minor*. Multiple taxa are included here to reflect classification in the New Zealand Threat Classification Scheme.

*** OSNZ (2010) classify a single species, white-fronted tern *Sterna striata*. Multiple taxa are included here to reflect classification in the New Zealand Threat Classification Scheme.

# indicates that the IUCN classification is based on a broader definition of the species than listed in this table.

† Taxonomically Indeterminate in the New Zealand Threat Classification Scheme.

6.2 BIOLOGY

Taylor (2000) provided an excellent summary of the characteristics, ecology, and life history traits of seabirds (defined for the purpose of this document by the list in Table 6.1) which is further summarised here.

All seabirds spend part of their life cycle feeding over the open sea. They have webbed feet, water-resistant feathering to enable them to fully immerse in salt water, and powerful wings or flippers. All have bills with sharp hooks, points, or filters which enable them to catch fish, cephalopods, crustaceans, and plankton. Seabirds can drink saltwater and have physiological adaptations to remove excess salt.

Most seabird taxa are relatively long-lived; most live to 20 years and 30–40 years is typical for the oldest individuals. A few groups, notably albatrosses, can live for 50–60 years. Most taxa have relatively late sexual maturity. Red-billed gull and blue penguin have been recorded nesting as yearlings and diving petrels and yellow-eyed penguins can begin as 2-year-olds, but most seabirds start nesting only at age 3–6 years, and some albatross and petrel taxa delay nesting until 8–15 years old. In these late developers, individuals first return to colonies at 2–6 years old. Richard et al (2011) list values for several demographic parameters that they used for a comprehensive seabird risk assessment. Most seabirds, and especially albatrosses and some petrels, usually return to the breeding colony where they were reared, or nest close-by. Seabirds also have a tendency to mate for long periods with the same partner, and albatross pairs almost always remain together unless one partner dies.

The number of eggs laid varies among families. Albatrosses and petrels lay only one egg per year (sometimes nesting every other year) and do not lay again that year if it is lost. Other taxa such as gannets lay one egg but can replace it if the egg is lost. Most penguins lay two eggs but some raise only one chick and eject the second egg; replacement laying is uncommon. Blue penguins, gulls, and terns lay 1–3 eggs and can lay up to three clutches in a year if eggs are damaged or lost. Shags lay 2–5 eggs, can replace clutches, and have several breeding seasons in a year. Incubation in albatrosses and petrels lasts 40–75 days and chick rearing 50–280 days. In gulls and terns, incubation is completed in 20–25 days and chicks fledge in 20–40 days. In general, the lower the potential reproductive output of a taxon, the higher the adult survival rates and longevity.

Some seabirds such as shags, blue penguins, and yellow-eyed penguins live their lives and forage relatively close to where they breed, but many, including most albatrosses and petrels, spend large parts of their lives in international waters or in the waters of other nations far from their breeding locations. They can travel great distances across oceans during foraging flights and migratory journeys.

6.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

Fishing related mortality of seabirds has been recognised as a serious, worldwide issue for only about 20 years (Bartle 1991, Brothers 1991, Brothers et al 1999, Croxall 2008) and the Food & Agriculture Organization of the United Nations (FAO) released its International Plan of Action for reducing incidental catch of seabirds in longline fisheries (IPOA-seabirds) in 1999 (FAO 1999). The IPOA-Seabirds called on countries with (longline) fisheries that interact with seabirds to assess their fisheries to determine if a problem exists and, if so, to develop national plans (NPOA–seabirds) to reduce the incidental seabird catch in their fisheries. Lewison et al (2004) noted that, in spite of the recognition of the problem, few comprehensive assessments of the effects of fishing-related mortality had been conducted in the decade or so after the problem was recognised. They reasoned that: many vulnerable species live in pelagic habitats, making surveys logistically complex and expensive; capture data are sparse; and understanding of the potential for affected populations to sustain additional mortality is poor. Soykan et al (2008) identified similar questions in a Theme Section published in Endangered Species Research, including: Where is bycatch most prevalent? Which species are taken as bycatch? Which fisheries and gear types result in the highest bycatch of marine megafauna? What are the population-level effects on bycatch species? How can bycatch be reduced?

There has been substantial progress on these questions since 2004. Croxall et al (2012) reviewed the threats to 346 seabird taxa and concluded that: seabirds are more threatened than other comparable groups of birds; that their status has deteriorated faster over recent decades; and that fishing-related mortality is the most pervasive and immediate threat to many albatross and petrels. They listed the principal threats while at sea as being posed by commercial fisheries (through competition for food and mortality associated with fishing gear) and pollution, and those on land being alien predators, habitat degradation and human disturbance. Direct exploitation, impacts of aquaculture, energy generation operations, and climate change were listed as threats for some taxa or areas where understanding was particularly poor.

Croxall et al (2012) categorise responses to the issue of fishing-related mortality as:

using long-term demographic studies of relevant seabird species, linked to observational and recovery data to identify the cause of population declines (e.g. Croxall et al 1998, Tuck et al 2004, Poncet et al 2006);

- risk assessments, based on spatiotemporal overlap between seabird species susceptible to bycatch and effort data for fisheries likely to catch them (e.g. Waugh et al 2008b; Filippi et al 2010; Tuck et al 2011);
- working with multinational and international bodies (e.g. FAO and RFMOs) to develop and implement appropriate regulations for the use of best-practice techniques to reduce or eliminate seabird bycatch and;
- working with fishers (and national fishery organisations) to assist cost-effective implementation of these mitigation techniques.

Seabirds are ranked by the International Union for the Conservation of Nature (IUCN) as the world's most threatened bird grouping (Croxall et al 2012). Globally they face a number of threats to their long term viability, both at their breeding sites and while foraging at sea. Work at the global level on reducing threats at breeding sites is a major focus of the Agreement on the Conservation of

Albatrosses and Petrels (ACAP) and DOC is the lead New Zealand lead agency. However, the key threat to seabirds at sea, especially albatrosses and petrels, is incidental capture and death in fisheries managed by MPI.

Some seabirds do not range far from their breeding or roosting sites and incidental captures of these taxa can be managed by a single jurisdiction. Conversely, conservation of highly migratory taxa such as albatrosses and petrels cannot be achieved by one country acting independently of other nations which share the same populations. Because of this, in recent years countries which share populations of threatened seabirds have sought to take actions on an international level (e.g. at ACAP) to complement policy and actions taken within their own jurisdictions.

The ICES Working Group on Seabird Ecology agreed (WGSE 2011) that the three most important indirect effects of fisheries on seabird populations were: the harvesting of seabird food; discards as food subsidies; and modification of marine habitats by dredges and trawls. Many seabird prey species are fished commercially (e.g., Furness 2003) or can be impacted indirectly by fishing of larger predators. These relationships are complex and poorly understood but WGSE (2011) agreed that impacts on populations of seabirds were inevitable. Fishery discards and offal have the potential to benefit seabird species, especially those that ordinarily scavenge (Furness et al 1992, Wagner & Boersma 2011). However, discarding can also modify the way in which birds forage for food (e.g., Bartumeus et al 2010, Louzao et al 2011), sometimes with farther-reaching behavioural consequences with negative as well as positive effects (including the “junk food hypothesis”, e.g., Romano et al 2006; Grémillet et al 2008). Louzao et al (2011) stated that discards can affect movement patterns (Arcos & Oro 1996), improve reproductive performance (Oro et al 1997, 1999) and increase survival (Oro & Furness, 2002; Oro et al 2004). Benefits for scavengers and kleptoparasitic taxa (those that obtain food by stealing from other animals) feeding on discards can also have consequent negative impacts on other species, especially diving species, that share breeding sites or are subject to displacement (Wagner & Boersma 2011). Dredging and bottom trawling both affect benthic habitat and fauna (see Rice 2006 and the benthic effects chapter in this document) and WGSE (2011) agreed that this probably affects some seabird populations, although little work has been done in this area.

6.4 STATE OF KNOWLEDGE IN NEW ZEALAND

Before the arrival of humans, the absence of terrestrial mammalian predators in New Zealand made it a relatively safe breeding place for seabirds and large numbers of a wide variety of taxa bred here, including substantial numbers on the main North and South Islands. Today, New Zealand’s extensive coastline, numerous inshore and offshore islands (many of them predator free) and surrounding seas and oceans continue to make it an important foraging and breeding ground for about 145 seabird taxa, second only to the USA (GA Taylor, Department of Conservation, personal communication). Roughly 95 of these taxa breed in New Zealand (Figure 6.1 and Figure 6.2; Table 6.2), including the greatest number of albatrosses (14), petrels (32), shags (13) and penguins (9) of any area in the world (Miskelly et al 2008). More than a third are endemic (i.e. breed nowhere else in the world), giving New Zealand by far the largest number of endemic seabird taxa in the world.

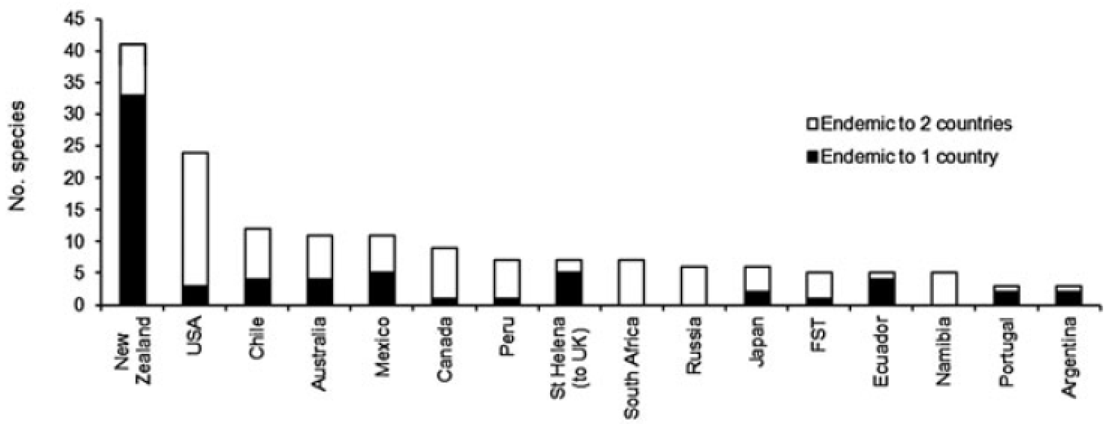


Figure 6.1: (from Croxall et al 2012). Number of endemic breeding seabird taxa by country.

Some seabirds use New Zealand waters but do not breed here. Some visit here occasionally to feed (e.g. Indian Ocean yellow-nosed albatross and snowy wandering albatross), whereas others are frequent visitors (e.g. short-tailed shearwater and Wilson's storm petrel), sometimes for extended durations (e.g. juvenile giant petrels).

Taylor (2000) lists a wide range of threats to New Zealand seabird taxa including introduced mammals, avian predators (e.g., weka), disease, fire, weeds, loss of nesting habitat, competition for nest sites, coastal development, human disturbance, commercial and cultural harvesting, volcanic eruptions, pollution, plastics and marine debris, oil spills and exploration, heavy metals or chemical contaminants, global sea temperature changes, marine biotoxins, and fisheries interactions. Seabirds are caught in commercial trawl, longline, set-net, and, occasionally, other fisheries (e.g, annual assessments by SJ Baird from 1994 to 2005, Baird & Smith 2008, Waugh et al 2008a, b, Abraham et al 2010b) as well as in non-commercial fisheries (Abraham et al 2010a). New Zealand released its first National Plan of Action to reduce the incidental catch of seabirds (NPOA-seabirds) in 2004 and this was revised in 2013. This stated that there was, at that time, limited information about the level of incidental catch and population characteristics of different seabird taxa, and that this made quantifying the overall impact of fishing difficult. This situation had improved somewhat by the time 2013 NPOA-seabirds was published but, nevertheless, that document seeks to ensure, among other things, that the development of new mitigation measures, new observation and monitoring methods, and relevant research are encouraged and resourced. Seabird taxa caught in New Zealand fisheries range in IUCN threat ranking from critically endangered (e.g. Chatham Island shag), to least concern (e.g. flesh-footed shearwater) (e.g., Vié et al 2009).

Different taxa and populations face different threats from fishing operations depending on their biological characteristics and foraging behaviours. Biological traits such as diving ability, agility, size, sense of smell, eyesight and diet, foraging factors such as the season and areas they forage, their aggressiveness, the boldness (or shyness) they display in their attraction to fishing activity can all affect their susceptibility to capture, injury, or death from fishing operations. Some fishing methods pose particular threats to some guilds or types of seabirds. For example, penguins are particularly vulnerable to set net operations and large albatrosses appear to be vulnerable to all forms of longlining. The nature and extent of interactions differs spatially, temporally, seasonally and diurnally between sectors, fisheries and between fleets and vessels within fisheries. In 2010–11 the taxa most frequently observed caught in New Zealand commercial fisheries in descending order were white-chinned petrel, sooty shearwater, southern Buller's albatross, white-capped albatross, Salvin's albatross, and flesh footed shearwater, grey petrel, Cape petrel species, storm petrels, and black petrel.

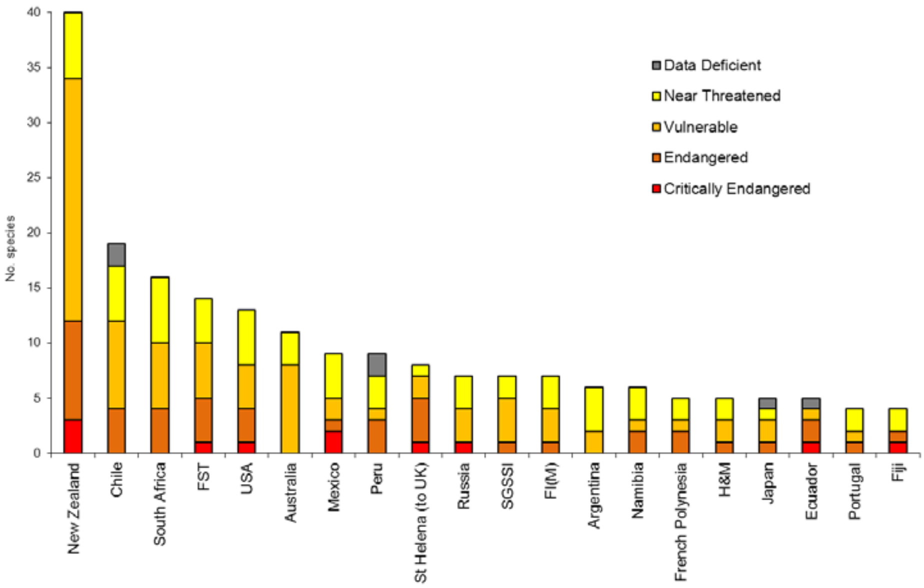


Figure 6.2: (from Croxall et al 2012, supplementary material): The number of breeding and resident seabird species by country in each IUCN category (excluding Least Concern). FST, French Southern Territories; SGSSI, South Georgia and South Sandwich Islands; FI(M), Falkland Islands (Malvinas); H&M, Heard Island and McDonald Islands.

Table 6.2: (from Taylor 2000): Number of species (spp.) and taxa of seabirds of different families in New Zealand and worldwide in 2000. Additional taxa may have been recorded since.

Family	Common name	World breeding		NZ breeding		NZ visitors,vagrants	
		N spp.	N taxa	N spp.	N taxa	N spp.	N taxa
Spheniscidae	Penguins	17	26	6	10	8	10
Gaviidae	Divers, loons	4	6	–	–	–	–
Podicipedidae	Grebes	10	20	2	2	–	–
Diomedeidae	Albatrosses	24	24	13	13	7	7
Procellariidae	Petrels, shearwaters	70	109	28	31	20	23
Hydrobatidae	Storm-petrels	20	36	4	5	2	3
Pelecanoididae	Diving petrels	4	9	2	4	–	–
Phaethontidae	Tropicbirds	3	12	1	1	1	1
Pelecanidae	Pelicans	7	12	–	–	1	1
Sulidae	Gannets	9	19	2	2	1	1
Phalacrocoracidae	Shags	39	57	12	13	–	–
Fregatidae	Frigatebirds	5	11	–	–	2	2
Anatidae	Marine ducks	18	27	–	–	–	–
Scolopacidae	Phalaropes	2	2	–	–	2	2
Chionididae	Sheathbills	2	5	–	–	–	–
Stercorariidae	Skuas	7	10	1	1	4	4
Laridae	Gulls	51	78	3	3	–	–
Sternidae	Terns, noddies	43	121	10	11	8	8
Rynchopidae	Skimmers	2	4	–	–	–	–
Alcidae	Auks, puffins	22	45	–	–	–	–
	Total	359	633	84	96	56	62

The management of fisheries to ensure the long-term viability of seabird populations requires an understanding of the risks posed by fishing and other anthropogenic drivers. Several studies have already estimated the number of seabirds caught annually within the New Zealand Exclusive Economic Zone (EEZ) in a range of fisheries (e.g., Baird & Smith 2008, Waugh et al 2008a, b, Abraham et al 2010b). Seabirds that breed in New Zealand die as a result of interactions with commercial or recreational fishing operations in waters under New Zealand jurisdiction, through interactions with New Zealand vessels or other nations' vessels on the High Seas and through interactions with commercial, recreational or artisanal fishing operations in waters under the jurisdiction of other states.

In order to evaluate whether the viability of seabird populations is jeopardised by incidental mortality from commercial fishing, the number of annual fatalities needs to be compared with the capacity of the populations to replace those losses; this depends on the size and productivity of each population. Unfortunately, sufficient data to build fully quantitative population models to assess risks and explore the likely results of different management approaches are available for only very few taxa (e.g., Fletcher et al 2008, Francis & Bell 2010, Francis et al 2008, Dillingham & Fletcher 2011). For this reason, broad seabird risk assessments need to rely on expert knowledge (level-1) or to be semi-quantitative (level-2) (Hobday et al 2007). Rowe 2013 described a level-1 seabird risk assessment and Baird et al (2006, updated by Baird & Gilbert 2010) described a semi-quantitative assessment for seabird taxa for which reasonable numbers of observed captures were available. These assessments were based on expert knowledge or were not comprehensive and could not be used directly to quantify risk for all seabird taxa and fisheries. More comprehensive and quantitative level-2 risk assessments have since been conducted and are described in more detail in Section 6.4.5.1.

6.4.1 SEABIRD DEMOGRAPHIC AND DISTRIBUTION STUDIES

This section summarises the key results of project PRO2006-01, *Demographic, distributional and trophic information on selected seabird species*, initiated by the Ministry of Fisheries (now MPI) to address some of the major information gaps on the demographics and distribution of seabird species commonly caught by commercial fishing in New Zealand waters. Other demographic studies have been conducted by the Department of Conservation or other parties and these are noted where possible.

6.4.1.1 CHATHAM ISLAND ALBATROSS

The Chatham Island albatross breeds only at The Pyramid, a small southern islet in the Chatham Island group (note that a translocation project began in early 2014 transferring chicks to the main Chatham Island with the hopes of establishing a second breeding site). In order to index the population size of the Chatham Islands albatross, nest counts are conducted on The Pyramid. The islet is divided into 19 areas and, within each, every accessible nest site is counted and its status recorded (Scofield et al 2008a, Fraser et al 2009b, 2010b).

Nest counts have been conducted when the birds are in the early stages of chick rearing. The total number of Chatham Island albatross nest sites counted in the most recent trip was 5245 (Fraser et al 2011). This result compared closely with previous counts (which have ranged from 5194 to 5407 in late November and early December, Table 6.3) indicating a stable number of occupied nests on The Pyramid.

Chatham Island albatross have been banded on The Pyramid since 1974 and, at each visit, the recaptures have added to the growing number of known-aged birds. This banding record enables an assessment of annual adult mortality. A total of 304 banded Chatham Island albatross were recaptured between 19 November and 2 December 2010 on The Pyramid and a further 50 new Chatham Island albatross were banded during the 2010 trip (Fraser et al 2011).

To determine foraging movements and behaviour of Chatham Island albatross during the incubation and early chick rearing stages of the breeding season, GPS loggers were applied to breeding birds for the duration of one foraging trip. Where possible, birds were also tagged with a geolocator logger to record activity (i.e. salt water immersion) during foraging trips. The resulting distributional range of Chatham Islands albatross during incubation and early chick rearing from these tracking studies from November to December 2007–2009 are given in Figure 6.3 (Fraser et al 2010b).

To track the birds on a longer time- scale during the non-breeding season, geolocation loggers (GLS) were used. These devices have a life span of up to about 6 years and are intended to remain on the birds for at least one year. They were applied to each banded bird’s leg using a plastic band to which the loggers were attached with glue and a cable tie.

Table 6.3: (from Fraser et al 2011) Counts of Chatham Island albatross nest sites for the years: 2007 (19–29 November); 2008 (22 November – 7 December); 2009 (9–12 December); and 2010 (24–30 December).

	2007	2008	2009	2010
Total nests counted	5 247	5 407	5 194	5 245

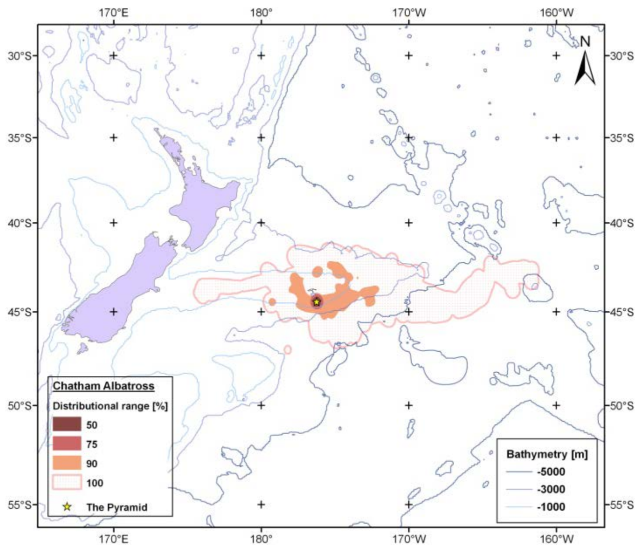


Figure 6.3: (from Fraser et al 2010b) Distributional range of Chatham Island albatross during incubation and early chick rearing as derived from tracking studies in November/December 2007–2009 (n=51 tracks).

6.4.1.2 NORTHERN BULLER’S ALBATROSS AND NORTHERN GIANT PETREL AT THE FORTY -FOURS, CHATHAM ISLANDS

The Forty-Fours, a small group of islands, are located about 35 km east of Chatham Island. They are home to the main breeding populations of northern royal albatross (*Diomedea sanfordi*) and northern Buller’s albatross (*Thalassarche nov* sp.). A large colony of northern giant petrel (*Macronectes halli*) also breeds at the Forty-Fours. The northern Buller’s albatross nest estimate on the Forty-Fours for 2007 was 15 238 (Scofield et al 2008b), for 2008 was 14 674 (Fraser et al 2009a), and for 2009 was 14 185 (Fraser et al 2010a). Fixed grids sampled each year also confirmed the consistent population count (Fraser et al 2010a). Northern giant petrels nest mainly in the north-eastern part of the island along the cliff tops, interspersed with the northern royal albatross. Estimates of nests with chicks in them (both alive and dead) were: 430 in November 2007 (Scofield et al 2008b); 349 in November 2008 (Fraser et al 2009a); and 270 in December 2009 (Fraser et al 2010a). Ten geolocators were placed on five incubating pairs of northern royal albatross in November 2007 (Scofield et al 2008b). Some of the geolocators have not yet been removed from the birds and data are still to be presented.

6.4.1.3 NORTHERN ROYAL ALBATROSS

The main breeding populations of northern royal albatross are on the Forty-Fours and The Sisters which are small island groups off the main Chatham Island. There is also a small colony at Taiaroa Head, South Island. The islands where northern royal albatross nest at the Chatham Islands are privately-owned, and landing there is weather-dependent. In order to monitor populations effectively, counts are required immediately following egg-laying (because this provides the most reliable estimates of the numbers of breeding pairs), and at fledging but prior to any chick departing each year (because this allows breeding success to be estimated each year). Aerial photography is the most cost-effective method of making these counts at these times and locations. Aerial counts of nesting northern royal albatross were made during each of the four breeding seasons 2006–07 to 2009–10.

Three trips to the Chatham Islands were planned each year during this study, with the primary objectives of each trip being to take aerial photographs for population counts on both the Forty-Fours and The Sisters. Trips were timed to coincide with key events in the breeding seasons and were planned for:

- Late November or early December (to count the number of northern royal albatrosses at the completion of egg laying);
- April (to count northern royal albatross chicks shortly after hatching); and
- September (to count northern royal albatross chicks just prior to fledging).

The November 2007 aerial survey was made just before the field team arrived on the Forty-Fours to study northern Buller's albatross and northern giant petrels. A ground count of breeding northern royal albatross was made at about the same time of day as the aerial photography was completed. This one-off exercise showed that aerial and ground counts are broadly comparable and there is probably little bias caused by birds being obscured to aerial counting or the counting of non-breeding birds. Aerial counts suggested that the estimated total number of breeding pairs ranged from 5 388 to 5 744 (Table 6.4). These estimates do not differ markedly from an estimate made in the 1970s (Robertson 1998, cited in Scofield 2011).

At the small population that self-established on the mainland of New Zealand at Taiaroa Head, banding as well as monitoring of individuals has been carried out since 1938. Richard and Abraham (2013) estimated the overall annual adult survival rate at 0.95 (95% c.i.: 0.941–0.959). Estimates of other demographic rates were also obtained during the estimation process. The mean age at first return of juveniles to the colony was estimated at 4.81 years (95% c.i.: 4.63–5.06), and the mean age at first breeding as 8.85 years (95% c.i.: 8.53–9.29).

Table 6.4: (from Scofield 2011) Aerial counts of northern royal albatross eggs and chicks at their key Chatham Islands nesting sites, 2006–07 to 2009–10.

	2006–07		2007–08		2008–09		2009–10	
	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks
Forty-Fours	1 879	1 018	2 212	1 093	2 055	1 036	2 692	1 083
Big Sister	2 128	871	2 018	288	2 081	496	1 893	665
Middle Sister	1 381	670	1 371	435	1 316	483	1 159	569
Total	5 388	2 559	5 601	1 816	5 452	2 015	5 744	2 317

6.4.1.4 SALVIN'S ALBATROSS ON BOUNTY ISLANDS

Salvin's albatross (*Thalassarche salvini*) is endemic to New Zealand, breeding only on the Bounty Islands and the Western Chain of The Snares. The Bounty Islands are a group of bare rocky islands/islets situated 659 km south-east of New Zealand's South Island. In October 2010, Baker et al (2010a) completed an aerial survey of the Bounty Islands to photograph all albatross colonies. This was the first complete population survey of Salvin's albatross on the Bounty Islands. Photo montages were created from the aerial photography and the number of nesting birds was counted. From these data, Baker et al (2010a) estimated the total count of nesting Salvin's albatrosses in the Bounty Islands in October 2010 to be 41 101 (95%c.i.: 40 696–41 506).

This estimate may be biased high by the presence of "loafers" (non-breeding birds) as it was not possible to ground truth the aerial photography or detect the proportion of loafers within the colony from close-up photography (because of the general lack of nest pedestals resulting from low availability of nesting material on the island). Conversely, the estimate maybe biased low because aerial photography was not possible on some small areas of steep cliff where albatross nests may have been missed (Baker et al 2012).

A review of existing ground counts was reported by Amey & Sagar (2013). To estimate population trends and examine the accuracy of ground counts, whole-island surveys of Salvin's albatross breeding at Proclamation Island, Bounty Islands, were undertaken during November in 1997, 2004, and 2011. These counts suggest that the numbers of Salvin's Albatross nests on Proclamation Island declined by 14% between 1997, and 2004, by 13% between 2004 and 2011, and overall by 30% between 1997 and 2011. Counts of nests on Depot Island decreased by 10% between 2004 and 2011.

Baker et al (2014a) conducted a repeat aerial survey of the Bounty Islands in October 2013. Using the same correction factor applied to the 2010 counts, they estimated the total annual breeding pairs at 39 995 (95% c.i.: 39 595 - 40 395) compared to the corrected estimate for 2010 of 31 786 (95% c.i: 31 430 – 32 143).

6.4.1.5 SALVIN'S ALBATROSS ON SNARES WESTERN CHAIN

In 2008, a 3-year study of Salvin's albatrosses was initiated at the Snares Western Chain. The three main objectives of the Salvin's albatross field work were:

- to estimate the breeding population size from counts of occupied nests;
- to determine foraging locations and activity by retrieving geolocator tracking devices deployed in 2008; and
- to estimate annual survival rates of banded adult birds from recapture analyses.

Totals of 1195 and 1116 breeding pairs were counted on Toru and Rima Islets during October 2008 (Charteris et al 2009) and September-October 2009, respectively (Carroll et al 2010) (Table 6.5). Only Toru Island was sampled in 2010.

Table 6.5: (from Sagar et al 2011) Numbers of Salvin's albatross pairs breeding on Toru and Rima Isles, Western Chain, The Snares, 2008–2010. Failed nests are those assessed to contain fresh egg fragments. No count was made on Rima Islet in 2010.

Islet	Date	Adult + egg	Obvious failed nest	Total
Toru	6–7 October 2008	828	70	898
	2 October 2009	783	51	834
	28–29 September 2010	780	49	829
Rima	16 October 2008	279	18	297
	30 September 2009	265	17	282

In order to estimate the adult survival of Salvin's albatross, a total of 257 occupied nests were counted within a clearly-defined study area established in October 2008 (Charteris et al 2009). Within this area, 116 birds banded in previous years were recaptured, and a further 20 breeding birds were banded in the study area during October 2010. Among the recaptured birds were 13 that had been banded as chicks on Toru Islet during 1986, and 23 of the 123 birds banded as breeding adults in 1995. These recapture rates lead to an estimated adult survival probability of 0.967 for Salvin's albatross, one of the highest estimates for any species of annual-breeding albatross (Sagar et al 2011).

Twenty-four of the 35 geolocation loggers deployed on breeding birds during October 2008 were retrieved. Data were processed by the British Antarctic Survey and a preliminary assessment of the distribution of Salvin's albatrosses during the entire year is presented in Figure 6.4. None of the 24 birds tracked was within the New Zealand EEZ during April; 23 were in South American waters between Tierra del Fuego and northern Peru and one was in eastern Bass Strait and along the eastern coast of Tasmania (Figure 6.4a). Birds began to return to New Zealand waters during May and this continued throughout June and July. The tracks of birds exiting South American waters originated from either the Peruvian or southern Chilean coasts. During this period, birds recently arrived in New Zealand waters occurred primarily east of the Chatham Islands, off Puysegur and on the Stewart- Snares Shelf (Figure 6.4b). Eggs are laid starting in August and all of the birds occurred within Australasian waters throughout August to October, primarily on the Challenger Plateau, off Puysegur, the Stewart-Snares Shelf, and Campbell Plateau (Figure 6.4c). During this period these birds from the Snares Western Chain occupy a relatively narrow longitudinal range between 160°E and 175°E and appear to avoid, or be excluded from, the area around the Bounty Islands, where there is another colony of Salvin's albatross. Beginning in mid-October chicks hatch and, between November and March, presumed successful breeders foraged primarily on the Challenger Plateau, off Puysegur, the Stewart- Snares Shelf, and Campbell Plateau (Figure 6.4d). There was some movement across the Pacific in each of the months between November and March with presumed failed breeders leaving the New Zealand EEZ during the earlier part of this period and presumed successful breeders migrating east during March (Sagar et al 2011).

Further research has been recently conducted on the Salvin's albatross on the Snares Western Chain, under DOC CSP project PRO2014-02. This research included a ground based census, aerial survey (including ground truthing) and collection of information on tagged birds. The final reports for this research were not available at time of printing.

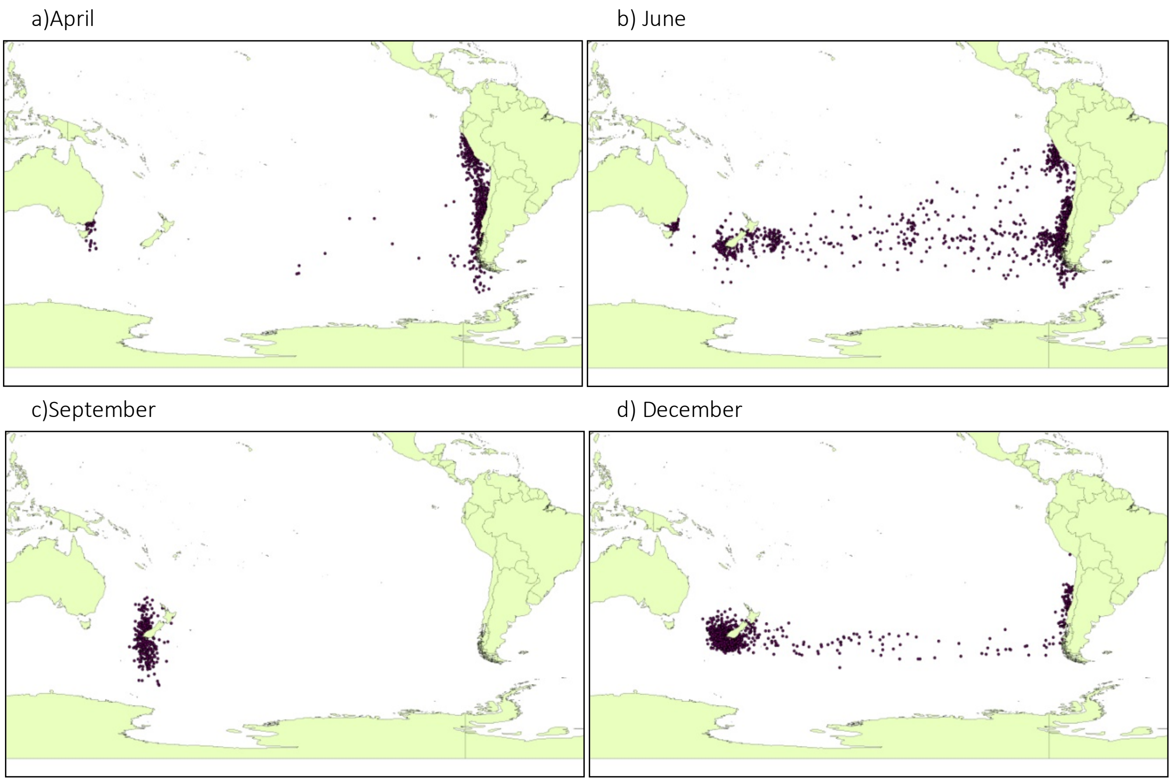


Figure 6.4: (from Sagar et al 2011) Distribution of Salvin's albatrosses Thalassarche salvini from the Snares Western Chain tagged with geolocators at four times of the year: a) April, after the completion of their breeding season, b) June, showing their return tracks from South American waters to New Zealand waters prior to egg laying, c) September, when their partners were incubating an egg, and d) December, the birds around New Zealand are presumed to be foraging for food for themselves and their chick, whilst the birds crossing the Pacific and in South American waters are presumed to be failed breeders.

6.4.1.6 WHITE CAPPED ALBATROSS

Repeated population censuses of the white-capped albatrosses breeding in the Auckland Islands were conducted in the month of December between 2006 and 2010, and the month of January in 2012 and 2013, using aerial photography (Baker et al 2007b, 2008a, 2009a, 2011a, 2013). These population censuses were carried out to estimate population size and track population trends. Photo montages were created from the aerial photography and counted by an observer. Counts of photo montages in all years except 2006 were undertaken by one observer only. Multiple counts of photomontages from the December 2006 census to estimate counter variability associated with miscounting and misidentifying white spots on the ground as birds. Ground truthing was conducted to determine the number of birds sitting or standing on nests, the number of pairs (partners accompanying an incubating bird), and the number of loafers present in the colony.

2006–2010: In 2010, the total count of nesting white-capped albatrosses was estimated to be 72 635 (95%CI 72 096–73 174), 4370 (4238–4502) and 117 (95–139) annual breeding pairs, respectively, at Disappointment Island, South West Cape and Adams Island, giving a total for these sites of 76 913 (76 358–77 468) breeding pairs (Table 6.6). The counts of nesting white-capped albatross over the previous four years were significantly lower than the counts taken in 2006, when a total of 117 197 breeding pairs were present at the Auckland Islands. These differences in counts may represent normal inter-annual variation in breeding rather than indicating a decline in numbers due to fisheries mortalities (Baker et al 2011a).

2011–13: Surveys suggested 99 776 breeding pairs in 2011 and 118 098 breeding pairs in 2012 and 95 278 in 2013. However, evidence from a series of 'close-up' photographs taken each year over the entire series indicates that the number of non-breeding birds present in the colonies differed somewhat between December and January. The proportion was very low in December counts (1–2% of birds present) to 7 and 15% for the January counts taken in 2012 and 2013, respectively. Estimated annual counts for all three breeding sites in the Auckland Islands were adjusted to account for the presence of non-breeding birds (Table 6.6). These adjusted figures were used as inputs into models used for assessment of population trend. The population size estimates computed from a TRIM model indicate an average growth rate of - 3.16% per year (λ = 0.9684 ± 0.001); assessed by TRIM as moderate decline. However, a simple linear trend analysis, as performed by TRIM is not well suited to a data set with high inter-annual variability. Trend analysis using smoothing splines is more appropriate to such data sets, and showed no evidence for systematic monotonic decline over the 8 years of the study, therefore providing support to the null hypotheses of no trend (stability) in the total population. Full details are provided by Baker et al (2013, 2014b).

Table 6.6: (after Baker et al 2013, 2014b) Aerial-photographic counts of breeding pairs of white-capped albatrosses on three islands in the Auckland Islands group in December 2006–2013.

Year	Adams	Disappointment	SW Cape	Total	95% limits	Adjusted for loafers
2006	–	110 649	6 548	117 197	116 570–117 823	116 025
2007	79	86 080	4 786	90 945	90 342–91 548	90 036
2008	131	91 694	5 264	97 089	96 466–97 712	96 118
2009	132	70 569	4 161	74 862	74 315–75 409	73 838
2010	117	72 635	4 370	77 122	76 567–77 677	76 119
2011	178	93 752	5 846	99 776	99 144–100 408	92 692
2012	215	111 312	6 571	118 098	117 411–118 785	102 273
2013	184	89 552	5 542	95 278	94 661-95 895	74 031

6.4.1.7 WHITE-CHINNED PETREL ON ANTIPODES ISLANDS

In 2007, a 5-year study of white-chinned petrels (*Procellaria aequinoctialis*) was initiated on Antipodes Island. Four seasons of fieldwork have been completed (Sommer et al 2008, 2009, 2010). The objectives of the white-chinned petrel field work were:

- to estimate the population trend from mark-recapture in the three study areas;

- to determine foraging locations and activity; and
- to estimate burrow occupancy in a range of habitats in order to increase the accuracy of a total island population estimate.

Three study areas were established and all white-chinned petrel burrows in each were checked at least three times during each field trip to identify both birds. Identifying white-chinned petrel burrows can involve a degree of subjectivity because white-headed petrels, *Pterodroma lessoni*, also nest on Antipodes Island. Although many white-chinned petrel burrows have very large entrances, and many white-headed petrel burrows have much smaller entrances with steep tunnels, white-chinned petrel have been found in burrows with entrances that have characteristics somewhere between the two. Estimated occupancy rates were similar in the years studied (Table 6.7). Overall, the number of burrows fluctuates between years as new burrows are dug and the number of burrows with unidentified eggshell remains varies (Sommer et al 2010).

Table 6.7: (from Sommer et al 2010) White-chinned petrel (WCP) study burrow occupancy between years.

Year	Timing	Total "WCP" burrows counted	"WCP" burrows with breeding WCP	% with breeding WCP
2008	mid Jan to end Feb	280	71	25.4
2009	late Jan to end Feb	285	77	27.0
2010	mid Dec to early Jan	295	81	27.5

To determine the foraging area of breeding white chinned petrels, 34 dataloggers (30 British Antarctic Survey, 4 Lotek) were deployed on breeding white-chinned petrels in 2008 (Sommer et al 2008). Seventeen and 13 of these birds were recaptured during the 2009 and 2010 field trips and their dataloggers were removed (Sommer et al 2009, 2010). Data from the 17 geolocators recovered during 2009 have been processed and enable initial conclusions to be made of the foraging movements of white-chinned petrels from the Antipodes. In summary, these are:

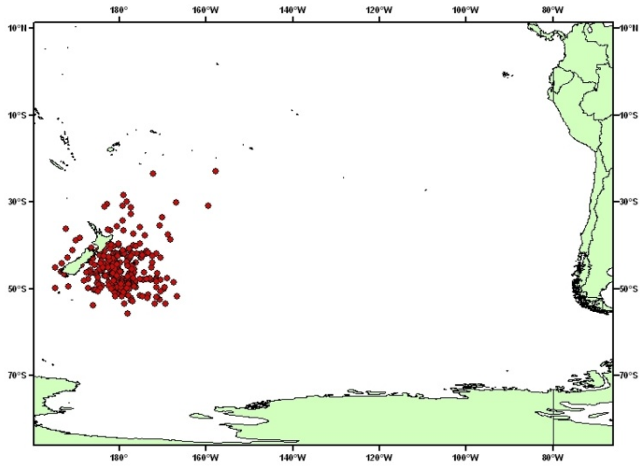
- During the breeding season, the birds foraged within the EEZ, mostly north of Antipodes Island and to the east of the mainland (Figure 6.5a).
- There was movement of birds across the Pacific to the coasts of Chile and Peru during February, presumably by failed breeders (Figure 6.5b).
- In the latter part of the breeding season (April and May) the birds tended to forage south of Antipodes Island.
- In May, after breeding, all birds migrated across the Pacific to forage off the west coast of South America, remaining there until August (Figure 6.5c).
- In September, the birds returned across the Pacific to Antipodes Island from the coast of Peru for the start of the new breeding season.

Occupancy was also estimated across a range of habitats throughout the island using transects. These transects varied in length and were measured by saving tracks on a handheld GPS. All white-chinned petrel burrows within 1 m either side of the transect (i.e., a 2 m-wide strip in total) were recorded (Table 6.8) and occupancy determined using a stick or burrowscope. Habitat type and slope were also recorded for each burrow (Sommer et al 2008, 2009, 2010).

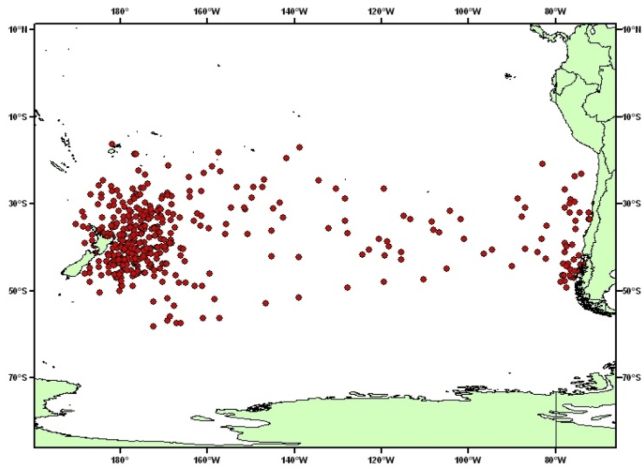
Table 6.8: (from Sommer et al 2010) Results of white-chinned petrel occupancy transects in various habitats spread throughout Antipodes Island.

No. transects	Total burrows	No. containing white-chinned petrel breeding (non-breeding)	No. containing white-headed petrel	No. empty	No. not used for occupancy estimate	% burrows with breeding white-chinned petrel
20	247	59 (10)	21	144	13	25.2

a) December



b) February



c)June-August

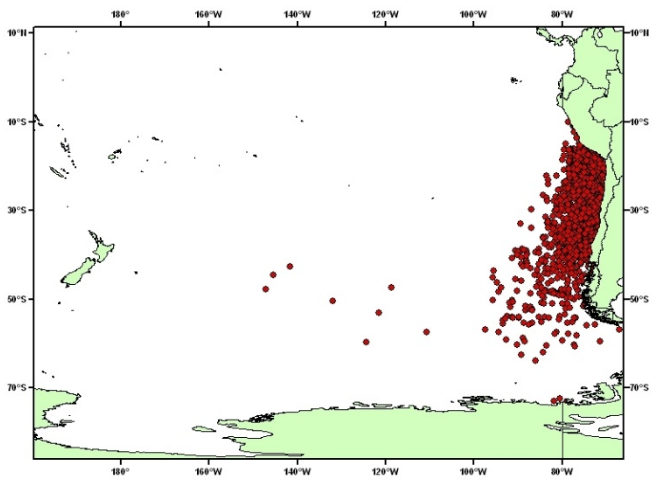


Figure 6.5: (from Sommer et al 2010) Foraging locations of white-chinned petrels from the Antipodes, in a) December, b) February and in c) June-August, after the end of the breeding season.

Between December 2009 and January 2010, breeding white-chinned petrels were estimated to have an average density across all sampled habitats of 45 occupied burrows.ha^{-1}. The total area of Antipodes Island is 2 025 ha (Bell 2002) and, assuming all of this area is similarly suitable to the sampled areas, a preliminary estimate of the total population is 91 125 breeding pairs (Sommer et al 2010), compared with 100 000 pairs estimated by Taylor (2000). Habitat information (slope, aspect, vegetation) has been recorded for each transect and a quantitative survey of the extent of different habitat types over the entire area were completed during the 2011 field season to allow a more robust population estimate to be calculated, based on burrow densities in different habitat types.

6.4.1.8 GREY PETREL ON ANTIPODES ISLANDS

A 2-year study of grey petrels (*Procellaria cinerea*) on Antipodes Island commenced during 2009 and was completed during the period 19 March – 30 April 2010. The objectives of the grey petrel field work were:

- to estimate the population trend from mark-recapture analysis in the study areas;
- to determine foraging location and activity; and
- to estimate the total island population by examining burrow occupancy in a range of habitats.

In 2009, a total of 69 burrows in Alert Bay, the Crater and Crater Ridge containing grey petrels were marked as study burrows (Sommer et al 2009). In addition, 64 grey petrel burrows within the white-chinned petrel study areas were used as study burrows (Sommer et al 2010).

To establish the foraging distribution of grey petrels, 27 geolocation dataloggers were deployed on breeding grey petrels in 2009 (Sommer et al 2009). Eighteen of the 27 geolocators deployed were subsequently retrieved, although one datalogger had dislodged from the attachment to the petrel. Data from the geolocators are being processed by the British Antarctic Survey (Sommer et al 2010).

Occupancy transects were carried out after peak egg-laying in the study burrows. Because of the short daylight hours at this time of year transects were limited to the northern half of the island. Transects were conducted in all habitat types on the coastal and inland slopes. A few transects were also done on the flatter ground more usually associated with white-chinned petrels. Transects were mapped and measured by recording the position of the start and end of each transect as well as each burrow with a hand held GPS.

Sommer et al (2010) estimated a breeding population of 48 960 pairs (96 pairs.ha^{-1} over 510 ha of suitable habitat). Although two seasons of field work on grey petrels is insufficient to allow an assessment of population trend over this period, a comparison of population trend is possible with reference to the earlier study of Bell (2002) who reported a mean of 104 occupied grey petrel burrows ha^{-1} from a survey completed during April-June 2001. Assuming the same 510 ha of suitable habitat on Antipodes Island, Bell estimated a breeding population of 53 040 pairs, similar to Sommer et al's (2010) estimate.

6.4.1.9 FLESH-FOOTED SHEARWATER

Flesh-footed shearwaters, *Puffinus carneipes*, breed around Australia and New Zealand and migrate to the northern hemisphere in the non-breeding season. In New Zealand, they nest in burrows on islands around the North Island and in Cook Strait. Of the breeding sites identified by DOC staff (G. Taylor unpublished, cited in Baker et al in prep) eight major breeding islands for the flesh-footed shearwater were chosen for re-survey: Lady Alice, West Chicken, Whatupuke and Coppermine (Hen and Chickens Group); Green (Mercury Group), Ohinau (Ohena Sub Group of Mercury Group), Karewa (Bay of Plenty) and Titi (Cook Strait). In addition, it is estimated that Middle Island (Mercury Group) held approximately 3000 pairs in 2003 (Waugh & Taylor 2012).

Baker & Double (2007) designed a survey methodology for estimating population size and assessing long-term trends for the flesh-footed shearwater. Surveys using this design were undertaken at the eight major breeding areas by Baker et al (2008b, 2009b, 2010b, in prep.). Field work was focussed on visiting all of the eight sites at least once during the 5 years of the study to estimate the number of pairs breeding at each site. A few sites were visited annually to estimate population trends. Baker et al (2008b, 2009b, 2010b, in prep.) searched these sites by locating ridgelines and systematically searching from the ridgeline to the sea or, where unsuitable terrain such as a cliff was encountered, using a series of 2 m-wide search transects. These search transects were established by following a compass bearing downhill from the ridgeline. When potential burrows were located, their location of that colony from the start point of the search transect was recorded, and the number of potential burrows subsequently found 1 m either side of the transect line counted. At some sites, colony transects were well marked to permit follow-up surveys in future years. The origin points for transects were randomly located along a central line or 'backbone' which was run through the colony. In practice, most colonies were centred on ridgelines or located on steep slopes, and the backbone was located along a ridgeline.

All colony areas, with the exception of those on Karewa, were mapped by using transect data and a hand-held GPS. On Karewa Island, the sensitive nature of the substrate meant that sampling was curtailed to working from boards laid on the surface along a sandy track used by DOC for park management purposes. This access point was used as a long transect, with other shorter transects established either side as permitted by the terrain encountered.

The density of potential burrows was scaled up to the estimated area of each colony to derive an estimate of the number of burrows for each colony (Table 6.9). Baker et al (in prep) estimate the total count of burrows on the eight islands surveyed to be 20 945 (95% c.i., 19 019 – 22 871), notably fewer than Taylor's (2000) estimate of 25 000–50 000 pairs. Baker et al (in prep) state that their estimates generally accord with the indicative population estimates developed by Graeme Taylor (cited in Baker et al in prep.) with the exception of that for Coppermine and Ohinau Islands. Baker et al's (in prep.) estimate of 1425 occupied burrows (1059–1791) for Coppermine is much lower than Taylor's indicative estimate of 10 000 (presumably breeding pairs). In contrast, Baker et al's (in prep.) estimate of 2071 occupied burrows (943–3200) for Ohinau greatly exceeds Taylor's indicative estimate.

Table 6.9: (from Baker et al in prep.) Estimated number of potential and occupied burrows for eight New Zealand islands surveyed 2007/08 to 2010/11. Note that some colonies on Lady Alice and Coppermine were visited in all years, and for these colonies the highest estimate was used to derive the island total. The number of occupied burrows can reasonably be considered an estimate of annual breeding pairs for each island.

Island	No. Potential burrows	Lower 95% CI	Upper 95% CI	No. Occupied burrows	Lower 95% CI	Upper 95% CI
West Chicken	193	-2	388	15	0	210
Lady Alice	2 763	2 079	3 447	921	237	1 605
Whatupuke	2 941	1 767	4 115	1 210	36	2 384
Coppermine	2 290	1 924	2 656	1 425	1 059	1 791
Titi	2 814	2 201	3 427	337	0	950
Green	132	82	182	74	24	124
Ohinau	3 883	2 755	5 011	2 071	943	3 200
Karewa	5 929	4 420	7 438	2 561	1 052	4 070
Total	20 945	19 019	22 871	8 614	6 689	10 540

Waugh et al (2014) assessed the feasibility of gaining improved estimates of key flesh-footed shearwater population parameters and investigated the at-sea distribution of flesh-footed shearwaters. Study plots were established at Lady Alice/Mauimua, Titi Island and Ohinau Island, with burrow mapping by GPS and hand-drawn maps. The occupancy of burrows and size of breeding population at each colony was assessed. Occupancy as assessed by burrow-scoping and through inspection of burrow contents through study hatches.

Analysis of island-wide population survey information, collected from 2011-12 to 2013-14 compared with previous surveys conducted from 2007-2010 (Baker et al 2008b, 2009b, 2010b, in prep) indicated a probable decline for the population on Ohinau Island, and stable populations on Lady Alice Island/Mauimua and Titi Island. Adult annual survival was within the range reported for other shearwaters, at 0.93 for Kauwahaia Island and 0.94 for burrow-caught birds at Lady Alice/Mauimua (Waugh et al 2014).

Tracking of flesh-footed shearwaters using GPS loggers showed that birds were foraging several hundreds of kilometres from their breeding site over deep oceanic waters to the east of the New Zealand region during incubation. During early chick-rearing period, the flesh-footed shearwaters contracted their range with a higher concentration of activity in waters near the breeding site and at zones of upwelling and relative high productivity within 400 km of the breeding site. The overlap of foraging activity with trawl, longline and gillnet fisheries indicated highest intensity of overlap when the breeding birds were foraging close to the breeding site during early chick rearing (Waugh et al 2014).

6.4.1.10 WESTLAND PETREL

The Westland petrel, *Procellaria westlandica*, is endemic to New Zealand and nests in burrows in dense rainforest near Punakaiki, Westland. This species is poorly studied, probably largely because they nest in burrows, inhabit dense forest, and attend their nests only at night. As for the flesh-footed shearwater a survey methodology for estimating population size and assessing long-term trends for the Westland petrel was designed (Baker & Double 2007). Once a colony was located, Baker et al (2007b, 2008c, 2011b) estimated population size through a three stage process. First, burrow densities were determined in each colony by using 2 m-wide strip 'colony transects', and mapped burrows along each transect. These transects differed from search transects in that they were confined to identified colonies and were randomly placed within the colonies. Second, the proportion of active nests per burrow was estimated using burrow scopes and 'inspection by hand' (inserting an arm down burrows to determine occupancy and feel for eggs, chicks, adult birds or nesting material). Finally, the area of each colony was measured by exploring the approximate boundaries on foot and mapping the densely-inhabited area and this area multiplied by the density to arrive at a population estimate for each colony.

Although Westland petrels breed throughout a 16 square kilometre area near Punakaiki, which has been designated as a Special Conservation Area, sampling effort was concentrated on estimating the population in high density areas, noting the challenges posed by the rugged terrain and often adverse weather conditions (Baker et al 2007b, 2008c, 2011b). Baker et al (2007b, 2008c, 2011b) estimated the number of potential burrows in all Westland petrel colonies to total 6846 (95% c.i. 6389 – 7302) during the period 2007 to 2011. Of these, an estimated 2827 (2143–3510) were occupied. The rugged terrain and inclement weather made it difficult to ensure that the permanent transects were replicated exactly each year and hence raises some doubts about the comparability of counts.

6.4.2 QUANTIFYING FISHERIES INTERACTIONS

Information with which to characterise seabird interactions with fisheries comes from a variety of sources. Some is opportunistically collected, whilst other information collection is targeted at specifically describing the nature and extent of seabird captures in fisheries. This section is focussed on the targeted information collection.

Many New Zealand commercial fisheries have MPI observer coverage, much of which is funded by DOC's CSP programme (e.g., Rowe 2009, 2010, Ramm 2011, 2012). Observers collect independent data on the number of captures of seabirds, the number of fishing events observed, and at-sea identification of the seabirds for these fisheries. Commercial fishers are legally required to provide effort data allowing estimation of the total number of fishing events in a fishery. In combination these data have been used for many years to assess the nature and extent of seabird captures in fisheries (e.g., Abraham et al 2010b, Abraham & Thompson 2009a, 2010, 2011a, b, Ayers et al 2004, Baird 1994, 1995, 1996, 1997, 1999, 2000a, b, 2001a, b, 2003, 2004 a–c, 2005, Baird et al 1998, 1999, Baird & Griggs 2004, Thompson & Abraham 2009). In this context, "captures" include all seabirds observed by an observer to be brought on-board a fishing vessel, whether reported as live or dead, but exclude non-fishing-related events (e.g., birds striking the superstructure and landing on deck) and decomposed carcasses. Specimens and photographs (especially for birds released alive) are also collected allowing verification of at-sea identifications (from carcasses or photographs) and description of biological characters (sex, age, condition, etc., available only from carcasses).

In some fisheries observer data are temporally and spatially well stratified, whilst in others data are only available from a spatially select part of the fishery, or a limited part of the year. Where sufficient observer data are available, estimates of total seabird captures in the fishery are calculated. The methods currently used in estimating seabird captures in New Zealand fisheries are described in Abraham & Thompson (2011a). In this context, captures include all seabirds recovered on a fishing vessel except birds that simply land on the deck or collide with a vessel's superstructure, decomposing animals, records of tissue fragments, and birds caught during trips carried out under special permit (e.g., for trials of mitigation methods). Observer coverage has been highly heterogeneous in that some fisheries and areas have had much higher coverage than others. This complicates estimation of the total number of seabirds captured, especially when estimates include more than one fishery, because the distribution of birds and captures is also heterogeneous (Figure 6.6).

Fisher-reported captures (on NFPSCR forms available since 1 October 2008) have not been used to estimate total captures because the reported capture rates are much lower than those reported by independent observers (Abraham & Thompson 2011b) and the species identification is less certain.

Abraham & Thompson (2011a) made model-based estimates of captures in New Zealand trawl and longline fisheries for the following taxa or groups: sooty shearwater (*Puffinus griseus*); white-chinned petrel (*Procellaria aequinoctialis*); white-capped albatross (*Thalassarche steadi*); Salvin's albatross (*Thalassarche salvini*); southern Buller's albatross (*Thalassarche bulleri*); other albatrosses; and all other birds. The five individual species were chosen because they are the most frequently caught in trawl and longline fisheries. Captures of other albatrosses are mostly Gibson's or Antipodean wandering albatrosses or Campbell Island albatrosses. The 'other birds' category includes many taxa but grey, black, great-winged, and Cape petrels (both sub-species but mostly Southern Cape petrels, *Daption capense capense*), flesh-footed shearwater, and spotted shag are relatively common observed captures (the latter based on few observations that included 31 captures in one event). Estimated captures up to and including the 2012–13 year are shown in Table 6.10 to Table 6.15.

Observed captures of seabirds in trawl fisheries were most common off both coasts of the South Island, along the Chatham Rise, on the fringes of the Stewart-Snares shelf, and around the Auckland Islands (Figure 6.7). This largely reflects the distribution of the major commercial fisheries for squid, hoki, and middle-depth species which have tended to have relatively high observer coverage. White-capped, Salvin's, and southern Buller's have been the most frequently observed captured albatrosses, and sooty shearwater and white chinned petrel have been the other species most frequently observed (Table 6.16). About 41% of observed captures were albatrosses.

Observed captures of seabirds in surface longline fisheries were most common off the southwest coast of the South Island and the northeast coast of the North Island (Figure 6.8), again largely reflecting the distribution of the major commercial fisheries (for southern bluefin and other tunas). The charter fleet targeting tuna has historically had much higher observer coverage than the domestic fleet. Southern Buller's and white-capped have been the most frequently observed captured albatrosses, and grey, white-chinned, and black petrels have been the other species most frequently observed (Table 6.17). About 80% of observed captures were albatrosses.

Observed captures of seabirds in bottom longline fisheries were most common off the south coast of the South Island, along the Chatham Rise, scattered throughout the Sub-Antarctic, and off the northeast coast of the North Island, especially around the Hauraki Gulf (Figure 6.9). This distribution largely reflects the distribution of the ling and snapper longline fisheries that have received most observer coverage; other bottom longline fisheries have had much less coverage. Salvin's and Chatham have been the most frequently observed captured albatrosses, and white chinned petrel, grey petrel, sooty shearwater, and black petrels have been the other species most frequently observed (Table 6.18). Only about 15% of observed captures were albatrosses.

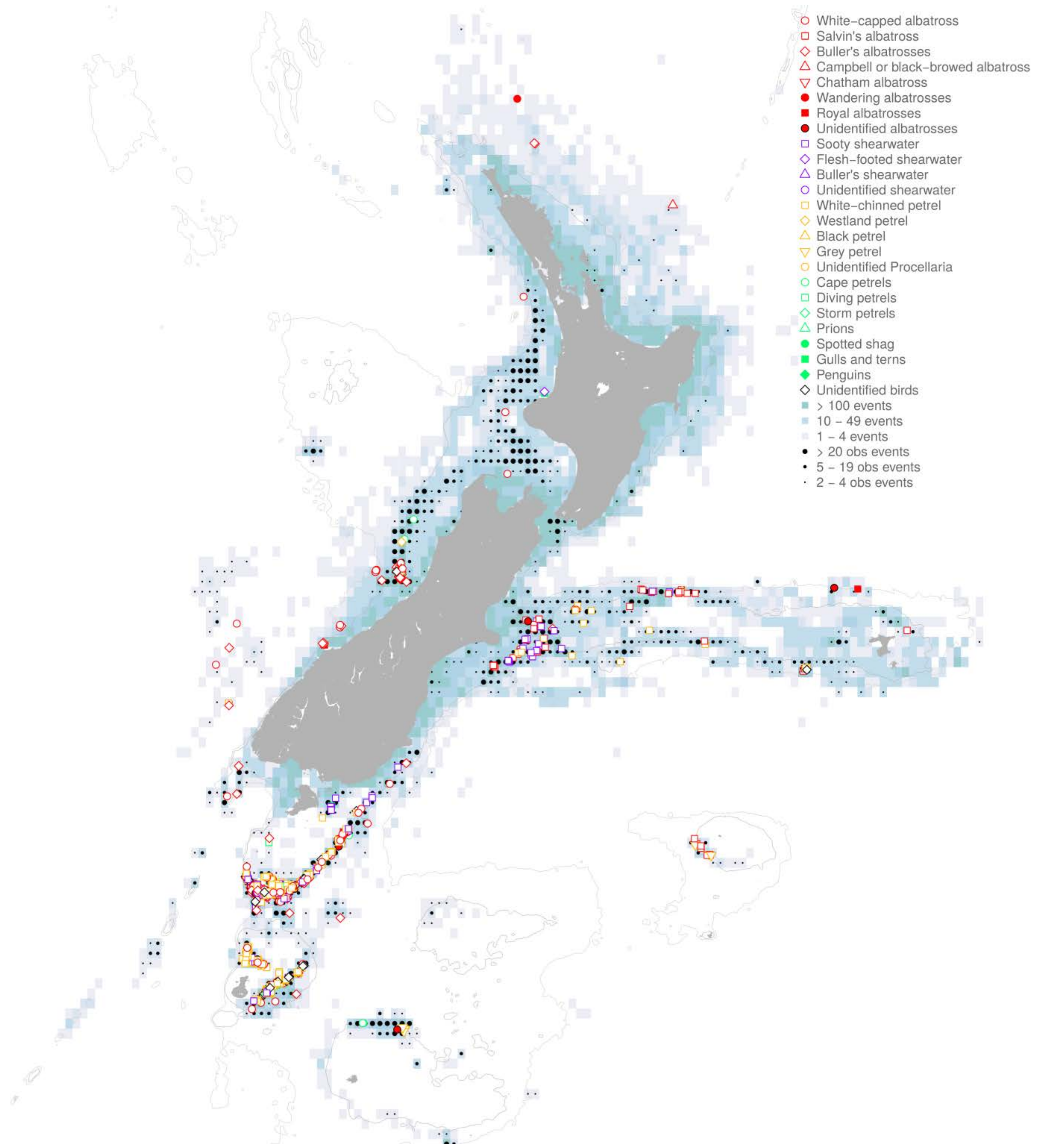


Figure 6.6: All observed seabird captures in trawl, surface longline, and bottom longline fishing within the New Zealand region, between October 2012 and September 2013. The colour within each 0.2 degree cell indicates the number of fishing events (tows and sets, darker colours indicate more fishing) and the black dots indicate the number of observed events (larger dots indicate more observations). The coloured symbols indicate the location of observed seabird captures, randomly jittered by 0.2 degrees. The 500 m and 1000 m depth contours are shown. Data version v20140131.

Table 6.10: Summary of observed and model-estimated total captures of all seabirds combined by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2012–13. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. Data version v20140131.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002/03	130 174	6 838	5.3	269	3.93	3311	2 540–4 449	100.0	2.54
2003/04	120 868	6 547	5.4	262	4.00	2763	2 138–3 664	100.0	2.29
2004/05	120 438	7 710	6.4	483	6.26	4509	3 466–6 089	100.0	3.74
2005/06	109 923	6 619	6.0	356	5.38	3585	2 779–4 630	100.0	3.26
2006/07	103 306	7 930	7.7	211	2.66	2310	1 774–3 035	100.0	2.24
2007/08	89 524	9 048	10.1	234	2.59	1868	1 476–2 385	100.0	2.09
2008/09	87 548	9 804	11.2	469	4.78	2460	2 039–3 033	100.0	2.81
2009/10	92 888	9 008	9.7	258	2.86	2023	1 592–2 674	100.0	2.18
2010/11	86 090	7 443	8.6	362	4.86	2468	1 990–3 121	100.0	2.87
2011/12	84 429	9 085	10.8	248	2.73	1863	1 480–2 387	100.0	2.21
2012/13	83 722	12 393	14.8	709	5.72	2604	2 055–3 465	100.0	3.11
Surface longline									
2002/03	10 772 188	2 195 152	20.4	115	0.05	2 088	1 613–2 807	100.0	0.019
2003/04	7 386 329	1 607 304	21.8	71	0.04	1 395	1 086–1 851	100.0	0.019
2004/05	3 679 765	783 812	21.3	41	0.05	617	483–793	100.0	0.017
2005/06	3 690 119	705 945	19.1	37	0.05	808	611–1 132	100.0	0.022
2006/07	3 739 912	1 040 948	27.8	187	0.18	958	736–1 345	100.0	0.026
2007/08	2 246 189	421 900	18.8	37	0.09	524	417–676	100.0	0.023
2008/09	3 115 633	937 496	30.1	57	0.06	609	493–766	100.0	0.020
2009/10	2 995 264	665 883	22.2	135	0.20	939	749–1 216	100.0	0.031
2010/11	3 187 879	674 572	21.2	47	0.07	705	532–964	100.0	0.022
2011/12	3 100 277	728 190	23.5	64	0.09	829	617–1 161	100.0	0.027
2012/13	2 862 182	560 333	19.6	27	0.05	783	567–1 144	100.0	0.027
Bottom longline									
2002/03	37 761 838	10 774 720	28.5	298	0.03	1 881	1 423–2 390	100.0	0.005
2003/04	43 225 599	5 050 557	11.7	54	0.01	1 219	844–1 632	100.0	0.003
2004/05	41 844 688	2 883 725	6.9	30	0.01	1 338	931–1 794	100.0	0.003
2005/06	37 141 633	3 802 951	10.2	41	0.01	1 133	800–1 505	100.0	0.003
2006/07	38 149 420	2 315 772	6.1	58	0.03	1 598	1 071–2 305	100.0	0.004
2007/08	41 507 547	3 589 511	8.6	40	0.01	1 443	1 020–1 921	100.0	0.003
2008/09	37 426 952	4 028 816	10.8	33	0.01	1 245	870–1 658	100.0	0.003
2009/10	40 440 801	2 272 873	5.6	68	0.03	1 214	856–1 604	100.0	0.003
2010/11	40 904 091	1 732 535	4.2	29	0.02	1 451	1 021–1 914	100.0	0.004
2011/12	37 877 121	2 100 831	5.5	10	0.00	1 135	772–1 530	100.0	0.003
2012/13	32 525 173	387 238	1.2	2	0.01	991	666–1 349	100.0	0.003

Table 6.11: Summary of observed and model-estimated total captures of white-capped albatross by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2012–13. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. Data version v20140131.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002/03	130 174	6 838	5.3	85	1.24	860	645–1 096	100.0	0.66
2003/04	120 868	6 547	5.4	148	2.26	948	752–1 192	100.0	0.78
2004/05	120 438	7 710	6.4	243	3.15	1 228	1 003–1 549	100.0	1.02
2005/06	109 923	6 619	6.0	69	1.04	643	478–845	100.0	0.58
2006/07	103 306	7 930	7.7	57	0.72	510	369–689	100.0	0.49
2007/08	89 524	9 048	10.1	42	0.46	358	238–500	100.0	0.40
2008/09	87 548	9 804	11.2	97	0.99	477	365–624	100.0	0.54
2009/10	92 888	9 008	9.7	48	0.53	414	293–568	100.0	0.45
2010/11	86 090	7 443	8.6	41	0.55	390	271–541	100.0	0.45
2011/12	84 429	9 085	10.8	67	0.74	441	322–602	100.0	0.52
2012/13	83 722	12 393	14.8	119	0.96	454	337–611	100.0	0.54
Surface longline									
2002/03	10 772 188	2 195 152	20.4	2	0.00	74	46–104	100.0	0.001
2003/04	7 386 329	1 607 304	21.8	17	0.01	136	94–186	100.0	0.002
2004/05	3 679 765	783 812	21.3	3	0.00	60	37–88	100.0	0.002
2005/06	3 690 119	705 945	19.1	2	0.00	37	21–57	100.0	0.001
2006/07	3 739 912	1 040 948	27.8	28	0.03	41	32–53	100.0	0.001
2007/08	2 246 189	421 900	18.8	4	0.01	54	34–79	100.0	0.002
2008/09	3 115 633	937 496	30.1	3	0.00	76	50–108	100.0	0.002
2009/10	2 995 264	665 883	22.2	31	0.05	155	111–206	100.0	0.005
2010/11	3 187 879	674 572	21.2	3	0.00	54	35–78	100.0	0.002
2011/12	3 100 277	728 190	23.5	8	0.01	134	88–187	100.0	0.004
2012/13	2 862 182	560 333	19.6	12	0.02	83	54–121	100.0	0.003
Bottom longline									
2002/03	37 761 838	10 774 720	28.5	0	0.00	10	2–25	100.0	0.000
2003/04	43 225 599	5 050 557	11.7	1	0.00	14	4–32	100.0	0.000
2004/05	41 844 688	2 883 725	6.9	0	0.00	23	6–51	100.0	0.000
2005/06	37 141 633	3 802 951	10.2	1	0.00	20	6–45	100.0	0.000
2006/07	38 149 420	2 315 772	6.1	0	0.00	24	6–57	100.0	0.000
2007/08	41 507 547	3 589 511	8.6	0	0.00	34	8–78	100.0	0.000
2008/09	37 426 952	4 028 816	10.8	0	0.00	26	6–58	100.0	0.000
2009/10	40 440 801	2 272 873	5.6	0	0.00	28	7–62	100.0	0.000
2010/11	40 904 091	1 732 535	4.2	0	0.00	28	6–65	100.0	0.000
2011/12	37 877 121	2 100 831	5.5	2	0.00	26	7–57	100.0	0.000
2012/13	32 525 173	387 238	1.2	0	0.00	21	4–48	100.0	0.000

Table 6.12: Summary of observed and model-estimated total captures of Salvin's albatross by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2012–13. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. Data version v20140131.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002/03	130 174	6 838	5.3	24	0.35	360	166–685	100.0	0.28
2003/04	120 868	6 547	5.4	11	0.17	383	162–768	100.0	0.32
2004/05	120 438	7 710	6.4	37	0.48	1052	496–2 160	100.0	0.87
2005/06	109 923	6 619	6.0	9	0.14	450	190–859	100.0	0.41
2006/07	103 306	7 930	7.7	14	0.18	376	170–720	100.0	0.36
2007/08	89 524	9 048	10.1	11	0.12	200	91–381	100.0	0.22
2008/09	87 548	9 804	11.2	36	0.37	355	207–586	100.0	0.41
2009/10	92 888	9 008	9.7	40	0.44	289	173–478	100.0	0.31
2010/11	86 090	7 443	8.6	20	0.27	350	176–652	100.0	0.41
2011/12	84 429	9 085	10.8	24	0.26	318	164–577	100.0	0.38
2012/13	83 722	12 393	14.8	47	0.38	387	212–685	100.0	0.46
Surface longline									
2002/03	10 772 188	2 195 152	20.4	1	0.00	44	20–77	100.0	0.000
2003/04	7 386 329	1 607 304	21.8	0	0.00	25	10–46	100.0	0.000
2004/05	3 679 765	783 812	21.3	1	0.00	15	5–27	100.0	0.000
2005/06	3 690 119	705 945	19.1	0	0.00	15	5–28	100.0	0.000
2006/07	3 739 912	1 040 948	27.8	1	0.00	26	6–28	100.0	0.001
2007/08	2 246 189	421 900	18.8	1	0.00	12	4–22	100.0	0.001
2008/09	3 115 633	937 496	30.1	3	0.00	15	7–26	100.0	0.000
2009/10	2 995 264	665 883	22.2	1	0.00	15	5–28	100.0	0.001
2010/11	3 187 879	674 572	21.2	0	0.00	16	6–30	100.0	0.001
2011/12	3 100 277	728 190	23.5	1	0.00	15	5–27	100.0	0.000
2012/13	2 862 182	560 333	19.6	0	0.00	11	3–23	100.0	0.000
Bottom longline									
2002/03	37 761 838	10 774 720	28.5	15	0.00	122	74–208	100.0	0.000
2003/04	43 225 599	5 050 557	11.7	10	0.00	109	63–191	100.0	0.000
2004/05	41 844 688	2 883 725	6.9	0	0.00	125	56–255	100.0	0.000
2005/06	37 141 633	3 802 951	10.2	1	0.00	106	46–218	100.0	0.000
2006/07	38 149 420	2 315 772	6.1	22	0.01	149	78–276	100.0	0.000
2007/08	41 507 547	3 589 511	8.6	0	0.00	128	56–262	100.0	0.000
2008/09	37 426 952	4 028 816	10.8	1	0.00	126	56–249	100.0	0.000
2009/10	40 440 801	2 272 873	5.6	0	0.00	118	53–230	100.0	0.000
2010/11	40 904 091	1 732 535	4.2	2	0.00	133	56–275	100.0	0.000
2011/12	37 877 121	2 100 831	5.5	0	0.00	113	48–230	100.0	0.000
2012/13	32 525 173	387 238	1.2	0	0.00	88	33–190	100.0	0.000

Table 6.13: Summary of observed and model-estimated total captures of southern Buller's albatross by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2012–13. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. Data version v20140131.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002/03	130 174	6 838	5.3	6	0.09	67	29–129	100.0	0.05
2003/04	120 868	6 547	5.4	9	0.14	89	41–178	100.0	0.07
2004/05	120 438	7 710	6.4	24	0.31	200	108–386	100.0	0.17
2005/06	109 923	6 619	6.0	9	0.14	87	43–155	100.0	0.08
2006/07	103 306	7 930	7.7	5	0.06	53	23–102	100.0	0.05
2007/08	89 524	9 048	10.1	18	0.20	97	57–161	100.0	0.11
2008/09	87 548	9 804	11.2	18	0.18	83	50–136	100.0	0.09
2009/10	92 888	9 008	9.7	11	0.12	63	32–110	100.0	0.07
2010/11	86 090	7 443	8.6	20	0.27	98	58–158	100.0	0.11
2011/12	84 429	9 085	10.8	36	0.40	156	99–248	100.0	0.18
2012/13	83 722	12 393	14.8	57	0.46	112	80–174	100.0	0.13
Surface longline									
2002/03	10 772 188	2 195 152	20.4	41	0.02	305	236–385	100.0	0.003
2003/04	7 386 329	1 607 304	21.8	39	0.02	211	163–265	100.0	0.003
2004/05	3 679 765	783 812	21.3	21	0.03	107	80–138	100.0	0.003
2005/06	3 690 119	705 945	19.1	14	0.02	109	81–143	100.0	0.003
2006/07	3 739 912	1 040 948	27.8	49	0.05	168	135–209	100.0	0.004
2007/08	2 246 189	421 900	18.8	21	0.05	108	80–143	100.0	0.005
2008/09	3 115 633	937 496	30.1	30	0.03	116	90–146	100.0	0.004
2009/10	2 995 264	665 883	22.2	69	0.10	169	139–204	100.0	0.006
2010/11	3 187 879	674 572	21.2	28	0.04	116	89–147	100.0	0.004
2011/12	3 100 277	728 190	23.5	31	0.04	118	91–149	100.0	0.004
2012/13	2 862 182	560 333	19.6	10	0.02	97	70–130	100.0	0.003
Bottom longline									
2002/03	37 761 838	10 774 720	28.5	1	0.00	52	18–105	100.0	0.000
2003/04	43 225 599	5 050 557	11.7	0	0.00	40	13–80	100.0	0.000
2004/05	41 844 688	2 883 725	6.9	0	0.00	83	28–165	100.0	0.000
2005/06	37 141 633	3 802 951	10.2	0	0.00	72	24–142	100.0	0.000
2006/07	38 149 420	2 315 772	6.1	0	0.00	119	41–240	100.0	0.000
2007/08	41 507 547	3 589 511	8.6	6	0.00	111	40–214	100.0	0.000
2008/09	37 426 952	4 028 816	10.8	0	0.00	84	28–166	100.0	0.000
2009/10	40 440 801	2 272 873	5.6	0	0.00	86	29–173	100.0	0.000
2010/11	40 904 091	1 732 535	4.2	0	0.00	77	26–153	100.0	0.000
2011/12	37 877 121	2 100 831	5.5	3	0.00	59	21–118	100.0	0.000
2012/13	32 525 173	387 238	1.2	0	0.00	49	16–101	100.0	0.000

Table 6.14: Summary of observed and model-estimated total captures of white-chinned petrel by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2012–13. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. Data version v20140131.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002/03	130 174	6 838	5.3	13	0.19	129	69–218	100.0	0.10
2003/04	120 868	6 547	5.4	18	0.27	97	57–153	100.0	0.08
2004/05	120 438	7 710	6.4	55	0.71	221	153–319	100.0	0.18
2005/06	109 923	6 619	6.0	70	1.06	359	239–529	100.0	0.33
2006/07	103 306	7 930	7.7	29	0.37	140	84–220	100.0	0.14
2007/08	89 524	9 048	10.1	59	0.65	252	174–363	100.0	0.28
2008/09	87 548	9 804	11.2	104	1.06	305	227–411	100.0	0.35
2009/10	92 888	9 008	9.7	74	0.82	288	198–415	100.0	0.31
2010/11	86 090	7 443	8.6	130	1.75	454	324–643	100.0	0.53
2011/12	84 429	9 085	10.8	58	0.64	222	152–324	100.0	0.26
2012/13	83 722	12 393	14.8	276	2.23	372	328–437	100.0	0.44
Surface longline									
2002/03	10 772 188	2 195 152	20.4	4	0.00	89	51–137	100.0	0.001
2003/04	7 386 329	1 607 304	21.8	2	0.00	59	32–93	100.0	0.001
2004/05	3 679 765	783 812	21.3	3	0.00	33	18–53	100.0	0.001
2005/06	3 690 119	705 945	19.1	1	0.00	34	17–55	100.0	0.001
2006/07	3 739 912	1 040 948	27.8	5	0.00	33	19–50	100.0	0.001
2007/08	2 246 189	421 900	18.8	4	0.01	24	13–38	100.0	0.001
2008/09	3 115 633	937 496	30.1	3	0.00	29	16–46	100.0	0.001
2009/10	2 995 264	665 883	22.2	3	0.00	28	15–44	100.0	0.001
2010/11	3 187 879	674 572	21.2	8	0.01	37	22–56	100.0	0.001
2011/12	3 100 277	728 190	23.5	4	0.01	29	16–46	100.0	0.001
2012/13	2 862 182	560 333	19.6	1	0.00	24	12–40	100.0	0.001
Bottom longline									
2002/03	37 761 838	10 774 720	28.5	132	0.01	494	338–708	100.0	0.001
2003/04	43 225 599	5 050 557	11.7	15	0.00	228	125–374	100.0	0.001
2004/05	41 844 688	2 883 725	6.9	11	0.00	272	139–472	100.0	0.001
2005/06	37 141 633	3 802 951	10.2	13	0.00	238	127–391	100.0	0.001
2006/07	38 149 420	2 315 772	6.1	12	0.01	461	203–1 056	100.0	0.001
2007/08	41 507 547	3 589 511	8.6	10	0.00	387	197–714	100.0	0.001
2008/09	37 426 952	4 028 816	10.8	1	0.00	304	146–532	100.0	0.001
2009/10	40 440 801	2 272 873	5.6	1	0.00	235	117–396	100.0	0.001
2010/11	40 904 091	1 732 535	4.2	24	0.01	422	243–666	100.0	0.001
2011/12	37 877 121	2 100 831	5.5	1	0.00	227	108–388	100.0	0.001
2012/13	32 525 173	387 238	1.2	0	0.00	190	88–347	100.0	0.001

Table 6.15: Summary of observed and model-estimated total captures of sooty shearwaters by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2012–13. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. Data version v20140131.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002/03	130 174	6 838	5.3	120	1.75	1 205	726–2 013	100.0	0.93
2003/04	120 868	6 547	5.4	54	0.82	508	283–904	100.0	0.42
2004/05	120 438	7 710	6.4	74	0.96	642	378–1 097	100.0	0.53
2005/06	109 923	6 619	6.0	169	2.55	1 315	819–2 085	100.0	1.20
2006/07	103 306	7 930	7.7	84	1.06	659	399–1 062	100.0	0.64
2007/08	89 524	9 048	10.1	82	0.91	523	330–835	100.0	0.58
2008/09	87 548	9 804	11.2	152	1.55	631	435–931	100.0	0.72
2009/10	92 888	9 008	9.7	43	0.48	260	156–420	100.0	0.28
2010/11	86 090	7 443	8.6	109	1.46	573	373–895	100.0	0.67
2011/12	84 429	9 085	10.8	31	0.34	214	121–376	100.0	0.25
2012/13	83 722	12 393	14.8	110	0.89	321	212–518	100.0	0.38
Surface longline									
2002/03	10 772 188	2 195 152	20.4	8	0.00	15	8–30	100.0	0.000
2003/04	7 386 329	1 607 304	21.8	3	0.00	6	3–18	100.0	0.000
2004/05	3 679 765	783 812	21.3	0	0.00	2	0–8	100.0	0.000
2005/06	3 690 119	705 945	19.1	0	0.00	2	0–8	100.0	0.000
2006/07	3 739 912	1 040 948	27.8	2	0.00	4	2–9	100.0	0.000
2007/08	2 246 189	421 900	18.8	0	0.00	1	0–6	100.0	0.000
2008/09	3 115 633	937 496	30.1	0	0.00	2	0–7	100.0	0.000
2009/10	2 995 264	665 883	22.2	0	0.00	1	0–7	100.0	0.000
2010/11	3 187 879	674 572	21.2	0	0.00	2	0–8	100.0	0.000
2011/12	3 100 277	728 190	23.5	0	0.00	1	0–7	100.0	0.000
2012/13	2 862 182	560 333	19.6	0	0.00	1	0–6	100.0	0.000
Bottom longline									
2002/03	37 761 838	10 774 720	28.5	32	0.00	82	45–160	100.0	0.000
2003/04	43 225 599	5 050 557	11.7	17	0.00	59	25–136	100.0	0.000
2004/05	41 844 688	2 883 725	6.9	3	0.00	66	18–166	100.0	0.000
2005/06	37 141 633	3 802 951	10.2	3	0.00	31	5–96	100.0	0.000
2006/07	38 149 420	2 315 772	6.1	1	0.00	37	5–110	100.0	0.000
2007/08	41 507 547	3 589 511	8.6	6	0.00	49	16–116	100.0	0.000
2008/09	37 426 952	4 028 816	10.8	0	0.00	41	6–119	100.0	0.000
2009/10	40 440 801	2 272 873	5.6	7	0.00	37	9–108	100.0	0.000
2010/11	40 904 091	1 732 535	4.2	0	0.00	45	5–145	100.0	0.000
2011/12	37 877 121	2 100 831	5.5	0	0.00	50	6–153	100.0	0.000
2012/13	32 525 173	387 238	1.2	0	0.00	46	5–145	100.0	0.000

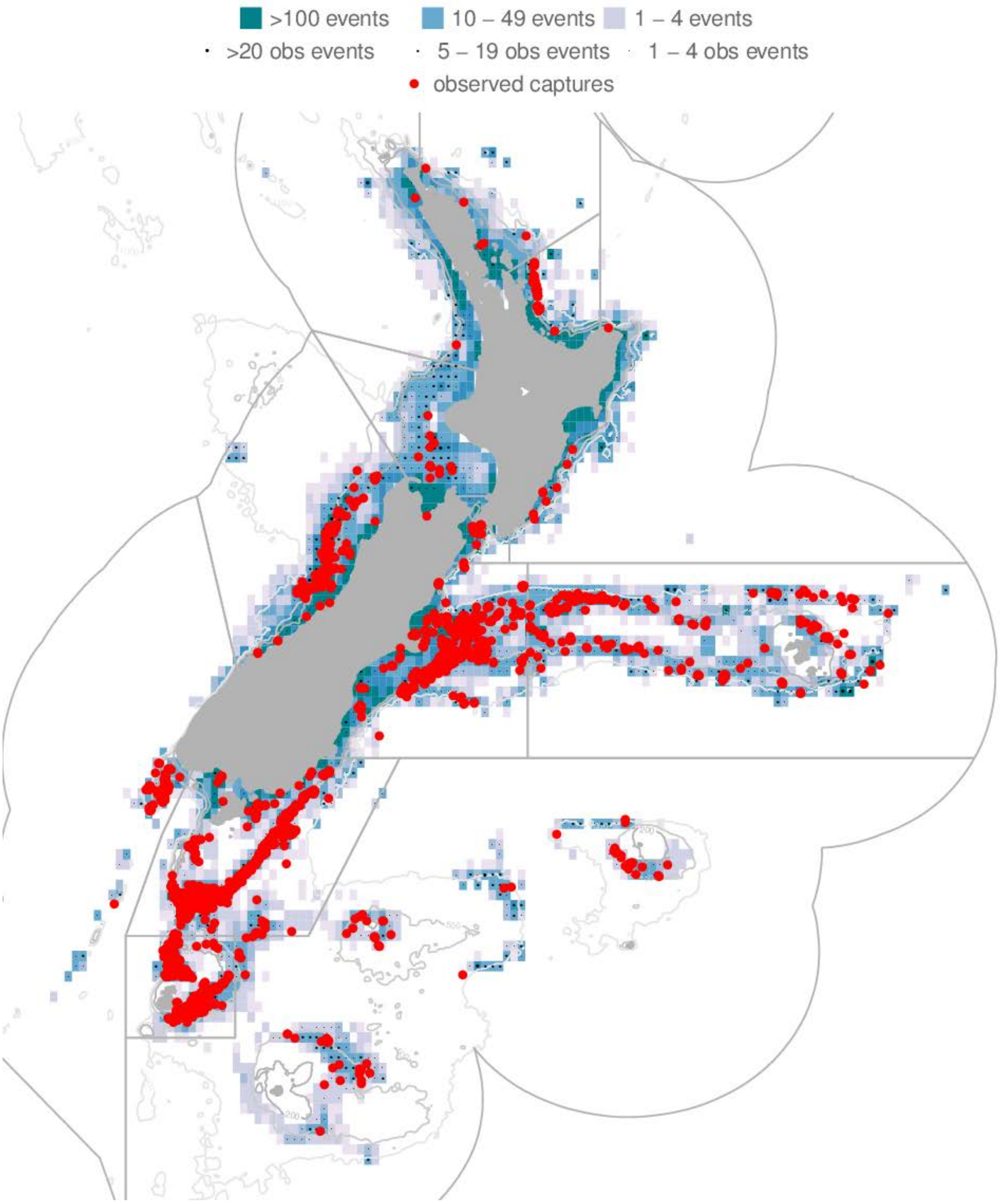


Figure 6.7: Map of trawl fishing effort and all observed seabird captures in trawls, October 2002 to September 2013. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is shown only if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell.

Table 6.16: Summary of seabirds observed captured in trawl fisheries 2002–03 to 2012–13. Declared target species are: SQU, arrow squid; HOK+, hoki, hake, ling; Mid., other middle depth species silver, white, and common warehou, barracouta, alfonsinos, stargazer; SCI, scampi; ORH+, orange roughy and oreos; SBW, southern blue whiting; JMA, Jack mackerels; Ins., other inshore species for which one or more captures have been observed; tarakihi, red cod, spiny dogfish, John dory, snapper; FLA, flatfishes. Data version v20140131.

	Declared target species									
Species or group	SQU	HOK+	Mid.	SCI	ORH+	SBW	JMA	Ins.	FLA	Total
White-capped albatross	792	84	82	19	4	0	9	23	3	1016
Salvin's albatross	22	118	53	32	18	8	0	21	1	273
Southern Buller's albatross	87	83	29	8	3	1	2	0	0	213
Campbell albatross	2	9	0	1	0	2	0	0	0	14
Southern royal albatross	8	1	1	0	1	1	0	0	0	12
Chatham Island albatross	0	0	1	1	8	0	0	0	0	10
Southern black-browed	1	2	0	0	0	0	0	2	0	5
Gibson's albatross	0	0	0	0	1	0	0	0	0	1
Sooty albatross	1	0	0	0	0	0	0	0	0	1
Northern royal albatross	0	0	0	0	1	0	0	0	0	1
Albatross indet.	15	13	4	6	1	3	0	1	0	43
All albatrosses	**928**	**310**	**170**	**67**	**37**	**15**	**11**	**47**	**4**	**1589**
Sooty shearwater	615	208	143	37	4	0	15	5	1	1028
White-chinned petrel	652	60	74	73	1	0	26	0	0	886
Cape petrels	1	42	2	3	19	3	2	0	0	72
Flesh-footed shearwater	0	1	1	35	0	0	0	1	0	38
Grey petrel	1	2	0	0	3	32	0	0	0	38
Spotted shag	0	0	0	0	0	0	0	0	32	32
Westland petrel	0	16	1	0	0	0	1	0	0	18
Common diving petrel	5	4	2	1	2	0	3	0	0	17
Fairy prion	3	5	0	0	0	0	5	0	0	13
Giant petrel	3	4	1	1	1	0	0	0	0	10
Antarctic prion	7	0	0	0	0	0	0	0	0	7
Grey-backed storm petrel	3	1	0	0	0	0	0	0	0	4
Black petrel	0	0	0	1	0	0	0	2	0	3
Fulmar prion	0	0	0	0	0	0	3	0	0	3
White-faced storm petrel	0	0	0	0	2	0	1	0	0	3
Black-bellied storm petrel	1	1	0	0	0	0	0	0	0	2
Black-backed gull	0	0	0	0	0	0	0	0	1	1
Short-tailed shearwater	0	0	1	0	0	0	0	0	0	1
White-headed petrel	1	0	0	0	0	0	0	0	0	1
Other bird indet.	64	13	6	2	0	4	1	2	3	95
All other birds	**1356**	**357**	**231**	**153**	**32**	**39**	**57**	**10**	**37**	**2272**
All observed birds	**2284**	**667**	**401**	**220**	**69**	**54**	**68**	**57**	**41**	**3861**
Approx. proportion obs.	0.26	0.17	0.07	0.09	0.25	0.44	0.34	0.01	0.01	0.08

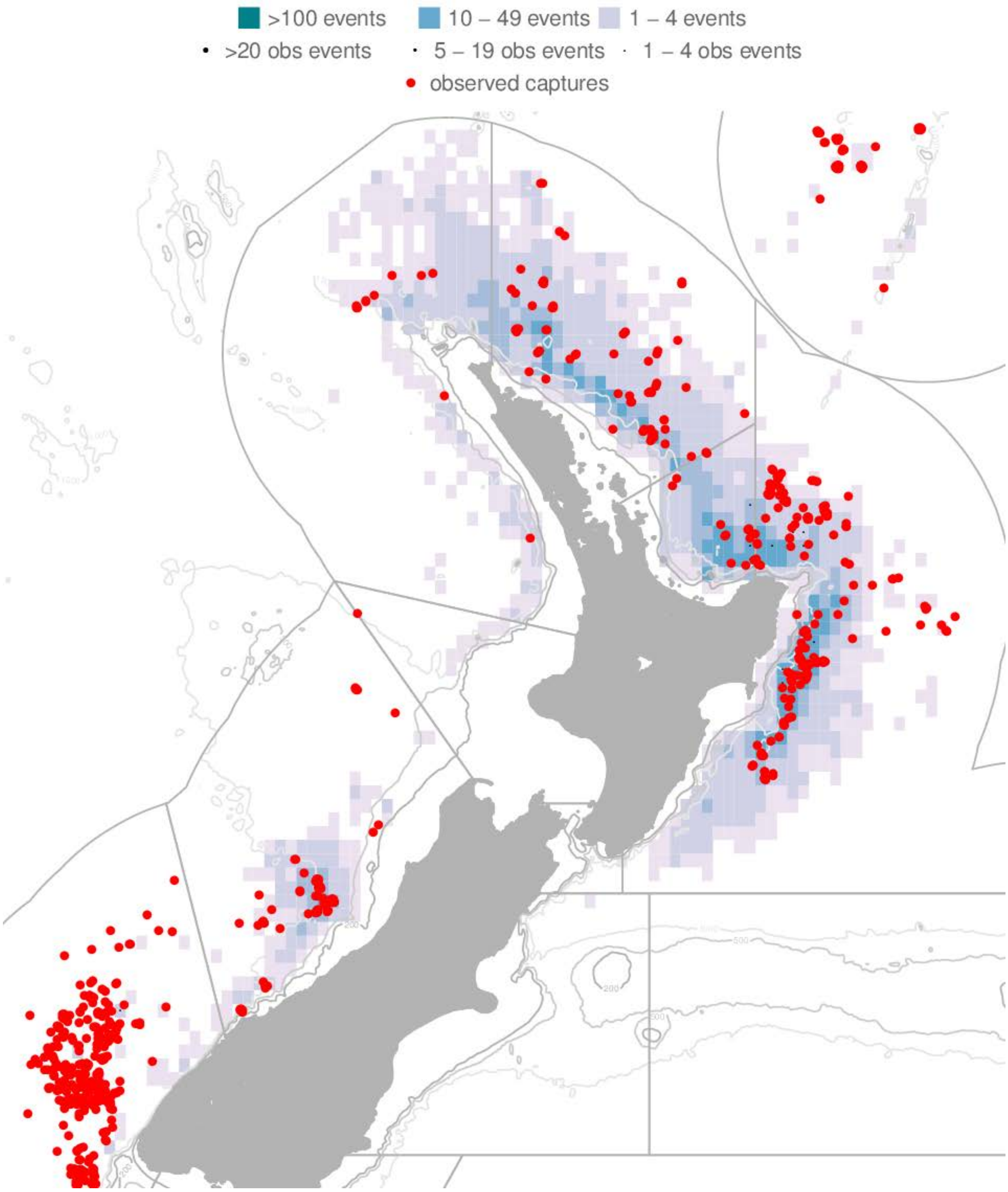


Figure 6.8: Map of surface longline fishing effort and all observed seabird captures by surface longlines, October 2002 to September 2013. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is shown only if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell (here, 89.4% of effort is displayed).

Table 6.17: Summary of seabirds observed captured in surface longline fisheries 2002–03 to 2012–13. Declared target species are: SBT, southern bluefin tuna; BIG, bigeye tuna; SWO, broadbill swordfish; ALB, albacore tuna. Data version v20140131.

Species or group	Declared target species				
	SBT	BIG	SWO	ALB	Total
Southern Buller's albatross	335	9	1	8	353
White-capped albatross	109	1	3	0	113
Campbell albatross	23	3	3	17	46
Gibson's albatross	10	8	10	7	35
Antipodean albatross	6	8	15	3	32
Salvin's albatross	4	4	0	1	9
Southern royal albatross	5	1	0	0	6
Wandering albatross	1	3	0	0	4
Black-browed albatrosses	1	1	2	0	4
Southern black-browed	2	0	0	0	2
Sooty albatross	1	0	0	0	1
Northern Buller's	1	0	0	0	1
Northern royal albatross	0	1	0	0	1
Albatross indet.	8	4	38	0	50
All albatrosses	506	43	72	36	657
Grey petrel	40	0	3	5	48
White-chinned petrel	23	8	5	2	38
Grey-faced petrel	0	1	2	17	20
Black petrel	0	10	2	1	13
Sooty shearwater	4	0	1	8	13
Flesh-footed shearwater	0	11	1	0	12
Westland petrel	6	0	1	2	9
Cape petrels	2	0	0	0	2
Southern giant petrel	2	0	0	0	2
White-headed petrel	0	0	0	2	2
Gadfly petrels	0	1	0	0	1
Other bird indet.	1	0	0	0	1
All other birds	78	31	15	37	161
All observed birds	584	74	87	73	818
Approx. proportion obs.	0.22	0.03	0.1	0.14	0.1

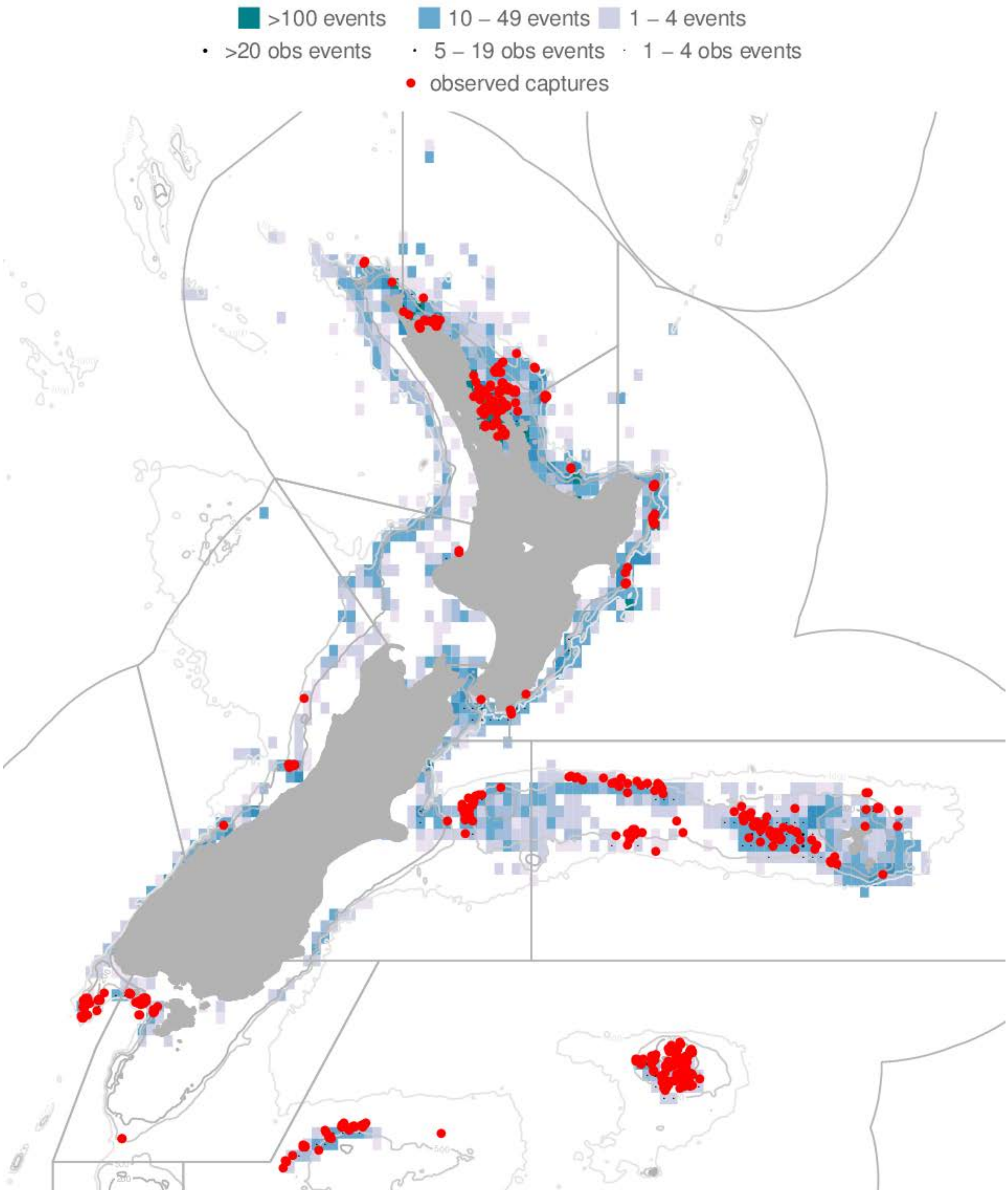


Figure 6.9: Map of bottom longline fishing effort and all observed seabird captures by bottom longlines, October 2002 to September 2013. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is shown only if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell (here, 95.8% of effort is displayed).

Table 6.18: Summary of seabirds observed captured in bottom longline fisheries 2002–03 to 2012–13. Declared target species are: LIN, ling; SNA, snapper; BNS, bluenose; HPB, hapuku or bass. Data version v20140131.

Species or group	Declared target species				
	LIN	SNA	BNS	HPB	Total
Salvin's albatross	51	0	0	0	51
Chatham Island albatross	18	0	0	0	18
Southern Buller's	7	0	3	0	10
White-capped albatross	4	0	0	0	4
Campbell albatross	0	0	2	1	3
Southern royal albatross	3	0	0	0	3
Yellow-nosed albatross	1	0	0	0	1
Black-browed albatrosses	1	0	0	0	1
Albatross indet.	4	0	1	0	5
All albatrosses	**89**	**0**	**6**	**1**	**96**
White-chinned petrel	218	0	2	0	220
Grey petrel	79	0	0	0	79
Sooty shearwater	68	0	0	1	69
Black petrel	0	28	21	16	65
Flesh-footed shearwater	0	37	0	3	40
Cape petrels	24	0	0	0	24
Common diving petrel	23	0	0	0	23
Grey-faced petrel	0	0	0	6	6
Giant petrel	5	0	0	0	5
Fluttering shearwater	0	3	0	0	3
Australasian gannet	0	2	0	0	2
Pied shag	0	2	0	0	2
Broad-billed prion	2	0	0	0	2
Black-backed gull	0	1	0	0	1
Buller's shearwater	0	1	0	0	1
Crested penguins	1	0	0	0	1
Red-billed gull	0	1	0	0	1
Westland petrel	0	0	0	0	0
Other bird indet.	8	10	0	0	18
All other birds	**428**	**85**	**23**	**26**	**562**
All observed birds	**517**	**85**	**29**	**27**	**658**
Approx. proportion obs.	**0.1**	**0.01**	**0.01**	**0.01**	**0.03**

Model-based estimates of captures can be combined across trawl and longline fisheries (Figure 6.10). Summed across all bird taxa, trawl, surface longline, and bottom longline fisheries account for 54%, 19%, and 27% of captures, respectively, but there are substantial differences in these proportions among seabird taxa. A high proportion (85% between 2003-04 and 2012-13) of white-capped albatross captures are taken in trawl fisheries with most of the remainder taken in surface longline fisheries. The trawl fishery also accounts for 92% of sooty shearwaters captured, with most of the remainder taken by bottom longliners. The proportion captured by trawl fisheries reduces to 26% for all other albatrosses combined, with 48% and 26% taken in surface and bottom longline fisheries, respectively. Bottom longline and trawl take similar proportions of the white-chinned petrels captured (42% and 51%, respectively).

Figure 6.10: Model-based estimates of captures of the most numerous seabird taxa observed captured in trawl, surface longline, and bottom longline fisheries between 2002–03 and 2012-13. For confidence limits see Table 6.10 to Table 6.15. Note that this level of aggregation conceals any different trends within a fishing method (e.g., deepwater vs. inshore and flatfish trawl or large vs. small longliners).

Over the 2003-04 to 2012-13 period, there appear to have been downward trends (across all fisheries) in the estimated captures of all birds combined, white-capped albatross, and non-albatross taxa other than white-chinned petrel (Figure 6.10). Estimated captures of other albatrosses and white-chinned petrel appear to have fluctuated without much trend, although there is some evidence for an increasing trend for white-chinned petrel, especially in trawl fisheries.

Because fishing effort often changes with time, estimates of total captures may not be the only index required for comprehensive monitoring. The number of captures (with certain caveats, see later) is clearly more biologically relevant for birds, but capture rates by fishery may be more useful measures to assess fishery performance and the effectiveness of mitigation approaches. Dividing modelled catch estimates by the number of tows or hooks set in a particular fishery in each year provides catch rate indices by fishery. These are typically reported as the number of birds captured per 100 trawl tows or per 1000 longline hooks (Figure 6.11 to Figure 6.15).

For white-capped albatross, captures rates in the major offshore trawl fisheries for squid and hoki declined between 2002–03 and 2010/12, especially after 2004–05 (Figure 6.11) but showed no trend for inshore trawlers and increased for surface longliners targeting southern bluefin tuna. Together, these fisheries account for 78% of all estimated captures of white-capped albatross in these years.

For Salvin's albatross, captures rates have fluctuated without trend or increased in all fisheries taking substantial numbers of this species between 2002–03 and 2012-13, especially after 2006–07 (Figure 6.12). Capture rates were unusually high in all trawl fisheries in 2004–05. Together, these fisheries account for 75% of all estimated captures of Salvin's albatross in these years.

For Southern Buller's albatross, estimated captures decreased in bigeye tuna target surface longline fisheries between 2002-03 and 2012-13, while capture rates increased. Captures and capture rates fluctuated with no trend in southern bluefin tuna target fisheries and displayed no apparent trend in longline bottom longline and hoki trawl fisheries (Figure 6.13). Together these fisheries account for 62% of all estimated captures of Southern Buller's albatross in these years.

For white-chinned petrel, captures rates increased between 2002–03 and 2012-13 in squid trawlers (Figure 6.14) but showed little trend for bottom longliners targeting ling and bluenose, and scampi trawl. Together, these fisheries account for 85% of all estimated captures of white-chinned petrel in these years.

For sooty shearwaters, captures rates decreased between 2002–03 and 2012-13 for bottom longliners targeting ling, but fluctuated without apparent trend in squid, middle-depth, and hoki trawlers (Figure 6.15). High capture rates of this species occur across all three trawl fisheries in some years. Together, these fisheries account for 73% of all estimated captures of sooty shearwaters in these years.

On-board captures recorded by observers represent the most reliable source of information for monitoring trends in total captures and capture rates, but these data have three main deficiencies with respect to estimating total fatalities, especially to species level. First, some captured seabirds are released alive (26% in trawl fisheries between 2002–03 and 2012–13, 27% in surface longline fisheries, and 27% in bottom longline fisheries), meaning that, all else being equal, estimates of captures may overestimate total fatalities, depending on the survival rate of those released. There is a trend in the percentage of albatross observed caught on trawl vessels that were released alive with an general increase from 2009-10, this trend is less apparent for across all birds or in other methods (Table 6.19). Second, identifications by observers are not completely reliable and sometimes use generic codes rather than species codes. While a proportion of dead captures are returned for necropsy and photographs taken for confirmation of identification, there remains uncertainty about the identity of 24% of observed captures in trawl fisheries between 2002–03 and 2012–13, 32% from surface longline fisheries, and 30% from bottom longline fisheries. The number of uncertain identifications is always higher than the number of birds released alive in previous years, but in the last 3 years, photo identification has been quite common, including for birds captured and released alive. Third, not all birds killed or mortally wounded by fishing gear are recovered on a fishing vessel. Some birds caught on longline hooks fall off before being recovered, and birds that collide with trawl warps may be dragged under the water and drowned or injured to the extent that they are unable to fly or feed. Excluding this "cryptic" mortality means that, all else being equal, estimates of captures will underestimate total fatalities, and the extent of underestimation will vary among taxa and fisheries. These deficiencies do not greatly affect the suitability of estimates of captures and capture rates for monitoring purposes, but they have necessitated the development of alternative methods for assessing risk and population consequences.

Table 6.19: Percentage of observed captures that were released alive (http://data.dragonfly.co.nz/psc/ Data version v20140131)

	All birds			Albatross spp only		
	Trawl	SLL	BLL	Trawl	SLL	BLL
2002-03	24	18	20	7	28	11
2003-04	9	30	28	4	31	82
2004-05	20	41	37	11	48	100
2005-06	18	38	49	7	40	43
2006-07	18	22	12	13	24	0
2007-08	18	38	10	13	38	30
2008-09	26	26	36	19	34	50
2009-10	34	30	54	31	32	N/A
2010-11	30	45	31	38	51	88
2011-12	25	16	70	24	18	30
2012-13	40	26	0	35	27	N/A

6.4.3 MANAGING FISHERIES INTERACTIONS

New Zealand had taken steps to reduce incidental captures of seabirds before the advent of the IPOA in 1999 and the NPOA in 2004. For example, regulations were put in place under the Fisheries Act to prohibit drift net fishing in 1991 and prohibit the use of netsonde monitoring cables ("third wires") in trawl fisheries in 1992. The use of tori lines (streamer lines designed to scare seabirds away from baited hooks) was made mandatory in all tuna longline fisheries in 1992.

The fishing industry also undertook several initiatives to reduce captures, including funding research into new or improved mitigation measures, and adopting voluntary codes of practice and best practice fishing methods. Codes of practice have been in place in the joint venture tuna longline fishery since 1997–98, requiring, among other things, longlines to be set at night and a voluntary upper limit on the incidental catch of seabirds. That limit was steadily reduced from 160 "at risk" seabirds in 1997–98, to 75 in 2003–04. Most vessels in the domestic longline tuna fishery had also voluntarily adopted night setting by 2004. A code of practice was in place for the ling auto-line fishery by 2002–03. Other early initiatives included reduced deck lighting, the use of thawed rather than frozen baits, sound deterrents, discharging of offal away from setting and hauling, weighted branch lines, different gear hauling techniques and line shooters. Current regulated and voluntary initiatives are summarised by fishery in Table 6.20.

In 2002, MFish, DOC, and stakeholders began working with other countries to reduce the incidental catch of seabirds. As a result, a group called Southern Seabird Solutions was formed and formally established as a Trust in 2003 (http://www.southernseabirds.org/) and received royal patronage in 2012. Southern Seabird Solutions exists to promote responsible fishing practices that avoid the incidental capture of seabirds in New Zealand and the southern ocean. Membership includes representatives from the commercial fishing industry, environmental and conservation groups, and government departments. The Trust's vision is that: *All fishers in the Southern Hemisphere avoid the capture of seabirds*, and this is underpinned by the strategic goals on: Culture Change; Supporting Collaboration; Mitigation Development and Knowledge Transfer; Recognising Success; and Strengthening the Trust.

Building on these initiatives, New Zealand's 2004 NPOA established a more comprehensive framework to reducing incidental captures approach across all fisheries (because focussing on longline fisheries like the IPOA was considered neither equitable nor sufficient).

It included two goals that set the overall direction:

1. To ensure that the long-term viability of protected seabird species is not threatened by their incidental catch in New Zealand fisheries waters or by New Zealand flagged vessels in high seas fisheries; and
2. To further reduce incidental catch of protected seabird species as far as possible, taking into account advances in technology, knowledge and financial implications.

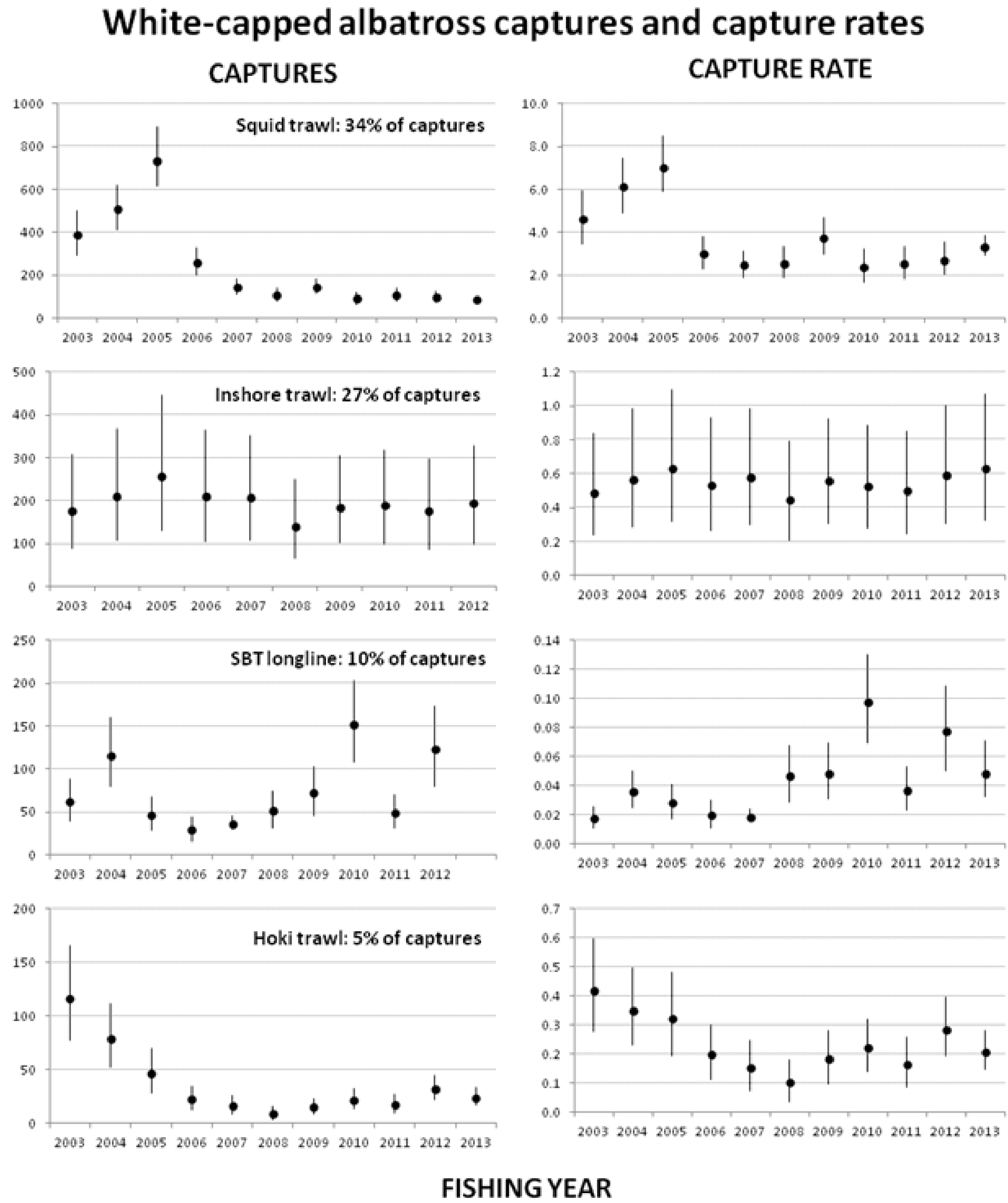


Figure 6.11: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of white capped albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2012–13 (cumulatively, 77% of all white-capped albatross captures). Data version v20140131.

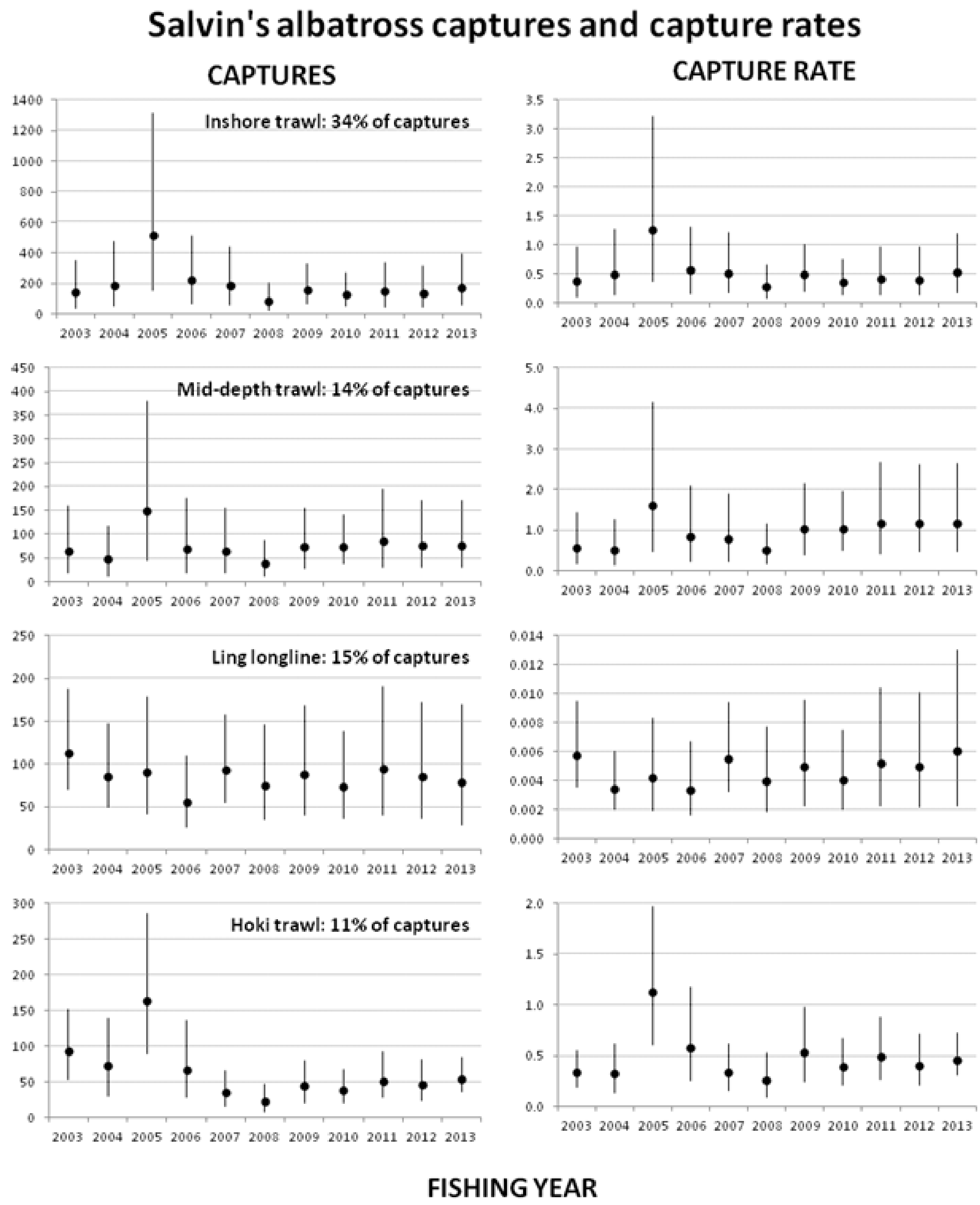


Figure 6.12: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of Salvin's albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2012–13 (cumulatively, 75% of all Salvin's albatross captures). Data version v20140131.

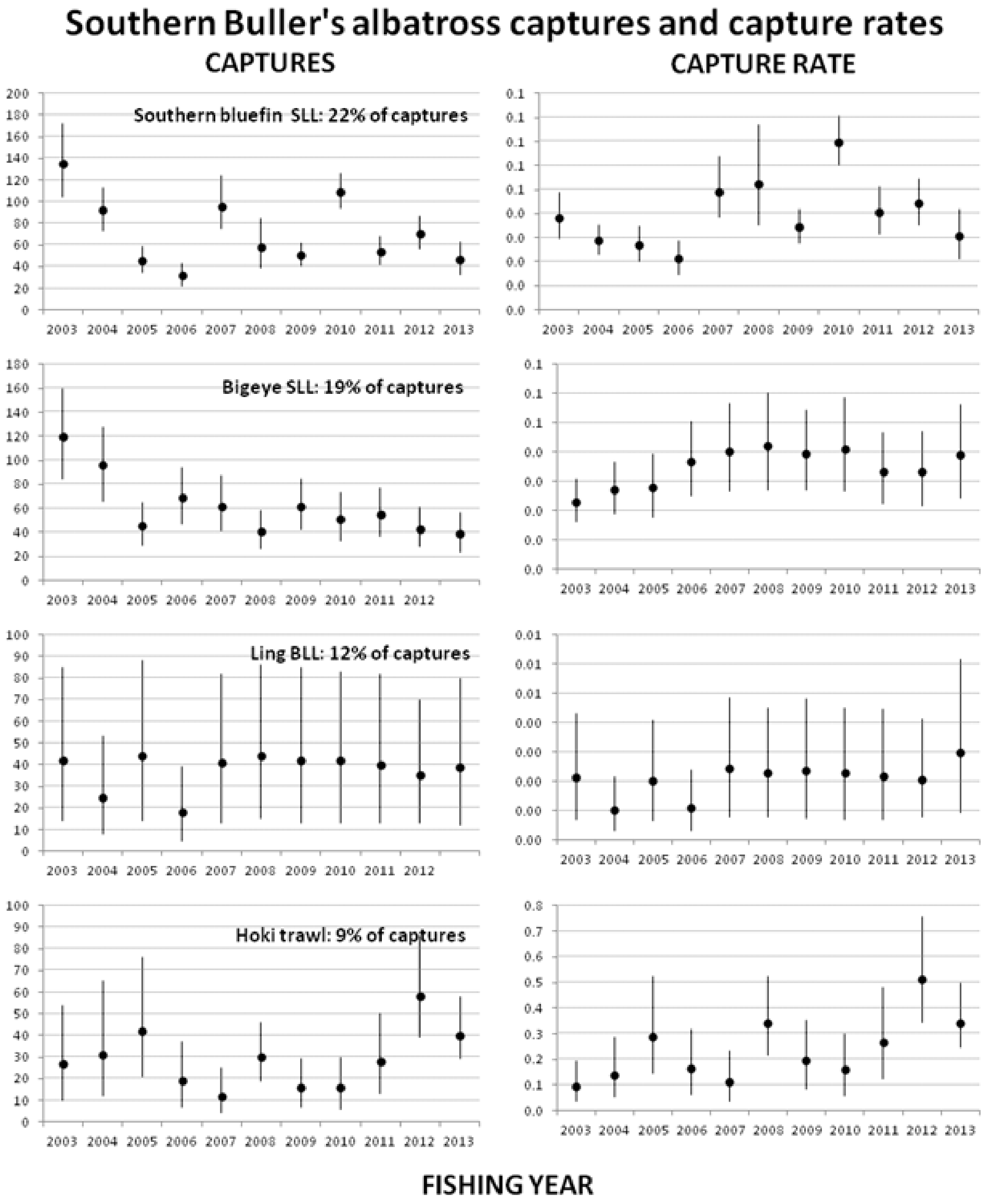


Figure 6.13: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of Southern Buller's albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2012–13 (cumulatively, 62% of all Southern Buller's albatross captures). Data version v20140131.

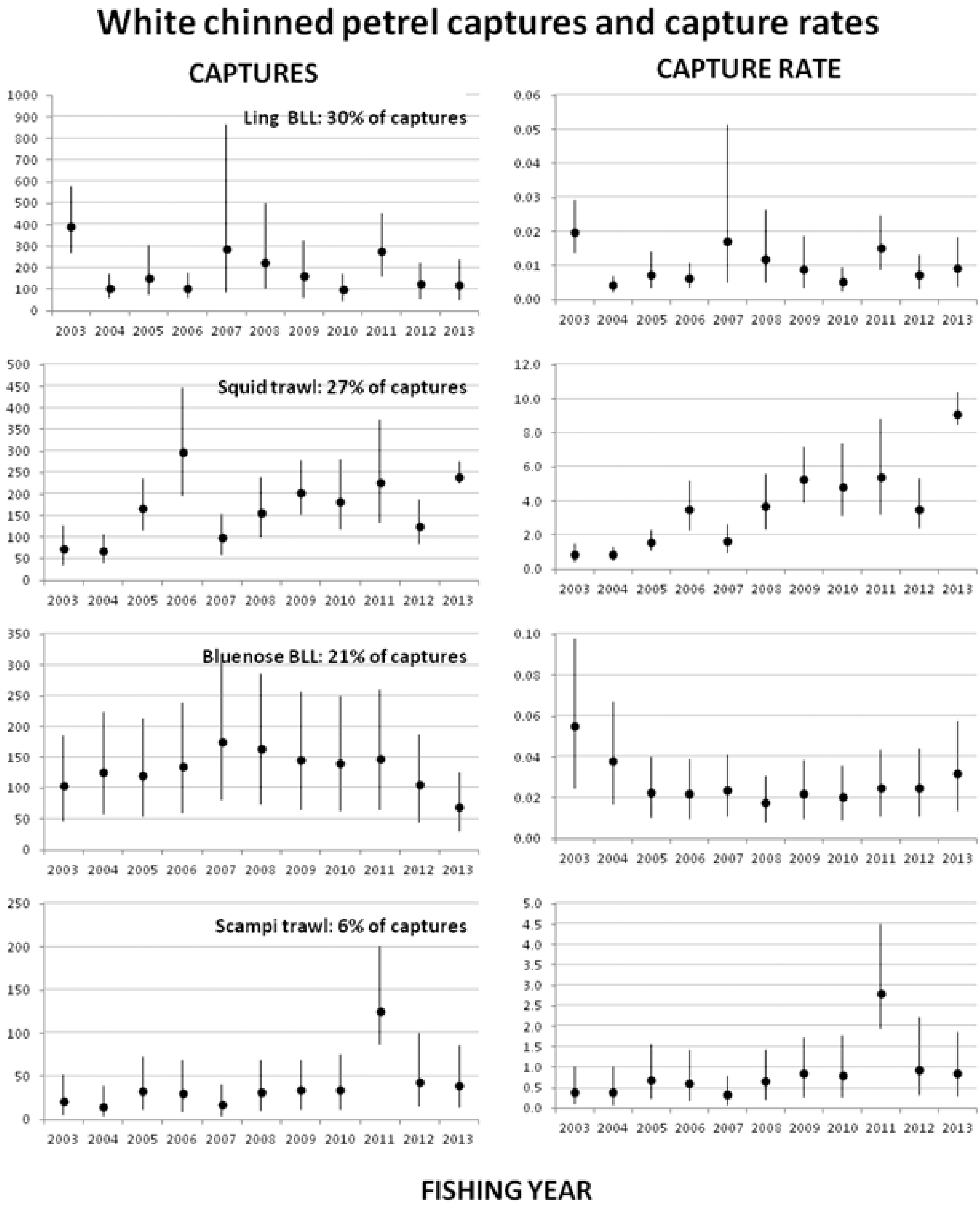


Figure 6.14: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of white chinned petrels in the four fisheries estimated to have taken the most captures between 2002–03 and 2012–13 (cumulatively, 85% of all white-chinned petrel captures). Data version v20140131.

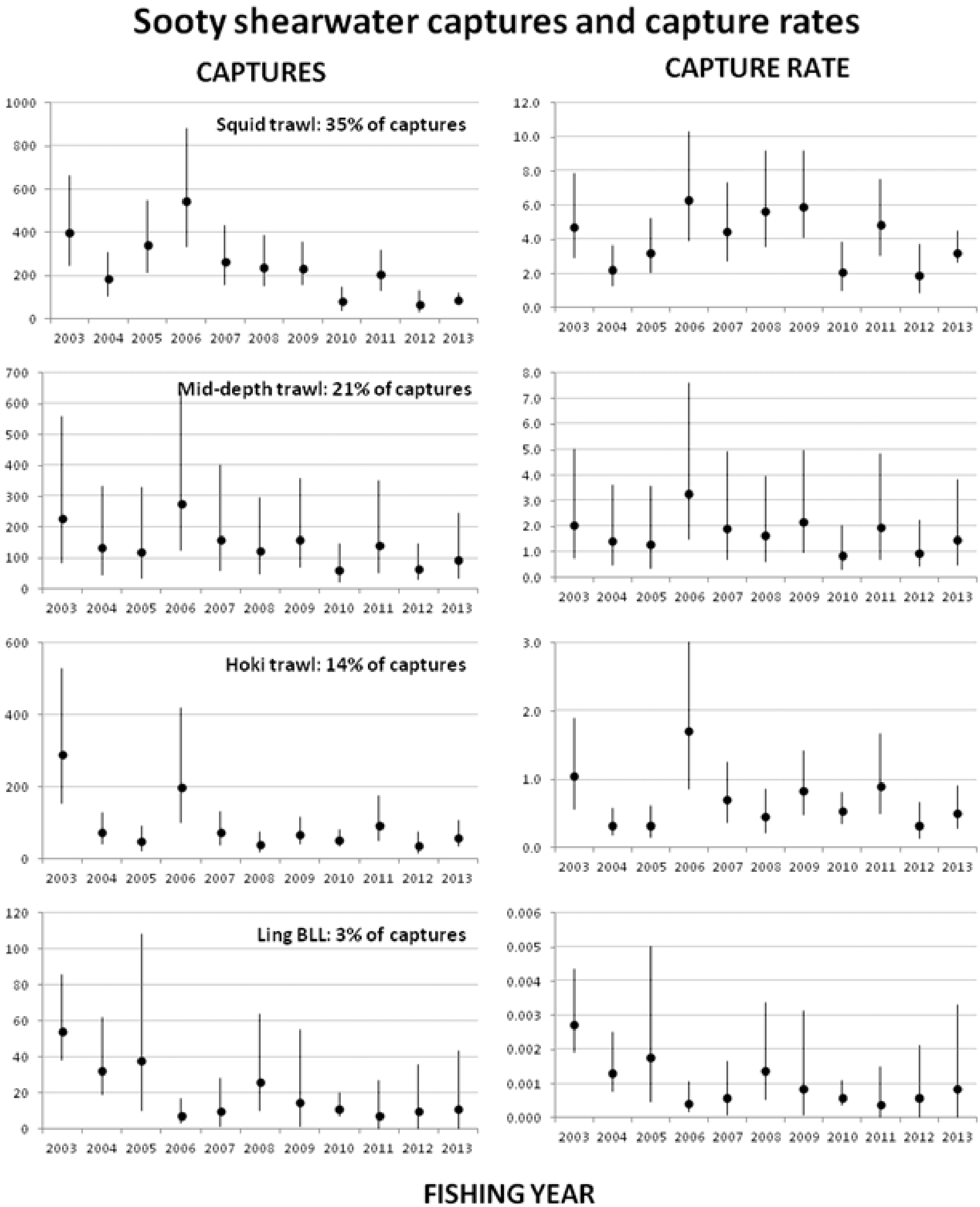


Figure 6.15: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of sooty shearwaters in the four fisheries estimated to have taken the most captures between 2002–03 and 2012–13 (cumulatively, 73% of all sooty shearwater captures). Data version v20140131.

Together the two goals established the NPOA as a long-term strategy. The second goal was designed to build on the first goal by promoting and encouraging the reduction of incidental catch beyond the level that is necessary to ensure long term viability. The goals recognised that, although seabird deaths may be accidentally caused by fishing, most seabirds are absolutely protected under the Wildlife Act. The second goal balances the need to continue reducing incidental catch against the factors that influence how this can be achieved in practice (e.g., advances in technology and the costs of mitigation). The scope of the 2004 NPOA included:

- all seabird species absolutely or partially protected under the Wildlife Act;
- commercial and non-commercial fisheries;
- all New Zealand fisheries waters; and
- high seas fisheries in which New Zealand flagged vessels participate, or where foreign flagged vessels catch protected seabird species.

Specific objectives were established in the 2004 NPOA as follows:

1. Implement efficient and effective management measures to achieve the goals of the NPOA, using best practice measures where possible.
2. Ensure that appropriate incentives and penalties are in place so that fishers comply with management measures.
3. Establish mandatory bycatch limits for seabird species where they are assessed to be an efficient and effective management measure and there is sufficient information to enable an appropriate limit to be set.
4. Ensure that there is sufficient, reliable information available for the effective implementation and monitoring of management measures.
5. Establish a transparent process for monitoring progress against management measures.
6. Ensure that management measures are regularly reviewed and updated to reflect new information and developments, and to ensure the achievement of the goals of the NPOA.
7. Encourage and facilitate research into affected seabird species and their interactions with fisheries.
8. Encourage and facilitate research into new and innovative ways to reduce incidental catch.
9. Provide mechanisms to enable all interested parties to be involved in the reduction of incidental catch.
10. Promote education and awareness programmes to ensure that all fishers are aware of the need to reduce incidental catch and the measures available to achieve a reduction.

The 2004 NPOA-seabirds set out the mix of voluntary and mandatory measures that would be used to help reduce incidental captures of seabirds, noted research into the extent of the problem and the techniques for mitigating it, and outlined mechanisms to oversee, monitor and review the effectiveness of these measures. It was not within the scope of the NPOA to address threats to seabirds other than fishing. Such threats are identified in DOC's Action Plan for Seabird Conservation in New Zealand (Taylor 2000) and their management is undertaken by DOC.

Since publication of the NPOA in 2004, more progress has been made in the commercial fishing sector, including:

- in the deepwater fishing sector;
  - industry has implemented vessel specific risk management plans (VMPs) comprising non-mandatory seabird scaring devices, offal management, and other measures to reduce risks to seabirds,
  - the government has implemented mandatory measures to reduce risk to seabirds (e.g., use and deployment of seabird scaring devices), and
  - industry has taken a proactive stance in resourcing a 24/7 liaison officer to undertake incident response actions, mentoring, VMP and regime development and reviewing, and fleet wide training;
- in the bottom and surface long-line sectors, the government has implemented mandatory measures including tori lines, night setting, line weighting and offal management;
- a number of research projects have been or are currently being undertaken by government and industry into offal discharge, efficacy of seabird scaring devices, line weighting and longline setting devices; and

- workshops organised by both industry bodies and Southern Seabird Solutions are being held for the inshore trawl and longline sectors.

Mitigation has developed substantially since FAO's IPOA was published and a number of recent reviews consider the effectiveness of different methods (Bull 2007, 2009) and summarise currently accepted best practice (ACAP 2011). In December 2010, FAO held a Technical Consultation where International Guidelines on bycatch management and reduction of discards were adopted (FAO 2010). The text included an agreement that the guidelines should complement appropriate bycatch measures addressed in the IPOA-Seabirds and its Best Practice Technical Guidelines (FAO 2009). The Guidelines were subsequently adopted by FAO in January 2011.

In 2013 the Ministry for Primary Industries released a revised and updated version of the NPOA-Seabirds. This revision seeks to address recommendations from the IPOA/NPOA Seabirds Best Practice Technical Guidelines (FAO 2009). The scope of the revised New Zealand NPOA-Seabirds 2013 is as follows:

- all seabird species absolutely or partially protected under the New Zealand Wildlife Act 1953;
- commercial, recreational and customary non-commercial fisheries in waters under New Zealand fisheries jurisdiction;
- all fishing methods which capture seabirds, including longlining, trawling, set netting, hand lining, trolling, purse seining and potting;
- all waters under New Zealand fisheries jurisdiction;
- high seas fisheries in which New Zealand flagged vessels participate, and, as appropriate and relevant, where foreign flagged vessels catch New Zealand seabirds; and
- other areas in which New Zealand seabirds are caught.

The long term objective of the 2013 NPOA-Seabirds is: *"New Zealand seabirds thrive without pressure from fishing related mortalities, New Zealand fishers avoid or mitigate against seabird captures and New Zealand fisheries are globally recognised as seabird friendly."*

The high level subsidiary objectives of the NPOA-Seabirds 2013 are:

i. Practical objective: All New Zealand fishers implement current best practice mitigation measures relevant to their fishery and aim through continuous improvement to reduce and where practicable eliminate the incidental mortality of seabirds.
ii. Biological risk objective: Incidental mortality of seabirds in New Zealand fisheries is at or below a level that allows for the maintenance at a favourable conservation status or recovery to a more favourable conservation status for all New Zealand seabird populations.
iii. Research and Development objectives:
    a. the testing and refinement of existing mitigation measures and the development of new mitigation measures results in more practical and effective mitigation options that fishers readily employ;
    b. research and development of new observation and monitoring methods results in improved cost effective assurance that mitigation methods are being deployed effectively; and
    c. research outputs relating to seabird biology, demography and ecology provide a robust basis for understanding and mitigating seabird incidental mortality.
iv. International objective: In areas beyond the waters under New Zealand jurisdiction, fishing fleets that overlap with New Zealand breeding seabirds use internationally accepted current best practice mitigation measures relevant to their fishery.

Areas identified in the NPOA-Seabirds 2013 which clearly require additional progress include:

i. mitigation measures for, and education, training and outreach in commercial set net fisheries and inshore trawl fisheries;
ii. implementation of spatially and temporally representative at sea data collection in inshore and some Highly Migratory Species (HMS) fisheries;

iii. mitigation measures for net captures for deepwater trawl fisheries;
iv. the extent of any cryptic mortality (seabird interactions which result in mortality but are unobserved or unobservable); and
v. mitigation measures for, education, training and outreach in, and risk assessment of non-commercial fisheries (in particular the set net and hook and line fisheries).

The most important factor influencing contacts between seabirds and trawl warp cables is the discharge of offal (Wienecke & Robertson 2002; Sullivan et al 2006b, ACAP 2011). Offal management methods used to reduce the attraction of seabirds to vessels include mealing, mincing, and batching. ACAP recommends (ACAP 2011) full retention of all waste material where practicable because this significantly reduced the number of seabirds feeding behind vessels compared with the discharge of unprocessed fish waste (Wienecke & Robertson 2002, Abraham 2009, Favero et al 2010) or minced waste (Melvin et al 2010). Offal management has been found to be a key driver of seabird bycatch in New Zealand trawl fisheries (Abraham 2007, Abraham & Thompson 2009b, Abraham et al 2009, Abraham 2010b, Pierre et al 2010, 2012a, b). Other best practice recommendations (ACAP 2011) are the use of bird-scaring lines to deter birds from foraging near the trawl warps, use of snatch blocks to reduce the aerial extent of trawl warps, cleaning fish and benthic material from nets before shooting, minimising the time the trawl net is on the surface during hauling, and binding of large meshes in pelagic trawl before shooting.

In New Zealand, the three legally permitted devices used for mitigation by trawlers are tori lines (e.g., Sullivan et al 2006a), bird bafflers (Crysel 2002), and warp scarers (Carey 2005). Middleton & Abraham (2007) reported experimental trials of mitigation devices designed to reduce the frequency of collisions between seabirds and trawl warps on 18 observed vessels in the squid trawl fishery in 2006. The frequencies of birds striking either warps or one of three mitigation devices (tori lines, 4-boom bird bafflers, and warp scarers) were assessed using standardised protocols during commercial fishing. Different warp strike mitigation treatments were used on different tows according to a randomised experimental design. Middleton & Abraham (2007) confirmed that the discharge of offal was the main factor influencing seabird strikes; almost no strikes were recorded when there was no discharge, and strike rates were low when only sump water was discharged (see also Abraham et al 2009). In addition to this effect, tori lines were shown to be most effective mitigation approach and reduced warp strikes by 80–95% of their frequency without mitigation. Other mitigation approaches were only 10–65% effective. Seabirds struck tori lines about as frequently as they did the trawl warps in the absence of mitigation but the consequences are unknown.

Recommended best practice for surface (pelagic) longline fisheries and bottom (demersal) longlines (ACAP 2011) includes weighting of lines to ensure rapid sinking of baits (including integrated weighted line for bottom longlines), setting lines at night when most vulnerable birds are less active, and the proper deployment of bird scaring lines (tori lines) over baits being set, and offal management (especially for bottom longlines). A range of other measures are offered for consideration.

6.4.4 MODELLING FISHERIES INTERACTIONS AND ESTIMATING RISK

6.4.4.1 HIERARCHICAL STRUCTURE OF RISK ASSESSMENTS

Hobday et al (2007) described a hierarchical framework for ecological risk assessment in fisheries (see Figure 6.16). The hierarchy included three levels: Level 1 qualitative, expert-based assessments (often based on a Scale, Intensity, Consequence Analysis, SICA); Level 2 semi-quantitative analysis (often using some variant of Productivity Susceptibility Analysis, PSA); and Level 3 fully quantitative modelling including uncertainty analysis. The hierarchical structure is designed to “screen out” potential effects that pose little or low risk for the least investment in data collection and analysis, escalating to risk treatment or higher levels in the hierarchy only for those potential effects that pose non-negligible risk. This structure relies for its effectiveness on a low potential for false negatives at each stage, thereby identifying and screening out activities that are ‘low risk’ with high certainty. This focuses effort on remaining higher risk activities. In statistical terms, risk assessment tolerates Type I errors (false positives, i.e. not screening out activities that may actually present a low risk) in order to avoid Type II errors (false negatives, i.e. incorrectly screening out activities that actually constitute high risk), and it is important to

Table 6.20: (from MPI 2013, the revised NPOA-seabirds): summary of current mitigation measures applied to New Zealand vessels fishing in New Zealand waters to avoid incidental seabird captures. R, regulated; SM, required via a self-managed regime (non-regulatory, but required by industry organisation and audited independently by government); V, voluntary with at least some use known; N/A, measure not relevant to the fishery; years in parentheses indicate year of implementation; *, part of a vessel management plan (VMP). Note, this table may not capture all voluntary measures adopted by fishers.

Mitigation Measure	Surface longline	Bottom longline	Trawl >=28 m	Trawl <28 m	Set net	Notes
Netsonde cable prohibition	N/A	N/A	R (1992)	R (1992)	N/A	Netsonde cables also called third wires
Streamer (tori) lines	R	R	N/A	N/A	N/A	
Additional streamer line	–	–	N/A	N/A	N/A	
Night setting	R (or line weighting)	R (or line weighting)	–	–	–	} Longlines must use night setting if not line weighting, or *vice-versa*
Line weighting	R (or night setting)	R (or night setting)	N/A	N/A	N/A	
Seabird scaring device	N/A	N/A	R (2006)	R?	N/A	To prevent warp captures and collisions
Additional bird scaring device	N/A	N/A	SM (2008)*	–	N/A	
Dyed bait	V	–	N/A	N/A	N/A	
Offal management	V	R	SM (2008)*	–	–	
VMPs			SM (2008)	V	–	Some VMPs developed for vessels < 28m
Code of Practice	V	–	VMP	–	–	

Note: A vessel management plan (VMP) is a vessel-specific seabird risk management plan which specifies seabird mitigation devices to be used, operational management requirements to minimise the attraction of seabirds to vessels, and incident response requirements and other techniques or processes in place to minimise risk to seabirds from fishing operations.

distinguish this approach from normal estimation methods. Whereas normal estimation strives for a lack of bias and a balance of Type I and Type II errors, risk assessment is designed to answer the question "how bad could it be?" The divergence between the risk assessment approach and normal, unbiased estimation approaches should diminish at higher levels in the risk assessment hierarchy, where the assessment process should be informed by good data that support robust estimation.

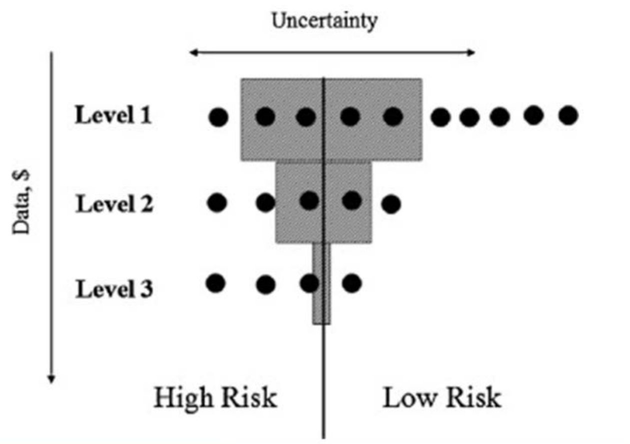


Figure 6.16: (from Hobday et al 2007): Diagrammatic representation of the hierarchical risk assessment process where activities that present low risk are progressively screened out by assessments of increasingly high data content, sophistication, and cost.

6.4.5 QUALITATIVE (LEVEL 1) RISK ASSESSMENT

Rowe (2013) summarised an expert-based, qualitative (Level 1) risk assessment, commissioned by DOC, for the incidental mortality of seabirds caused by New Zealand fisheries. The main focus was on fisheries operating within the NZ EEZ and on all seabirds absolutely or partially protected under the Wildlife Act 1953. New Zealand flagged vessels fishing outside the EEZ were included, but risk from non-NZ fisheries and other human causes were not included.

The panel of experts who conducted the Level 1 risk assessment assessed the threat to each of 101 taxa posed by 26 fishery groups, scoring exposure and consequence independently according to the schemas in Table 6.21 and Table 6.22 (details in Rowe 2013). The risk for a given taxon posed by a given fishery was calculated as the product of exposure and consequence scores. Potential risk was estimated as the risk posed by a fishery assuming no mitigation was in place, and residual risk (called "optimum risk" by Rowe 2013) was estimated assuming that mitigation was in place throughout a given fishery and deployed correctly. The panel also agreed a confidence score for each taxon-fishery interaction using the schema in Table 6.23.

Total potential and residual risk for a seabird taxon was estimated by summing the scores across all fisheries (Table 6.24 shows taxa with an aggregate score of 30 or higher), and total potential and residual risk posed by a fishery group was estimated by summing the scores across all seabird taxa (Table 6.25 shows the results for all 26 fishery groups).

White-chinned petrel, sooty shearwater, black petrel, Salvin's albatross, white-capped albatross, and flesh-footed shearwater were all estimated by this procedure to have an aggregate risk score of 90 or higher (range 92 to 123) even if mitigation was in place and deployed properly across all fisheries. Of the 101 seabird taxa considered, the aggregate risk score was less than 30 for 70 taxa with respect to potential risk and for 72 taxa with respect to residual risk.

Table 6.21: Exposure scores used by Rowe (2013) (modified from Fletcher 2005, Hobday et al 2007).

Score	Descriptor	Description
0	Remote	The species will not interact directly with the fishery
1	Rare	Interactions may occur in exceptional circumstances
2	Unlikely	Evidence to suggest interactions possible
3	Possible	Evidence to suggest interactions occur, but are uncommon
4	Occasional	Interactions likely to occur on occasion
5	Likely	Interactions are expected to occur

Table 6.22: Consequence scores used by Rowe (2013) (modified from Fletcher 2005, Campbell & Gallagher 2007, Hobday et al 2007).

Score	Descriptor	Description
1	Negligible	Some or one individual/s impacted, no population impact
2	Minor	Some individuals are impacted, but minimal impact on population structure or dynamics. In the absence of further impact, rapid recovery would occur
3	Moderate	The level of interaction / impact is at the maximum acceptable level that still meets an objective. In the absence of further impact, recovery is expected in years
4	Major	Wider and longer term impacts; loss of individuals; potential loss of genetic diversity. Level of impact is above the maximum acceptable level. In the absence of further impact, recovery is expected in multiple years
5	Severe	Very serious impacts occurring, loss of seabird populations causing local extinction; decline in species with single breeding population, measurable loss of genetic diversity. In the absence of further impact, recovery is expected in years to decades
6	Intolerable	Widespread and permanent / irreversible damage or loss occurring; local extinction of multiple seabird populations; serious decline of a species with a single breeding population, significant loss of genetic diversity. Even in the absence of further impact, long-term recovery period to acceptable levels will be greater than decades or may never occur

Table 6.23: Confidence scores used by Rowe (2013) (after Hobday et al 2007).

Score	Descriptor	Rationale for confidence score
1a 1b 1c 1d	Low	Data exists, but is considered poor or conflicting. No data exists. Agreement between experts, but with low confidence Disagreement between experts
2a 2b 2c	High	Data exists and is considered sound. Consensus between experts High confidence exposure to impact can not occur (e.g. no spatial overlap of fishing activity and at-sea seabird distribution)

Table 6.24: Potential and residual risk scores for each seabird taxon with a potential risk score of 30 or more in Rowe (2013). Residual risk ("optimal risk" in Rowe 2013, not tabulated therein for grey-faced petrel or light-mantled albatross) is estimated assuming mitigation is deployed and correctly used throughout all interacting fisheries.

Taxon	Potential score	Residual score	Percent reduction
White-chinned petrel	159	123	23
Sooty shearwater	126	108	14
Black petrel	139	106	24
Salvin's albatross	161	106	34
White-capped albatross	141	94	33
Flesh-footed shearwater	117	92	21
Southern Buller's albatross	123	85	31
Grey petrel	123	84	32
Black-browed albatross	114	80	30
Northern Buller's albatross	107	72	33
Chatham albatross	114	71	38
Campbell albatross	97	66	32
Westland petrel	89	59	34
Antipodean albatross	89	55	38
Gibson's albatross	89	55	38
Wandering albatross	89	55	38
Southern royal albatross	79	49	38
King shag	48	48	0
Pitt Island shag	46	46	0
Chatham Island shag	45	45	0
Hutton's shearwater	37	35	5
Northern giant petrel	62	35	44
Pied shag	35	35	0
Indian yellow-nosed albatross	58	34	41
Southern giant petrel	61	34	44
Fluttering shearwater	34	32	6
Spotted shag	31	31	0
Stewart Island shag	31	31	0
Yellow-eyed penguin	30	30	0
Grey-faced petrel	31	–	–
Light-mantled albatross	30	–	–

Setnet and inshore trawl fisheries groups posed the greatest residual risk to seabirds (summed across all taxa); both had aggregate scores of over 200 and had no substantive mitigation. Surface and bottom longline fisheries and middle-depth trawl fisheries for finfish and squid also had aggregate risk scores of 100 or more. These risk scores were substantially reduced if mitigation was assumed to be deployed throughout these fisheries (reductions of 24 to 56%), but all remained above 100. Trawling for southern blue whiting and deep-water species, inshore drift net, various seine methods, ring net, diving, dredging, and hand gathering all had aggregate risk scores of 40 or less if mitigation was assumed to be deployed throughout these fisheries. Diving, dredging, and hand gathering were all judged by the panel to pose essentially no risk to seabirds.

6.4.5.1 SEMI-QUANTITATIVE (LEVEL 2) RISK ASSESSMENT

The level 2 method developed by MPI is a generalisation of the spatial overlap approach described by Kirby & Hobday (2007) and arose initially from an expert workshop hosted by the then Ministry of Fisheries in 2008 and attended by experts with specialist knowledge of New Zealand fisheries, seabird-fishery interactions, seabird biology, population modelling, and ecological risk assessment. The overall framework is described in Sharp et al (2011) and has been variously applied and improved in multiple iterations (Waugh et al 2008a, b, developed further by Sharp 2009, Waugh & Filippi 2009, Filippi et al 2010, Richard et al 2011, Richard & Abraham 2013b). The method applies the "exposure-effects" approach where exposure refers to the number of fatalities arising from an

Table 6.25: Cumulative potential risk and residual risk scores across all seabird taxa for each fishery from Rowe (2013). Residual risk ("optimal risk" in Rowe 2013) is estimated assuming mitigation is deployed and correctly used throughout a given fishery.

Fishery group	No. taxa	Potential risk	Residual risk	Percent reduction
Setnet	42	374	374	0
Inshore trawl	44	225	225	0
Surface longline: charter	25	313	191	39
Surface longline: domestic	25	302	184	39
Bottom longline: small	33	354	154	56
Bottom longline: large	32	311	139	55
Mid-depth trawl: finfish	22	160	122	24
Mid-depth trawl: squid	21	156	118	24
Mid-depth trawl: scampi	23	94	94	0
Hand line	27	68	68	0
Squid jig	44	62	62	0
Dahn line	29	61	61	0
Pots, traps	17	61	61	0
Trot line	29	61	61	0
Pelagic trawl	27	63	51	19
Troll	23	50	50	0
Mid-depth trawl: southern blue whiting	21	53	40	25
Deep water trawl	21	46	35	24
Inshore drift net	12	33	33	0
Danish seine	15	32	32	0
Beach seine	16	29	29	0
Purse seine	11	22	22	0
Ring net	12	13	13	0
Diving	0	0	0	–
Dredge	0	0	0	–
Hand gather	0	0	0	–

activity and effect refers to the consequence of that exposure for the population. The relative encounter rate of each seabird taxon with each fishery group is estimated as a function of the spatial overlap between seabird distributions (e.g., Figure 6.17) and fishing effort distributions (e.g., see Figure 6.7 to Figure 6.9). These estimates are compared with observed captures in an integrated model including all seabird groups and fisheries to estimate vulnerability (capture rates per encounter) and total captures by taxon in each fishery group. All captures are assumed fatal because of the unknown survival rate of birds released alive. Potential fatality estimates also include scalars for cryptic mortality and are subsequently compared with population estimates and biological characteristics to yield estimates of population-level risk from fishing (see method diagram in Figure 6.18).

For each taxon, the risk was assessed by dividing the estimated number of annual potential fatalities (APF) by an estimate of Potential Biological Removals (PBR, after Wade 1998). This index represents the amount of human-induced mortality a population can sustain without compromising its ability to achieve and maintain a population size above its maximum net productivity (MNPL) or to achieve rapid recovery from a depleted state. In the risk assessment, PBR was estimated from the best available information on the demography of each taxon, including the seasonality of the distribution of various species where applicable (Figure 6.17). Because estimates of seabirds' demographic parameters and of fisheries related mortality are imprecise, the uncertainty around the demographic and mortality estimates was propagated through the analysis. This allowed uncertainty in the resulting risk to be calculated, and also allowed the identification of parameters where improved precision would reduce overly large uncertainties. However, not all sources of uncertainty could be included, and the results are best used as a guide in the setting of management and research priorities. In general, seabird demographics, the distribution of seabirds within New Zealand waters, and sources of cryptic mortality were poorly known.

Integral to Richard & Abraham's (2013b) update of the semi-quantitative risk assessment was a simulation study

(Richard & Abraham 2013a) to assess the accuracy of the approximations used in PBR calculations used by Richard et al (2011) for seabird demographics. They showed that the PBR is typically overestimated, largely because r_{max} is overestimated by Niel & Lebreton's (2005) approximation. Richard & Abraham (2013a) therefore recommended that an additional calibration factor, ρ, be included in the calculation of the PBR to correct the approximation. The calibration factor varied between 0.17 and 0.61, depending on the seabird type; in general, the calibration factor was smaller for species with slower population growth rates, such as albatrosses, and higher for species with higher growth rates, such as shags and penguins. Previous estimates of the PBR using Niel & Lebreton's (2005) approximation for seabird populations that did not include this calibration factor are likely to have overestimated the human caused mortalities that the populations could support (Richard & Abraham 2013a).

The management criterion used for developing the seabird risk assessment was that seabird populations should have a 95% probability of being above half the carrying capacity after 200 years, in the presence of ongoing human-caused mortalities, and environmental and demographic stochasticity (Richard & Abraham 2013b). By simulating seabird populations, the factor ρ was calculated so that this criterion would be satisfied, provided human caused mortalities were less than the base PBR (the PBR with a recovery factor, f, of 1 and using the population size rather than a minimum population estimate). In calculation of the PBR during the simulations, the Neil & Lebreton (2005) method was used for estimating r_{max}, and the Gilbert (2009) method was used for estimating total population size. The simulations did not allow for any bias in the input parameters for individual populations.

Calculation of the PBR for a seabird species requires specification of the recovery factor, f. This factor is typically set between 0.1 and 0.5 and can be used for several purposes (e.g. Lonergan 2011). It can be used to "protect" against errors in the input data used to calculate the PBR for individual populations, to provide for faster recovery rates, and to reflect general risk aversion (especially for endangered species). For the 2013 update to the risk assessment, Richard & Abraham (2013a b, 2014) set the recovery factor to f = 1 and suggested that appropriate values for each species should be determined at a later stage.

Following the completion of the 2013 iteration of the level two seabird risk assessment (Richard & Abraham 2013b), the Ministry for Primary Industries convened an expert workshop in November 2013 to review the level two seabird risk assessment inputs and results (Walker et al 2015). This workshop systematically reviewed input data and other available information for the 26 seabird taxa with the highest risk ratios as assessed by the level two risk assessment. In summary, the results of the workshop are that:

- risk appeared to be overestimated for fourteen taxa, including black petrel;
- risk appeared to be reasonably estimated for nine taxa;
- risk appeared to be underestimated for three taxa: New Zealand king shag and Gibson's and Antipodean albatrosses.

A general preponderance of overestimated risk is acceptable in a risk assessment framework so long as results are used carefully. Risk assessments are generally designed to be conservative in order to highlight gaps in information to direct future research accordingly. In contrast, any persistent significant underestimation of risk across many species is more problematic as a species may then not be subject to the additional research or management intervention required. Note however that the spatially explicit risk assessment framework is used not only to identify which species are potentially at risk, but also to inform choices about the likely effectiveness of various management options to reduce that risk, and to prioritise further research. In this context over-estimated risk scores for a particular species, fishery group, or area may lead to sub-optimal prioritization, and ultimately delay risk reduction interventions for those species genuinely at risk. For this reason, modification to improve the level two risk assessment consistent with the recommendations of this workshop was considered a high priority for all at-risk species, regardless of whether those modifications are expected to produce a decrease or an increase in overall species-level risk.

Where current risk estimates were thought to be biased in either direction, this workshop did not seek to replace or modify the existing risk estimates for each taxon, but rather gave advice on how to improve the risk assessment at the next iteration under the existing framework, and made some recommendations for further research.

The 2014 iteration of the risk assessment (as described by Richard & Abraham 2014) estimated the risk posed to each of 70 seabird taxa by trawl, longline and set net fisheries within New Zealand's TS and EEZ. Substantial modifications to the 2013 iteration of the risk assessment (Richard & Abraham 2013b) were made in the 2014 iteration following the recommendations of the review workshop (Walker et al 2015), these included:

- Based on their location and season, 26 captures of southern Buller's albatross were changed to be of northern Buller's albatross. One capture previously identified as Kermadec storm petrel was changed to New Zealand white-faced storm petrel. Captures identified as southern Cape petrel were removed, as only the Snares Cape petrel subspecies breeds in New Zealand.
- The population size was changed for 11 species. It was decreased for Antipodean albatross, Gibson's albatross, and Westland petrel, and increased for Salvin's albatross, New Zealand white capped albatross, black petrel, grey petrel, flesh-footed shearwater, pied shag, Stewart Island shag, and little black shag.
- The annual survival rate was increased for New Zealand white-capped albatross, Westland petrel, black petrel, and flesh-footed shearwater.
- The proportion of adults breeding was decreased for grey petrel and New Zealand white-capped albatross, and increased for pied shag.
- The breeding season was altered for 54 species.
- The royal albatrosses were separated from the Antipodean and Gibson's albatrosses for the estimation of vulnerability was amended. The grouping of shag species, depending on whether they forage in groups or not, was also amended. The two species of Buller's albatross were also disaggregated, although identification of these species was noted to be problematic and therefore an additional source of uncertainty.
- Swordfish target surface longline fishing was treated as a distinct fishery. The small vessel ling bottom-longline fishery was also treated as a separate fishery.
- The at-sea distribution was changed for black petrel, Salvin's albatross, Gibson's albatross, New Zealand white-capped albatross, yellow-eyed penguin, flesh-footed shearwater, Westland petrel, New Zealand storm petrel, and Kermadec storm petrel.
- A parameter was introduced to describe the proportion of birds that remain in New Zealand waters during the non-breeding season, instead of treating birds as absent during the non-breeding season.

Other changes included in the 2014 iteration of the risk assessment (Richard & Abraham 2014) were:

- The data on fishing effort and observed captures included two more years, and vulnerability was estimated using data between the 2006–07 and 2012–13 fishing years.
- The APFs were estimated on data between 2010–11 and 2012–13 fishing years to reflect the current level and spatial distribution of fishing effort.

While re-running the risk assessment, errors were found in the calculations used in the 2013 iteration of the risk assessment (Richard & Abraham 2013b). These affected both the calculation of the PBR_1, and the estimates of APF. An error during data preparation led to over-counting the effort observed in the poorly observed inshore trawl fishery. Also PBR_1 was not calculated using the lower quartile of the distribution of the number of annual breeding pairs as documented by Richard & Abraham (2013b).

In order to be confident in the integrity of the risk assessment, the PBR calculations were independently checked. A parser was written to read the input parameters, independently repeat the PBR calculations, and then confirm that the PBR_1 values could be reproduced. In repeating the calculation, the mean value of PBR_1 was calculated, by repeatedly drawing sets of 4000 samples from each of the distributions to derive a distribution of mean PBR_1 values. For each species, it was confirmed that the mean value lay within the 95% confidence interval of the resulting distribution (Richard & Abraham 2014). In addition, the code used for the calculations was reviewed and the PBR calculations were independently checked; no further errors were found (Webber 2014).

Richard & Abraham (2014) repeated the 2013 risk assessment before and after correcting these errors, the resulting risk ratios are given in Figure 6.19. Fixing the error where PBR_1 was calculated using the total number of annual breeding pairs, instead of the lower quartile of the distribution (N_{BPmin}) as was stated in the methods, resulted in a general increase in the estimated risk for all species.

The analyses by Richard & Abraham (2013a) used NBP, and adjustments in the calibration factor, *ρ*, were undertaken in order to meet the management objective. In the original form of the PBR approach evaluated by Wade (1998), it was proposed that allowance for various potential biases was made by adjusting the recovery factor, *f*. Calculating PBR_1 using N_{BPmin} rather than NBP yields a smaller PBR_1 than the base PBR (which assumes perfect knowledge of all input parameters) although the extent of bias accommodated through the substitution of N_{BPmin} for N_{BP} has not been evaluated.

Another error during data preparation led to over-counting the effort observed in the poorly observed inshore trawl fishery. Estimates of potential fatalities are large for New Zealand white-capped albatross and Salvin's albatross in this fishery, and fixing this error therefore led to a large increase in the estimate of APF for these species, with the overall risk increasing from a median of 0.8 to almost 2 for New Zealand white-capped albatross, and from 3 to over 6 for Salvin's albatross. The impact of correcting the errors made in the 2013 iteration on the resulting risk ratios can be seen in Figure 6.19.

Following the recommendations from the review workshop (Walker et al 2015) to the risk assessment structure and inputs, the overall changes between the corrected 2013 risk assessment and the 2014 iteration can be seen in Figure 6.20 and Table 6.26. The progressive change in risk ratio to each successive change in the risk assessment structure and input parameters is given in Figure 6.21.

Amongst the 70 studied taxa, three species clearly stood out as at most risk from commercial fishing activities within New Zealand waters (Figure 6.20 and Table 6.26, Table 6.27). Even with the recovery factor set to 1, three species had a probability of more than 95% of the risk ratio exceeding 1 (estimated annual potential fishing-related fatalities being greater than the PBR_1), with black petrel having the highest risk ratio (estimated annual potential fishing-related fatalities over 15 times higher than PBR_1: median, 15.09; 95% c.i.: 9.65-23.26). Potential fatalities for Salvin's albatross were over three times PBR_1 (3.54; 95% c.i.: 1.81-6.47). Potential fatalities for southern Buller's albatross were nearly three times PBR_1 (2.82; 95% c.i.: 1.56-5.60). Another three species are classified as at "very high risk" because they have a risk ratio with a median above 1 or with the upper 95% confidence limit above 2: flesh-footed shearwater, Gibson's albatross, and New Zealand white-capped albatross (Richard & Abraham 2014).

Six species had a median risk ratio above 0.3 or the upper 95% confidence limit above 1 and are classified as at "high risk": Chatham Island albatross; Antipodean albatross; Westland petrel; northern Buller's albatross; Campbell black-browed albatross and Stewart Island shag. The risk ratio of seven species had a median above 0.1 or the upper 95% confidence limit above 0.3 and are classified as at "medium risk": white-chinned petrel; the mainland population of yellow-eyed penguin (assuming that all fisheries-related mortalities are of the mainland population); northern giant petrel; spotted shag; northern royal albatross; Chatham petrel; and Chatham Island taiko (Richard & Abraham 2014).

In total, there were 16 200 (95% c.i.: 12 600 – 21 000) APF estimated across the four fishing methods (Table 6.28). The highest number of APF was in trawl fisheries with 11 500 (8 070-16 300) potential fatalities, mainly of albatross, Procellaria petrels, and large shearwater species. Species with over 1000 estimated fatalities in trawl fisheries were New Zealand white-capped albatross, Salvin's albatross, white-chinned petrel, and sooty shearwater (Richard & Abraham 2014).

In bottom-longline fisheries, there were a total of 2 900 (2 300-3 640) estimated APF (Table 6.28). The species with the highest number of estimated potential fatalities in these fisheries were: black petrel with 940 (685-1 240); flesh-footed shearwater with 492 (313-714); and Salvin's albatross with 398 (245-592) (Richard & Abraham 2014).

Estimated APF for surface-longline fisheries totalled 1 440 (1 180-1 780) across all seabird species (Table 6.28), with bigeye tuna target and small vessel southern bluefin tuna target fisheries each contributing over 40% of these captures. The species with the highest number of APF in these fisheries were: southern Buller's albatross with 304 (201-436); Gibson's albatross with 187 (136-252); and NZ white-capped albatross with 150 (92-223) (Richard & Abraham 2014).

Estimated APF from set net fisheries were relatively low, with a total of 327 (95% c.i.: 226-453) across all species

(Table 6.28). Although the total estimate was low, for some species, the highest number of estimated APF occurred in set-net fisheries. In particular, there were 33 (15-58) estimated annual potential fatalities of yellow-eyed penguin, assumed to come from the mainland population, and 47 (17-93) estimated APF of spotted shag in set-net fisheries.

(a) Breeding distribution (b) Non-breeding distribution

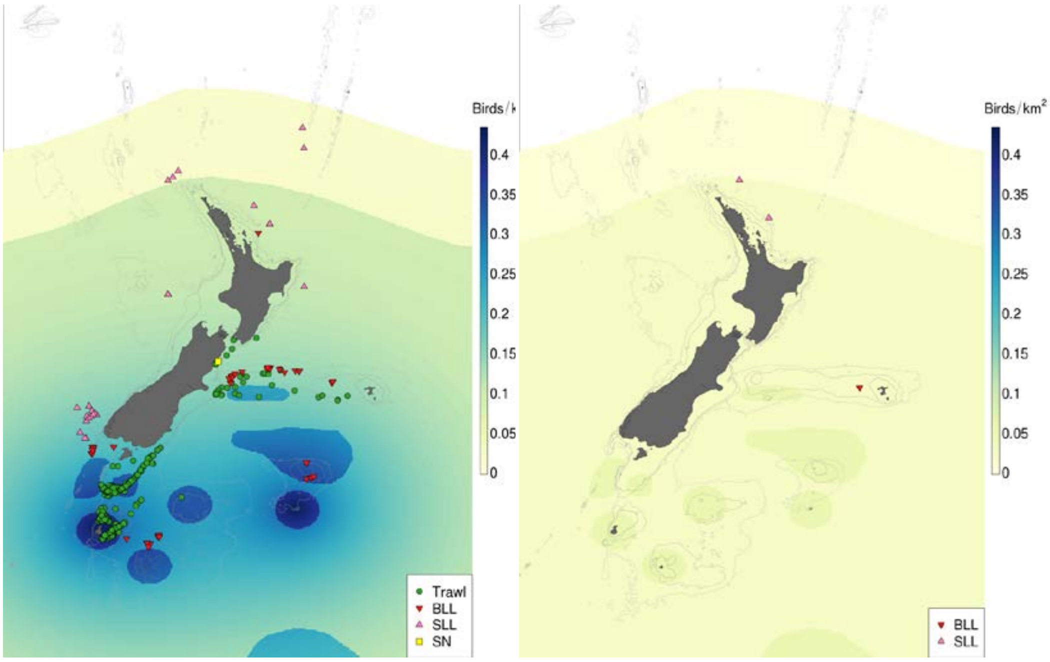


Figure 6.17: (from Richard & Abraham 2014 supplementary material) Relative density of white-chinned petrel. The base map for the distribution was obtained from the NABIS database. The breeding season runs from October to May. Also shown are incidental captures recorded by observers between 2006–07 and 2012–13 in trawl, surface-longline (SLL), bottom-longline (BLL), and set-net (SN) fisheries.

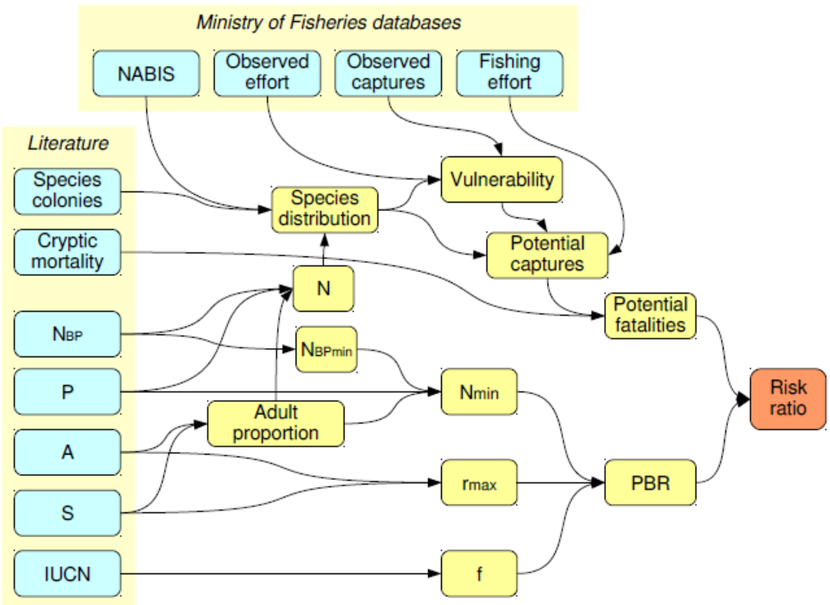


Figure 6.18: (reproduced from Richard et al 2011): Diagram of the modelling approach to calculate the risk index for each taxon. N_{BP}, number of annual breeding pairs; N, total number of birds over one year old; N_{BPmin}, lower 25% of the distribution of NBP; N_{min}, lower 25% of the distribution of the total number of birds over one year old; r_{max}, maximum population growth rate; *f*, recovery factor; PBR, Potential Biological Removal (set to 1.0 by Richard & Abraham 2013b); P, proportion of adults breeding in a given year; A, age at first reproduction; S, annual adult survival rate.

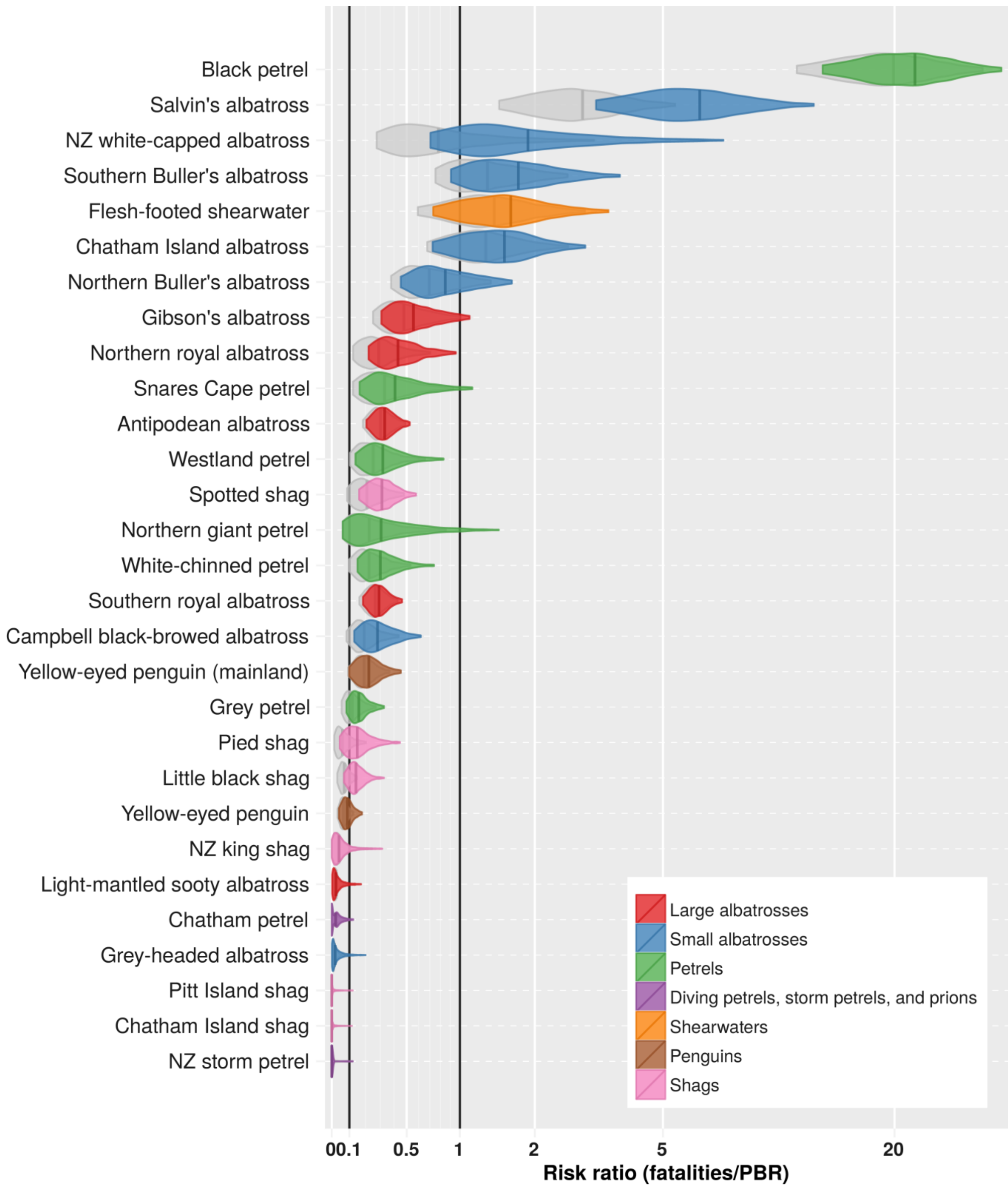


Figure 6.19: (reproduced from Richard & Abraham 2014) Risk ratio re-calculated on data from 2006–07 to 2012–13, after correcting errors in Richard & Abraham (2013b). The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential bird fatalities equalling the PBR with *f*= 0:1 and *f*= 1 indicated by the two vertical black lines, and the distribution of the corrected risk ratios within their 95% confidence interval indicated by the coloured shapes, including the median risk ratio (vertical line). The grey shapes indicate the risk ratios from the previous risk assessment report (Richard & Abraham 2013b). Seabird species are listed in decreasing order of the median risk ratio. Species with a risk ratio of almost zero were not included (95% upper limit with *f*= 1 less than 0.1). The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800.

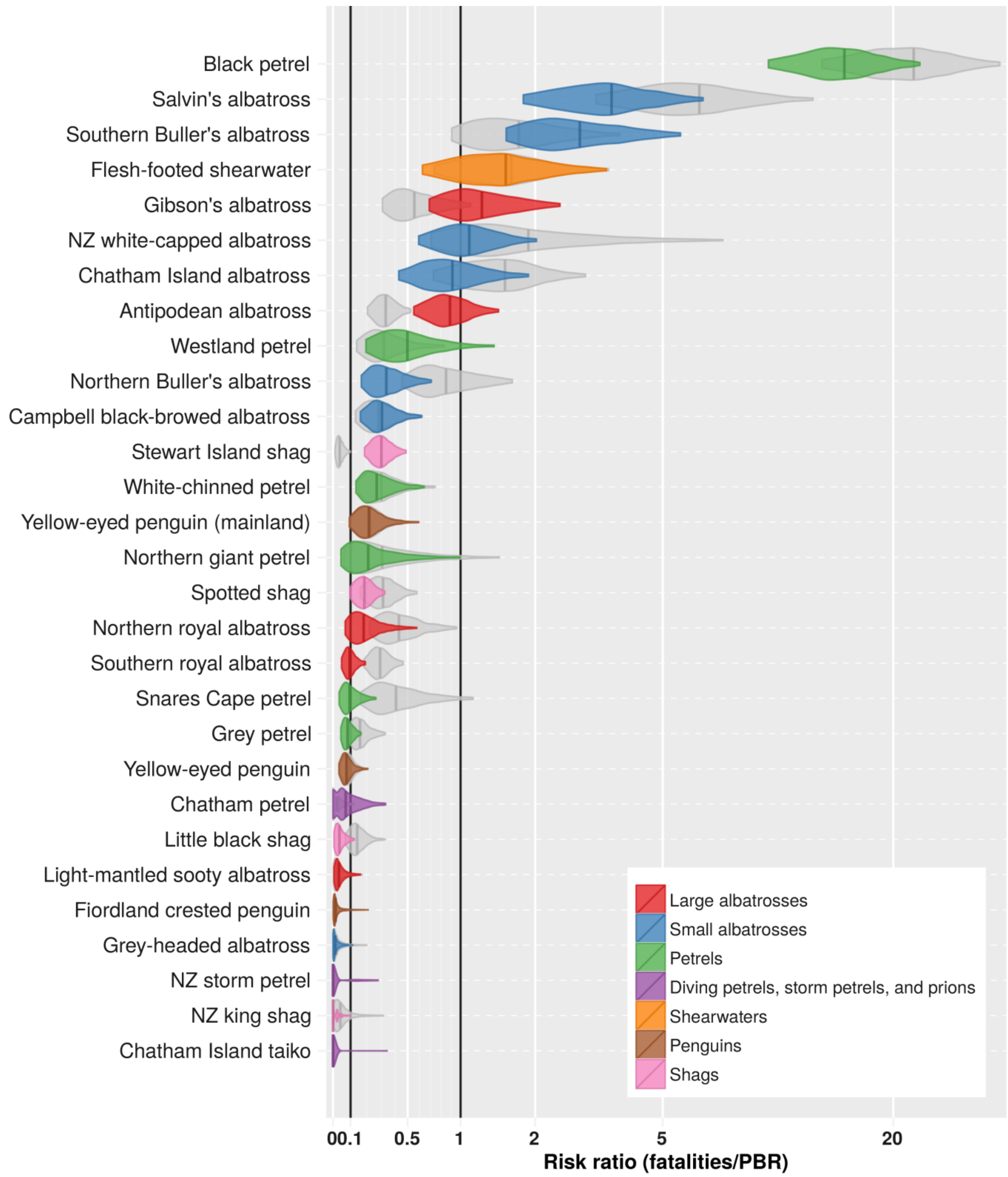


Figure 6.20: (reproduced from Richard & Abraham 2014) Risk ratio, updated to include data from the 2011–12 and 2012–13 fishing years. The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential bird fatalities equalling the PBR with *f* = 0:1 and *f* = 1 indicated by the two vertical black lines, and the distribution of the risk ratios within their 95% confidence interval indicated by the coloured shapes, including the median risk ratio (vertical line). Seabird species are listed in decreasing order of the median risk ratio. Species with a risk ratio of almost zero were not included (95% upper limit with *f* = 1 less than 0.1). The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800. The grey shapes indicate the risk ratios from the previous assessment (Richard & Abraham 2013b), corrected for errors, to show the change in risk since the 2010–11 fishing year.

Table 6.26: (reproduced from Richard & Abraham 2014) Comparison between the risk ratio reported by Richard & Abraham (2013b), after error correction, and in this study after updates. The table shows all species whose risk (in this study) had an upper 95% confidence limit greater than 0.1. Species names are coloured according to their risk category. Red: risk ratio with a median over 1 or upper 95% confidence limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1.

	Before updates		After updates	
	Median	95% c.i.	Median	95% c.i.
Black petrel	**22.46**	13.23–36.44	**15.09**	9.65–23.26
Salvin's albatross	**6.32**	3.18–12.57	**3.54**	1.81–6.47
Southern Buller's albatross	**1.74**	0.91–3.75	**2.82**	1.56–5.60
Flesh-footed shearwater	**1.63**	0.73–3.47	**1.56**	0.63–3.42
Chatham Island albatross	**1.55**	0.73–2.94	**0.91**	0.43–1.89
NZ white-capped albatross	**1.89**	0.71–7.32	**1.1**	0.59–2.02
Gibson's albatross	**0.56**	0.31–1.11	**1.24**	0.69–2.43
Northern Buller's albatross	**0.85**	0.45–1.65	**0.34**	0.17–0.71
Antipodean albatross	**0.33**	0.21–0.52	**0.89**	0.55–1.46
Westland petrel	**0.32**	0.14–0.83	**0.5**	0.20–1.40
Northern royal albatross	**0.43**	0.22–0.96	**0.18**	0.07–0.58
Snares Cape petrel	**0.41**	0.16–1.14	**0.09**	0.03–0.26
Campbell black-browed albatross	**0.28**	0.13–0.62	**0.3**	0.16–0.62
White-chinned petrel	**0.3**	0.15–0.74	**0.27**	0.13–0.64
Southern royal albatross	**0.29**	0.18–0.46	**0.09**	0.05–0.19
Northern giant petrel	**0.31**	0.06–1.47	**0.21**	0.04–0.99
Spotted shag	**0.31**	0.16–0.58	**0.19**	0.10–0.32
Grey petrel	**0.16**	0.08–0.33	**0.08**	0.04–0.16
Stewart Island shag	0.04	0.01–0.10	**0.3**	0.19–0.49
Little black shag	**0.14**	0.07–0.33	**0.04**	0.01–0.12
Yellow-eyed penguin	**0.09**	0.04–0.18	**0.08**	0.03–0.21
Chatham petrel	**0.02**	0.00–0.12	**0.07**	0.00–0.33
Light-mantled sooty albatross	**0.02**	0.00–0.17	**0.03**	0.01–0.16
NZ king shag	**0.04**	0.00–0.31	**0**	0.00–0.10
Grey-headed albatross	**0.02**	0.00–0.20	**0.01**	0.00–0.11
Fiordland crested penguin	0.01	0.00–0.06	**0.01**	0.00–0.21
NZ storm petrel	**0**	0.00–0.12	**0**	0.00–0.28
Chatham Island taiko	0	0.00–0.00	**0**	0.00–0.34

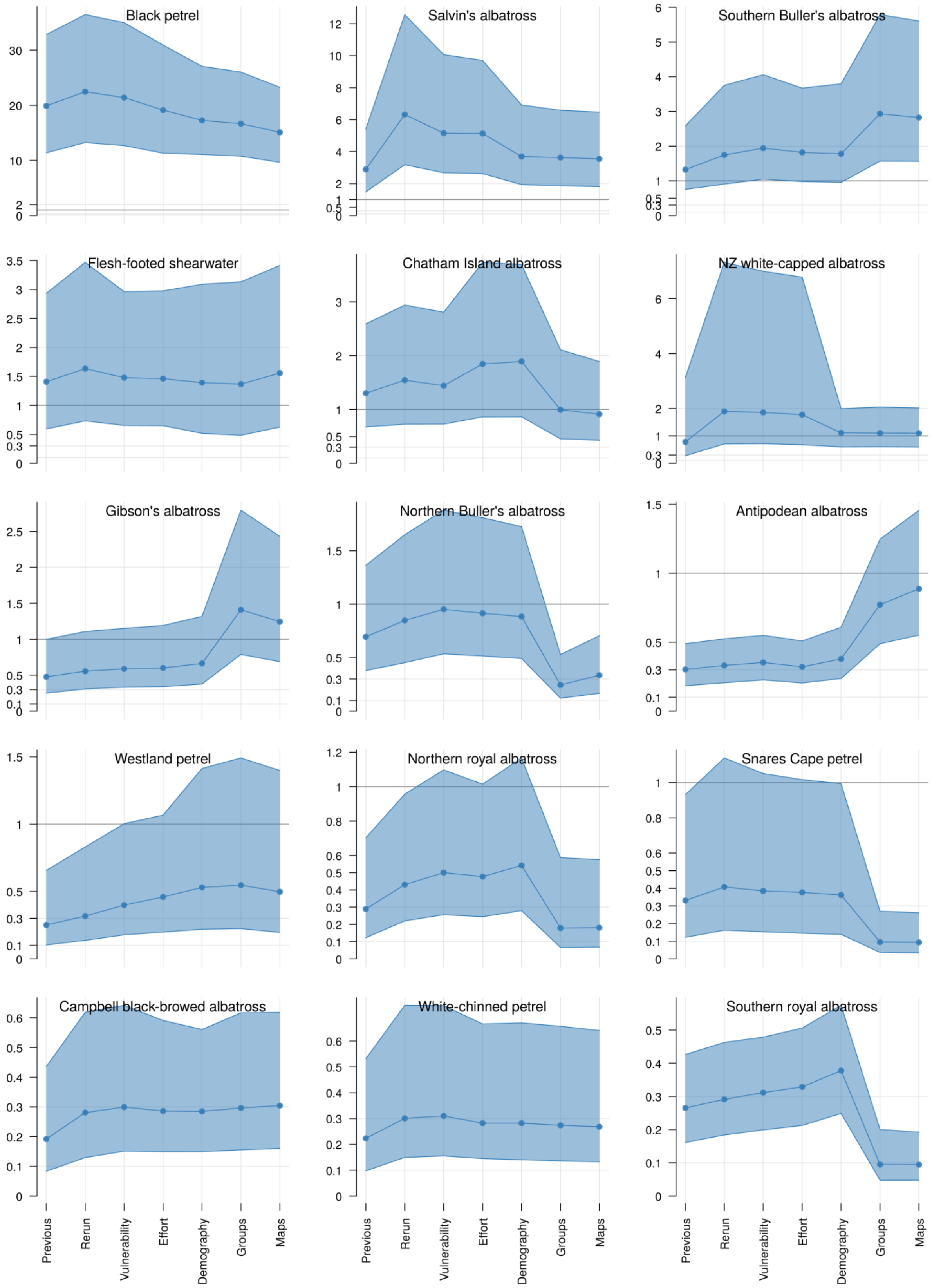


Figure 6.21: (reproduced from Richard & Abraham 2014) Progressive changes in the risk ratio. Previous: previous assessment (2013); Rerun: same years as 2013; Vulnerability: new fishing data, vulnerability estimated on 7 years, APFs on same 5 years as in previous assessment; Effort: effect of change in effort, vulnerability estimated on 7 years, APFs on last 3 years; Demography: updated demographic parameters; Groups: updated species and fishery groups; Maps: updated distribution maps. For the 15 species the most at risk.

Table 6.27: (reproduced from Richard & Abraham 2014) Potential Biological Removal (PBR_1, i.e., with a recovery factor f = 1), total annual potential fatalities (APF) in trawl, longline, and set-net fisheries, risk ratio with *f* = 1 (RR = APF/PBR_1), and the probability that APF > PBR with *f* = 1, *f* = 0:5, and *f* = 0:1 (P1, P0:5, and P0:1 respectively). Species are ordered in decreasing order of the median risk ratio. The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800. Species names are coloured according to their risk category. Red: risk ratio with a median over 1 or upper 95% confidence limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1. PBR_1 and APF are rounded to three significant digits.

	PBR_1		APF		Risk ratio		P_1	$P_{0.5}$	$P_{0.1}$
	Mean	95% c.i.	Mean	95% c.i.	Median	95% c.i.			
Black petrel	74	52–104	1 110	837–1 440	15.09	9.65–23.26	100.00	100.00	100.00
Salvin's albatross	1 010	632–1 600	3 520	2 280–5 330	3.54	1.81–6.47	99.97	100.00	100.00
Southern Buller's albatross	448	246–697	1 240	883–1 710	2.82	1.56–5.60	99.97	100.00	100.00
Flesh-footed shearwater	521	230–1 200	726	495–1 040	1.56	0.63–3.42	84.00	99.00	100.00
Gibson's albatross	182	98–285	222	161–307	1.24	0.69–2.43	73.85	99.92	100.00
NZ white-capped albatross	4 040	2 590–6 340	4 410	2 800–6 540	1.10	0.59–2.02	61.88	99.40	100.00
Chatham Island albatross	139	86–226	129	71–219	0.91	0.43–1.89	40.73	94.38	100.00
Antipodean albatross	136	99–188	121	84–176	0.89	0.55–1.46	31.45	99.00	100.00
Westland petrel	158	88–236	83	35–180	0.50	0.20–1.40	8.28	49.67	99.95
Northern Buller's albatross	542	297–848	178	111–273	0.34	0.17–0.71	0.05	15.90	99.97
Campbell black-browed albatross	677	428–947	210	118–354	0.30	0.16–0.62	0.02	7.80	99.97
Stewart Island shag	300	246–373	92	59–137	0.30	0.19–0.49	0.00	1.95	100.00
White-chinned petrel	5 210	2 660–8 260	1 420	876–2 600	0.27	0.13–0.64	0.22	8.15	99.95
Yellow-eyed penguin (mainland)	163	113–232	40	16–88	0.22	0.09–0.59	0.85	57.58	96.42
Northern giant petrel	168	56–356	36	9–95	0.21	0.04–0.99	2.40	14.20	82.83
Spotted shag	2 400	1 570–3 950	431	290–622	0.19	0.10–0.32	0.00	0.02	96.67
Northern royal albatross	261	134–432	50	20–113	0.18	0.07–0.58	0.18	4.03	87.38
Southern royal albatross	386	284–520	37	18–67	0.09	0.05–0.19	0.00	0.00	44.17
Snares Cape petrel	559	233–1 070	51	26–90	0.09	0.03–0.26	0.00	0.05	46.00
Grey petrel	2 160	1 230–3 200	175	109–271	0.08	0.04–0.16	0.00	0.00	30.75
Yellow-eyed penguin	466	319–650	40	16–90	0.08	0.03–0.21	0.10	0.48	25.15
Chatham petrel	9	4–20	1	0–2	0.07	0.00–0.33	0.00	0.40	37.38
Little black shag	216	128–358	9	1–23	0.04	0.01–0.12	0.00	0.00	5.42
Light-mantled sooty albatross	236	167–315	11	1–37	0.03	0.01–0.16	0.00	0.05	8.53
Pied shag	828	668–1 000	30	6–78	0.03	0.01–0.10	0.00	0.00	1.92
Fiordland crested penguin	323	214–426	10	0–66	0.01	0.00–0.21	0.02	0.20	7.50
Australasian gannet	2 770	1 220–5 730	39	3–126	0.01	0.00–0.06	0.00	0.00	0.35
Grey-headed albatross	219	132–329	5	0–22	0.01	0.00–0.11	0.00	0.05	3.05
Fluttering shearwater	1 780	1 040–2 780	25	3–94	0.01	0.00–0.06	0.00	0.00	0.20
Grey-faced petrel	12 100	5 590–27 100	100	43–189	0.01	0.00–0.02	0.00	0.00	0.00
Cook's petrel	2 250	1 050–5 040	16	6–33	0.01	0.00–0.02	0.00	0.00	0.00
Soft-plumaged petrel	59	26–130	0	0–2	0.01	0.00–0.04	0.00	0.00	0.00
Pycroft's petrel	94	44–213	1	0–2	0.01	0.00–0.03	0.00	0.00	0.00
Sooty shearwater	231 000	91 800–413 000	1 340	720–2 700	0.01	0.00–0.02	0.00	0.00	0.00
Northern little penguin	1 020	803–1 330	7	0–23	0.00	0.00–0.02	0.00	0.00	0.00
Mottled petrel	13 700	6 340–30 300	45	18–90	0.00	0.00–0.01	0.00	0.00	0.00
Hutton's shearwater	4 900	3 040–7 100	19	5–53	0.00	0.00–0.01	0.00	0.00	0.00
White-flippered little penguin	321	230–424	1	0–5	0.00	0.00–0.02	0.00	0.00	0.00
Southern little penguin	1 030	791–1 340	3	0–11	0.00	0.00–0.01	0.00	0.00	0.00
White-headed petrel	12 300	5 410–26 300	14	5–27	0.00	0.00–0.00	0.00	0.00	0.00
Common diving petrel	26 700	17 200–38 900	33	9–98	0.00	0.00–0.00	0.00	0.00	0.00
Snares crested penguin	3 210	2 120–4 320	4	0–18	0.00	0.00–0.01	0.00	0.00	0.00
Buller's shearwater	9 760	4 640–20 100	10	1–34	0.00	0.00–0.00	0.00	0.00	0.00
Black-bellied storm petrel	3 470	2 110–5 720	2	0–7	0.00	0.00–0.00	0.00	0.00	0.00
NZ white-faced storm petrel	56 200	33 300–93 400	46	8–181	0.00	0.00–0.00	0.00	0.00	0.00
Southern black-backed gull	199 000	132 000–298 000	94	26–212	0.00	0.00–0.00	0.00	0.00	0.00
Chatham Island little penguin	1 020	792–1 320	3	0–18	0.00	0.00–0.02	0.00	0.00	0.00
Fairy prion	85 100	53 800–133 000	41	9–132	0.00	0.00–0.00	0.00	0.00	0.00
Little shearwater	5 700	3 680–8 130	2	0–8	0.00	0.00–0.00	0.00	0.00	0.00
Eastern rockhopper penguin	6 410	5 290–7 960	2	0–11	0.00	0.00–0.00	0.00	0.00	0.00
Antarctic prion	13 900	7 820–23 800	2	0–6	0.00	0.00–0.00	0.00	0.00	0.00
Broad-billed prion	69 400	39 800–110 000	15	2–73	0.00	0.00–0.00	0.00	0.00	0.00
Erect-crested penguin	12 100	9 940–15 300	1	0–3	0.00	0.00–0.00	0.00	0.00	0.00
Auckland Island shag	164	122–217	0	0–2	0.00	0.00–0.01	0.00	0.00	0.00
Bounty Island shag	13	10–17	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Subantarctic skua	31	19–44	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Caspian tern	135	80–201	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Chatham Island shag	45	35–56	0	0–2	0.00	0.00–0.04	0.00	0.00	0.55
Campbell Island shag	196	127–264	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
White-bellied storm petrel	44	24–75	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
White tern	15	12–19	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
South Georgian diving petrel	3	2–4	0	0–0	0.00	0.00–0.00	0.00	0.00	0.75
NZ king shag	15	12–18	0	0–2	0.00	0.00–0.10	0.00	0.08	2.62
Kerm. storm petrel	2	1–3	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Masked booby	35	23–51	0	0–0	0.00	0.00–0.01	0.00	0.00	0.00
NZ storm petrel	2	1–4	0	0–1	0.00	0.00–0.28	0.02	0.42	15.03
Pitt Island shag	65	42–88	0	0–3	0.00	0.00–0.04	0.00	0.00	0.72
Chatham Island taiko	1	0–2	0	0–0	0.00	0.00–0.34	0.02	1.10	3.30
Wedge-tailed shearwater	3 890	2 600–5 360	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Kerm. petrel	295	139–634	0	0–1	0.00	0.00–0.00	0.00	0.00	0.00
White-naped petrel	1 950	856–4 370	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00

Table 6.28: Estimated of annual potential seabird fatalities by fishing method and target species/species group (from Richard & Abraham 2014, tables A-9 to A-16).

Fishing method	Target	Total annual potential seabird fatalities	95% c.i.
Trawl	Inshore	4 370	2 790-6 500
	Squid	1 950	1 330-2 980
	Hoki	1 420	989-2 020
	Scampi	1 200	786-1 880
	Middle depth	1 160	787-1 670
	Flatfish	928	571-1 460
	Ling	162	109-234
	Hake	117	76-172
	Deepwater	79	46-125
	Jack mackerel	77	48-125
	Southern blue whiting	64	39-105
Bottom longline	Snapper	759	535-1 020
	Small vessel, ling	706	484-978
	Bluenose	550	351-800
	Hapuka	434	268-671
	Minor targets	337	209-523
	Large vessel, ling	120	87-160
Surface longline	Bigeye	593	471-742
	Small vessel, southern bluefin	584	452-747
	Swordfish	206	146-282
	Large vessel, southern bluefin	39	23-57
	Minor targets	16	10-22
	Albacore	4	2-6
Setnet	Shark	136	97-184
	Flatfish	102	62-154
	Minor targets	75	51-105
	Grey mullet	14	7-23
Total		16 200	12 600-21 000

Table 6.29 provides a comparison of the estimated number of annual observable captures of seabirds including and not including cryptic mortality in trawl, bottom-longline, surface-longline, and set-net fisheries. Excluding cryptic mortalities, the estimated mean number of observable black petrel captures was 544 (95% c.i. 425–675), exceeding PBR_1 (Richard & Abraham 2014).

The method described by Richard et al (2011) and Richard & Abraham (2013b, 2014) offers the following advantages that make it particularly suitable for assessing risk to multiple seabird populations from multiple fisheries:

- risk is assessed separately for each seabird taxon; fisheries managers must assess risk to seabirds with reference to units that are biologically meaningful;
- the method does not rely on the existence of universal or representative fisheries observer data to estimate seabird mortality (fisheries observer coverage is generally too low and/or too spatially unrepresentative to allow direct impact estimation at the species or subspecies level); the method can be applied to any fishery for which at least some observer data exists;
- the method does not rely on detailed population models (the necessary data for which are unavailable for the great majority of taxa) because risk is estimated as a function of population-level potential fatalities and biological parameters that are generally available from published sources;
- the method assigns risk to each taxon in an absolute sense, i.e. taxa are not merely ranked relative to one another; this allows the definition of biologically meaningful performance standards and ability to track changes in performance over time and in relation to risk management interventions;

Table 6.29: (reproduced from Richard & Abraham 2014) Estimated number of annual observable captures of seabirds (not including cryptic mortality), and estimated number of annual potential fatalities (including cryptic mortality) in trawl, bottom-longline, surface-longline, and set-net fisheries in New Zealand's Exclusive Economic Zone. The species names are coloured according to their respective risk categories: Red: risk ratio with a median over 1 or upper 95% confidence limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1.

Species	No cryptic mortality		With cryptic mortality	
	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	95	71–125	223	163–307
Antipodean albatross	51	36–70	122	85–176
Southern royal albatross	12	7–21	38	19–69
Northern royal albatross	13	5–30	51	20–115
Campbell black-browed albatross	83	44–145	211	119–356
NZ white-capped albatross	633	525–751	4 420	2 820–6 540
Salvin's albatross	583	463–723	3 520	2 270–5 340
Chatham Island albatross	50	26–90	129	71–220
Grey-headed albatross	2	0–9	5	0–22
Southern Buller's albatross	330	256–421	1 260	901–1 730
Northern Buller's albatross	78	50–113	179	110–274
Light-mantled sooty albatross	3	0–12	11	1–38
Northern giant petrel	5	1–15	36	9–95
Grey petrel	77	51–117	176	111–273
Black petrel	544	425–675	1 110	834–1 440
Westland petrel	35	16–75	83	36–177
White-chinned petrel	507	454–571	1 430	885–2 600
Flesh-footed shearwater	316	227–423	726	498–1 030
Wedge-tailed shearwater	0	0–0	0	0–0
Buller's shearwater	5	0–16	10	1–34
Sooty shearwater	418	341–521	1 340	720–2 690
Fluttering shearwater	13	2–45	25	3–93
Hutton's shearwater	12	4–28	19	5–53
Little shearwater	1	0–4	2	0–8
Snares Cape petrel	37	19–63	51	26–91
Fairy prion	23	5–70	41	9–131
Antarctic prion	1	0–2	2	0–7
Broad-billed prion	7	1–36	15	2–72
Pycroft's petrel	0	0–1	1	0–2
Cook's petrel	8	3–16	16	6–33
Chatham petrel	0	0–1	1	0–2
Mottled petrel	22	9–44	45	17–90
White-naped petrel	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–1
Grey-faced petrel	48	21–90	100	44–187
Chatham Island taiko	0	0–0	0	0–0
White-headed petrel	6	2–13	14	5–27
Soft-plumaged petrel	0	0–1	0	0–1
Common diving petrel	14	4–39	33	9–99
South Georgian diving petrel	0	0–0	0	0–0
NZ white-faced storm petrel	26	4–94	46	8–182
White-bellied storm petrel	0	0–0	0	0–0
Black-bellied storm petrel	1	0–5	2	0–7
Kermadec storm petrel	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0
Yellow-eyed penguin	36	16–68	40	16–88
Northern little penguin	5	0–16	7	0–23
White-flippered little penguin	1	0–5	1	0–5
Southern little penguin	2	0–8	3	0–11
Chatham Island little penguin	1	0–9	2	0–18
Eastern rockhopper penguin	1	0–6	2	0–11
Fiordland crested penguin	6	0–32	10	0–66
Snares crested penguin	3	0–10	4	0–18
Erect-crested penguin	0	0–2	1	0–3
Australasian gannet	36	2–122	39	3–125
Masked booby	0	0–0	0	0–0
Pied shag	27	5–69	30	5–77
Little black shag	8	1–22	9	1–23
NZ king shag	0	0–1	0	0–1
Stewart Island shag	71	48–98	92	59–138
Chatham Island shag	0	0–1	0	0–2
Bounty Island shag	0	0–0	0	0–0
Auckland Island shag	0	0–1	0	0–1
Campbell Island shag	0	0–0	0	0–0
Spotted shag	339	239–464	431	289–630
Pitt Island shag	0	0–1	0	0–3
Subantarctic skua	0	0–0	0	0–0
Southern black-backed gull	45	13–95	94	27–213
Caspian tern	0	0–0	0	0–0
White tern	0	0–0	0	0–0

- risk scores are quantitative and objectively scalable between fisheries or areas, so that risk at a population level can be disaggregated and assigned to different fisheries or areas based on their proportional contribution to total impact to inform risk management prioritisation;
- the method allows explicit statistical treatment of uncertainty, and does not conflate uncertainty with risk; numerical inputs include error distributions and it is possible to track the propagation of uncertainty from inputs to estimates of risk; and
- the method readily incorporates new information; assumptions in the assessment are transparent and testable and, as new data becomes available, the consequences for the subsequent impact and risk calculations arise logically without the need to revisit other assumptions or repeat the entire risk assessment process.

The key disadvantages of the method of Richard et al (2011), many of which were addressed by subsequent iterations (Richard & Abraham 2013b, 2014), were that:

- fisheries for which no observer information on seabird interactions is available cannot be included in the analysis;
- the assumption that the vulnerabilities of particular seabirds to capture in different fisheries are independent does not allow “sharing” of scarce observer information between fisheries within the risk assessment (addressed in subsequent iterations);
- the spatial overlap method relies on appropriate spatial and temporal scales for the distributions of birds and fishing effort being used; use of inappropriate scales can lead to misleading results (partially addressed in 2013 revision);
- strong assumptions have to be made about the distribution and productivity of some taxa, the relative vulnerability of different taxa to capture by particular fisheries, cryptic mortality associated with different fishing methods, and the applicability of the allometric method of estimating Potential Biological Removals (partially addressed in 2013 revision).

Most of these limitations are a result of the scarcity of relevant data on seabird populations and fisheries impacts and can be addressed only through the collection of more information or, in some cases, sensitivity testing. Further refinement of this method would be possible if:

- Estimates of PBR could be compared with total annual human caused mortality rather than mortality from commercial fishing within the New Zealand region. Little is known about the impact of New Zealand recreational fishing on seabirds or fatalities in overseas fisheries of seabirds that forage beyond New Zealand’s waters.
- Better information on cryptic mortality was available. Studies on cryptic mortality are extremely limited.
- Further observer coverage was targeted at fisheries where substantial reductions in the uncertainty about potential fatalities would result (most such fisheries are poorly observed).

It should be noted that the level two risk assessments conducted thus far (Richard et al. 2011, Richard & Abraham 2013b, 2014) includes APFs in commercial fisheries within New Zealand’s EEZ but excludes non-commercial impacts, fatalities on the High Seas and in other jurisdictions, and all other anthropogenic sources of mortality. Because of this focus and the definition of PBR as a level of mortality that can support all anthropogenic sources of mortality and still lead to good population outcomes, the risk ratios estimated by Richard & Abraham (2014) will be underestimates of the total risk faced by each taxon and interpretation should be in this context. Many of the other anthropogenic sources of mortality excluded from the risk assessment are poorly understood, although MPI will shortly commission a “global” seabird risk assessment to include at least the commercial fishing components under project PRO2013-13.

6.4.5.2 FULLY QUANTITATIVE MODELLING

Fully quantitative population modelling has been conducted only for southern Buller’s albatross, black petrel, white capped albatross, and Gibson’s (wandering) albatross. Data of similar quality and quantity are available for Antipodean (wandering) albatross, and this modelling will be conducted in 2015 under MPI project PRO2012-10, but data for other species or populations appear unlikely to be adequate for comprehensive population modelling. The poor estimates of observable and cryptic fishing-related mortality have restricted such work to comprehensive population modelling rather than formal assessment of risk.

6.4.5.2.1 QUANTITATIVE MODELS FOR SOUTHERN BULLER'S ALBATROSS

Francis et al (2008, see also Francis & Sagar 2012) assessed the status of the Snares Islands population of southern Buller's albatross (*Thalassarche bulleri bulleri*). They estimated (see also Sagar & Stahl 2005) that the adult population had increased about 5-fold since about 1950 (Figure 6.22) at a rate of about 2% per year, and concluded from this that the risk to the viability of this population posed by fisheries had been small. This conclusion depends critically on the reliability of the first census of nesting birds conducted in 1969, but the authors give compelling reasons to trust that information. In summary, the later censuses did not find any concentrations of nests that were not present on the maps prepared during the 1969 census and the increase in counts after 1969 occurred in all census subareas and also in five colonies where counts were made in many non-census years. Francis et al (2008) noted, however, that population growth had slowed by about 2005 (and perhaps reversed) and adult survival rates were falling, but could discern neither the cause nor significance of these changes because they had included survival data only up to 2007. An additional 8 years of survival and other demographic data have since been recorded all monitored sites at the Snares Islands showed substantial declines in the number of breeding pairs from 2006 to 2010 (Sagar et al 2010) but increased since (Richard Wells, pers.comm.). The modelling will be repeated in 2015 under MPI project PRO2013-17.

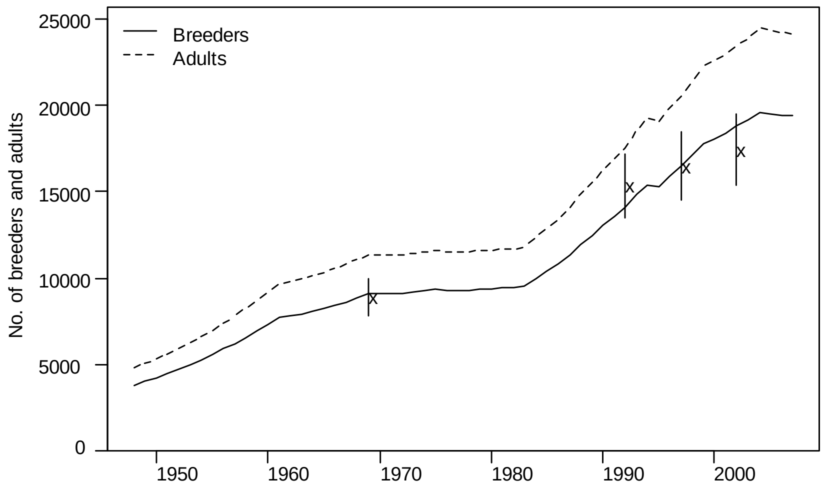


Figure 6.22: (from Francis et al 2008): Estimates from model SBA21 of numbers of breeders (solid line) and adults (broken line) in each year. Also shown are the census observations (after (Sagar & Stahl 2005) of numbers of breeders (crosses), with assumed 95% confidence intervals (vertical lines).

Fishery discards are an important component of the diet of chicks, but Francis et al (2008) were not able to assess whether the associated positive effect on population growth (e.g., from increased breeding success) is greater or less than the negative effect of fishing-related mortality.

6.4.5.2.2 QUANTITATIVE MODELS FOR BLACK PETREL

Francis & Bell (2010) analysed data from the main population of black petrel (*Procellaria parkinsoni*), which breeds on Great Barrier Island. Abundance data from transect surveys were used to infer that the population was probably increasing at a rate between 1.2% and 3.1% per year. Mark-recapture data were useful in estimating demographic parameters, like survival and breeding success, but contained little information on population growth rates. Fishery bycatch data from observers were too sparse and imprecise to be useful in assessing the contribution of fishing-related mortality. Francis & Bell (2010) suggested that, because the population was probably increasing, there was no evidence that fisheries posed a risk to the population at that time. They cautioned that this did not imply that there was clear evidence that fisheries do not pose a risk.

Subsequent analysis (Bell et al 2012) included an additional line transect survey in 2009-10 in which the breeding population was estimated to be about 22% lower than in 2004-05 (the latest available to Francis & Bell, 2010). Updating the model of Francis & Bell (2010) made little difference to estimates of demographic parameters such as adult survival, age at first breeding, and juvenile survival (which had 95% confidence limits of 0.67 and 0.91). The uncertainty in juvenile survival gave rise to uncertainty in the estimated population trend, with a mean rate of population growth over the modelling period ranging from -2.5% per year (if juvenile survival = 0.67) to +1.6% per year (if juvenile survival = 0.91, close to the average annual survival rate for older birds) (Figure 6.23). Bell et al (2012) concluded that the mean rate of change of the population over the study period had not exceeded 2% per year, though the direction of change was uncertain. The latest counts have increased, due mainly to increases in breeding rate and (Bell et al 2013), suggesting even more uncertainty about population trend than when the quantitative modelling was last updated.

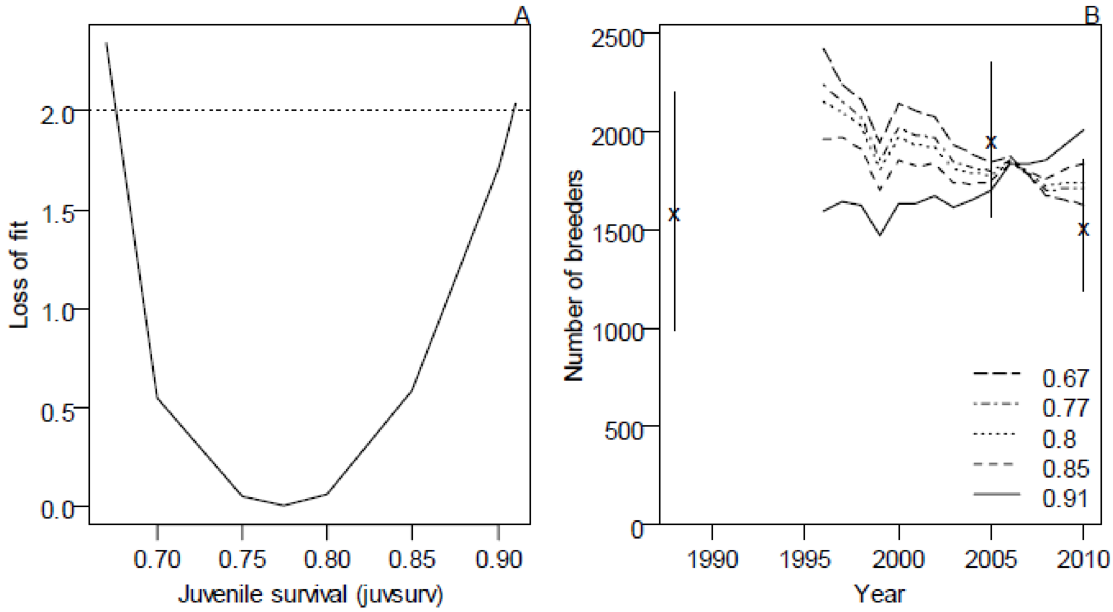


Figure 6.23: (from Bell et al 2012) Likelihood profile for annual probability of juvenile survival showing: A, the loss of fit (the horizontal dotted line shows a 95% confidence interval for this parameter); and B, population trajectories corresponding to different values of juvenile survival, together with population estimates from transect counts (crosses with vertical lines indicating 95% confidence intervals. Note that the 1988 population estimate was not used in the model.

6.4.5.2.3 QUANTITATIVE MODELS FOR WHITE-CAPPED ALBATROSS

Francis (2012) described quantitative models for white-capped albatross (*Thalassarche steadi*), New Zealand's most numerous breeding albatross, and the most frequently captured, focussing on the population breeding at the Auckland Islands. After a correction for a probable bias introduced by sampling at different times of day in one of the surveys, aerial photographic counts by Baker et al (2007b, 2008b, 2009a, and 2010a) suggest that the adult population declined at about 9.8% per year between 2006 and 2009. However, this estimate is imprecise and is not easily reconciled with the high adult survival rate (0.96) estimated from mark-recapture data. Francis (2012) also compared the trend with his estimate of the global fishing-related fatalities of white-capped albatross (slightly over 17 000 birds per year, about 30% of which is taken in New Zealand fisheries) and found that fishing-related fatalities were insufficient to account for the number of deaths implied by a decline of 9.8% per year (roughly 22 000 birds per year over the study period). The scarcity of information on cryptic mortality makes these estimates and conclusions uncertain, however. Since this modelling was conducted, further counts of white-capped albatross have been conducted (Baker et al 2014b, Figure 6.24) which show considerable annual variation. Baker et al. (2014b) consider that the substantial year to year variation in counts is real, and that trend analyses appropriate in this situation support the null hypothesis of no trend in the population.

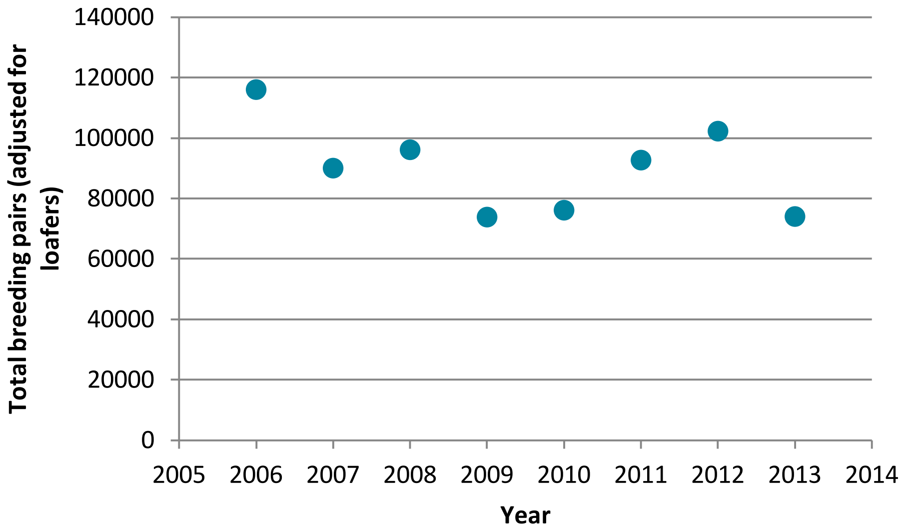


Figure 6.24: (Data from Baker et al 2014b): Total counts of white-capped albatross at the Auckland Islands (as adjusted for the presence of non-breeding birds).

6.4.5.2.4 QUANTITATIVE MODELS FOR GIBSON'S ALBATROSS

Francis et al (2013) concluded that there is cause for concern about the status of the population of Gibson's wandering albatross (*Diomedea gibsoni*) on the Auckland Islands. Since 2005, the adult population has been declining at 5.7%/yr (95% c.i. 4.5–6.9%) because of sudden and substantial reductions in adult survival, the proportion of adults breeding, and the proportion of breeding attempts that are successful (Figure 6.25). Forward projections showed that the most important of these to the future status of this population is adult survival (Figure 6.26).

The population in 2011 was 64% (58–73%) of its estimated size in 1991. The breeding population dropped sharply in 2005, to 59% of its 1991 level, but has been increasing since 2005 at 4.2% per year (2.3–6.1%). The 2011 breeding population is estimated to be only 54% of the average of 5831 pairs estimated by Walker & Elliott (1999) for 1991–97.

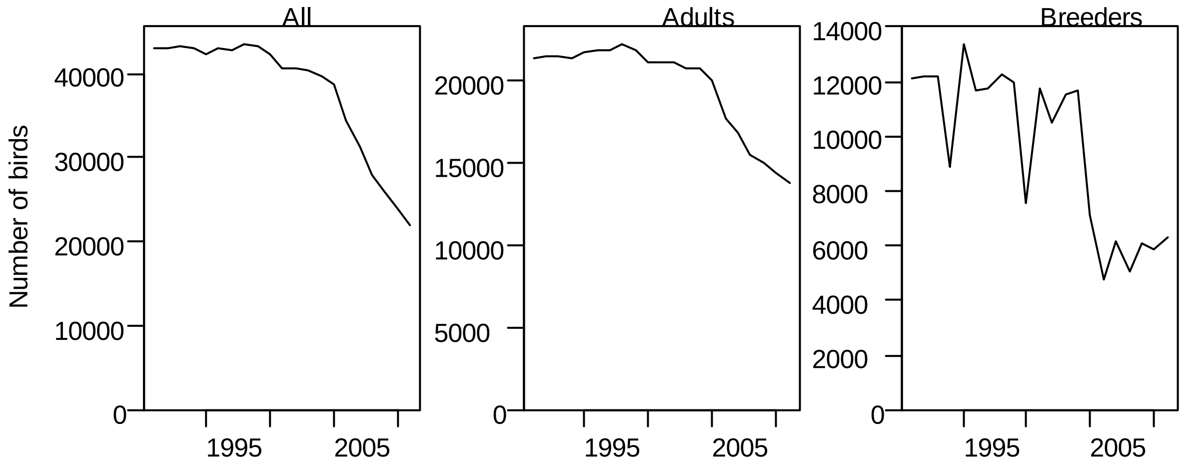


Figure 6.25: Estimated population trajectories for the whole Auckland Islands population of Gibson's wandering albatross. These were calculated by scaling up Francis et al's (2013) GIB5 trajectories to match the Walker & Elliott (1999) estimate for the whole population.

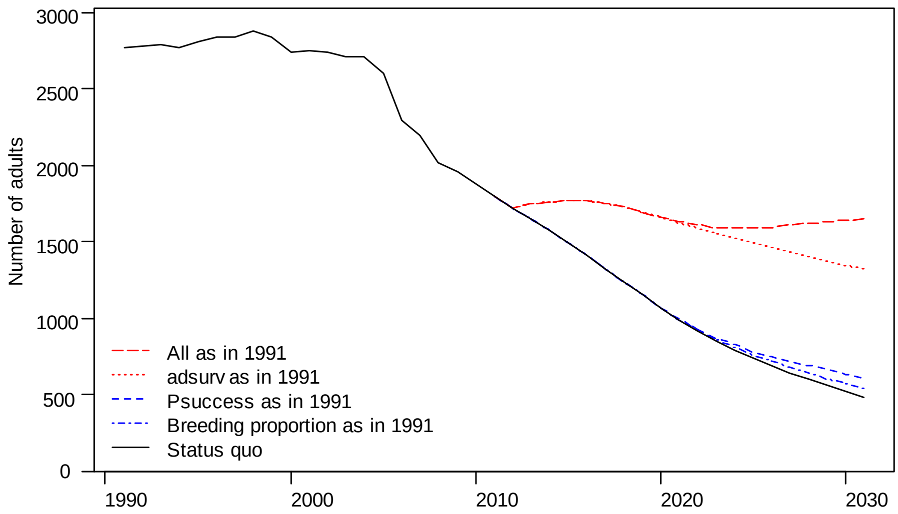


Figure 6.26: Estimated population trajectory for adults from Francis et al's (2013) model GIB5 with 20-year projections under five alternative scenarios about three demographic parameters: adult survival (adsurv); breeding success (Psuccess); and proportion of adults breeding. These scenarios differ according to whether each parameter remains at its status quo (i.e. 2011) level or recovers immediately to its 1991 level.

Francis et al (2013) found it difficult to assess the effect of fisheries mortality on the viability of this population because, although some information exists about captures in New Zealand and Australian waters, the effect of fisheries in international waters is unknown. Three conclusions are possible from the available data: most fisheries mortality of Gibson's is caused by surface longlines; mortality from fishing within the New Zealand EEZ is now probably lower than it was; and there is no indication that the sudden and substantial drops in adult survival, the proportion breeding, and breeding success were caused primarily by fishing.

6.4.5.2.5 OTHER QUANTITATIVE MODELS

This section is not intended to cover all quantitative modelling of seabird populations, rather to focus on recent studies that sought to assess the impact of fishing-related mortality.

Maunder et al (2007) sought to assess the impact of commercial fisheries on the Otago Peninsula yellow-eyed penguins using mark-recapture data within a population dynamics model. They found the data available at that time inadequate to assess fisheries impacts, but evaluated the likely utility of additional information on annual survival or an estimate of bycatch for a single year. Including auxiliary information on average survival in the absence of fishing allowed estimation of the fishery impact, but with poor precision. Including an estimate of fishery-related mortality for a single year improved the precision in the estimated fishery impact. The authors concluded that there was insufficient information to determine the impact of fisheries on yellow-eyed penguins and that quantifying fishing-related mortality over several years was required to undertake such an assessment using a population modelling approach.

Fletcher et al (2008) sought to assess the potential impact of fisheries on Antipodean and Gibson's wandering albatrosses (*Diomedea antipodensis antipodensis* and *D. a. gibsoni*); black petrel (*Procellaria parkinsoni*) and southern royal albatross (*Diomedea epomophora*). Because of problems with the available fisheries and biological data, they were unable to use their models to predict the impact of a change in fishing effort on the population growth rate of a given species. Instead, they used the models to estimate the impact that changes in demographic parameters like annual survival are likely to have on population growth rate. They found that: reducing breeder survival rate by k percentage points will lead to a reduction in the population growth rate of about 0.3k percentage points (0.4 for black petrel); and a reduction of k percentage points in the survival rate for each stage in the life cycle (juvenile, pre-breeder, non-breeder and breeder) will lead to a reduction in the population growth rate of approximately k percentage points. Fletcher et al (2008) also made estimates of PBR for 23 New Zealand seabird taxa and summarised and tabulated non-fishing-related threats for 38 taxa.

Newman et al (2009) combined survey data with demographic population models to estimate the total population of sooty shearwaters within New Zealand. They estimated the total New Zealand population between 1994 and 2005 to have been 21.3 (95% c.i. 19.0–23.6) million birds. The harvest of "muttonbirds" was estimated to be 360 000 (320 000–400 000) birds per year, equivalent to 18% of the chicks produced in the harvested areas and 13% of chicks in the New Zealand region. This directed harvest is much larger than estimates of captures in key fisheries or potential fatalities in the level 2 risk assessment (Table 6.29). Newman et al (2009) did not assess the likely impact of fishing-related mortality and did not consider the different population-level impacts of adult mortality in fisheries and chick mortality in the directed harvest, but concluded that the much larger directed harvest was not an adequate explanation for the observed declines in the past three decades.

6.4.5.2.6 GENERAL CONCLUSIONS FROM QUANTITATIVE MODELLING

Fully quantitative modelling has now been conducted for four of the five seabird populations for which apparently suitable data are available. This modelling suggests very strongly that one population had been increasing steadily (southern Buller's albatross, but note that this trend may have since reversed) and another is declining quite rapidly (Gibson's albatross). White-capped albatross and black petrel were both assessed at the time of the modelling to be more likely to be declining than not but, even for these relatively data rich populations, the conclusions were uncertain. Higher counts have been recorded for both species since the modelling was conducted. General conclusions from the modelling conducted to date, therefore, can be summarised as:

- Very few seabird populations have sufficient data for fully quantitative modelling.
- Except for the two most complete data sets (southern Buller's and Gibson's albatross) it has been difficult to draw firm conclusions about trends in population size.
- Information from surveys or census counts is much more powerful for detecting trends in population size than data from the tagging programmes and plot monitoring implemented for New Zealand seabirds to date.
- The available information on incidental captures in fisheries have not allowed rigorous tests of the role of fishing-related mortality in driving population trends.
- Although comprehensive modelling provides additional information to allow interpretation, we will have to rely on level 2 risk assessment approaches for much of our understanding of the relative risks faced by different seabird taxa and posed by different fisheries.

6.4.5.3 SEABIRD SPECIES IDENTIFIED AS BEING AT VERY HIGH RISK IN THE 2014 SEMI-QUANTITATIVE RISK ASSESSMENT

6.4.5.3.1 BLACK PETREL

The black petrel was found to be the species the most at risk from commercial fisheries in New Zealand, with a median risk ratio of 15.09 (95% c.i.: 9.65–23.26), a net decrease in the risk ratio from 22.46 in 2013 (95% c.i.: 13.23–36.44) (Figure 6.20, Figure 6.21, Table 6.26, Table 6.27, Richard & Abraham 2013b, with errors corrected). The mean PBR_1 was estimated at 74 (95% c.i.: 52–104), and the mean annual potential fatalities (APF) of black petrel was estimated to be 1 110 (95% c.i.: 837–1440). The estimated annual potential fatalities of black petrel were mostly in small-vessel bottom-longline fisheries.

Although the estimated risk ratio of black petrel is "Very High", the population trend of black petrel is unclear. Data from random transect surveys of the main Great Barrier Island colony, conducted in 2004–05, 2009–10, and 2012–13 suggested an apparent population decline of 22% over the 5 years to 2009–10, followed by an apparent increase of 110% between 2009–10 and 2012–13 (Bell et al. 2013). On the other hand, the trend obtained from census grid data estimated a population growth rate between -2.3% and 2.5% per year, depending on juvenile annual survival. Assuming a juvenile annual survival rate of 88%, the population growth rate was estimated to be -1.1% per year (Bell et al. 2013).

The calculation of the PBR included a correcting factor ρ to adjust the bias introduced by the approximations in the calculation of r_{max} and of the total population size from the number of annual breeding pairs (Richard & Abraham 2013a). Black petrel is the only species for which an estimate of the total population size was available, calculated from the proportion of banded birds in the observed captures at sea, in relation to the number of birds banded that were estimated to be alive. The number of annual breeding pairs was then back-calculated from the estimate of total population size to be treated in a similar way as other species. In that case, the correction of the calculation of the total population size is unnecessary. However, because the ρ factor also corrects for the calculation of r_{max}, it was left in the PBR calculation. As a consequence, the PBR may be underestimated, and the risk ratio therefore overestimated. However, correcting for this overestimation would not change the risk category nor the ranking of this species, as removing the ρ factor from the PBR calculation altogether would still result in a median risk ratio of 5.11 (95% c.i.: 3.14–7.76).

One explanation for the apparent relative stability of the black petrel population, despite the high risk ratio, is that the population size is substantially underestimated. The population counts are made within a 35 ha study area, at the top of Mount Hobson (Hirakimata) on Great Barrier Island. In this analysis, these counts were used as a lower estimate of the population size, with an analysis of the capture of banded birds at sea providing another method for estimating the total population that are available to be caught.

There were many assumptions needed to make this estimate, and it is possible that the population on Little Barrier is larger than assumed, or that there are more breeding black petrel on Great Barrier, away from the study colony. Confirming the estimate of the entire black petrel population will help to reduce uncertainty in the risk ratio.

Further research will be conducted during the 2014-15 summer to better understand the population size of black petrel on Great Barrier Island and Little Barrier Island. This project is being conducted under DOC CSP project POP2014-02 (Contract 4623), supported by MPI project PRO2014-05.

6.4.5.3.2 SALVIN'S ALBATROSS

The risk of fisheries to Salvin's albatross was estimated to be the second highest, with a median risk ratio of 3.54 (95% c.i.: 1.81–6.47). This was a decrease from the estimate of 6.32 (95% c.i.: 3.18–12.57) in 2013 (Figure 6.20, Figure 6.21, Table 6.26, Table 6.27, Richard & Abraham 2013b, corrected for errors). Most of this decrease was due to changes in the demographic parameters, which included an increase in the estimated number of breeding pairs. In this assessment, the mean PBR_1 was estimated at 1010 (95% c.i.: 632–1600) and the mean annual potential fatalities at 3520 (95% c.i.: 2280–5330), mainly in trawl fisheries. Of the estimated annual potential fatalities of this species, over half were in inshore trawl fisheries, with observed captures occurring at the western, inshore end of the Chatham Rise.

Population surveys in the Bounty Islands indicated that the annual number of breeding pairs of Salvin's albatross on Proclamation Island declined by an estimated 30% between 1997 and 2011, and by 10% between 2004 and 2011 on Depot Island (Amey & Sagar 2013). There wa some indication of a decline in the number of birds attending bird-watching vessels near Kaikoura (Richard et al. 2014), with a best estimate of the rate of decline of around 5% (although not significantly different from no decline). However, Baker et al (2014a) conducted repeated their 2010 aerial survey in 2013 and found 26% more birds breeding in 2013 than in 2010. The conservation status of this species changed in 2013 from Naturally Vulnerable to Nationally Critical, according to the New Zealand Threat Classification System (Robertson et al. 2013).

6.4.5.3.3 SOUTHERN BULLER'S ALBATROSS

The third highest risk ratio was estimated to be of the southern Buller's albatross, with a median risk ratio of 2.82 (95% c.i.: 1.56–5.6). The mean annual potential fatalities was estimated to be 1240 (95% c.i.:883–1710), including 215 in surface-longline and 163 in trawl fisheries. The mean PBR_1 was estimated to be 448 (95% c.i.: 246–697). The risk ratio in 2013 was 1.74 (95% c.i.:0.91–3.75) (Figure 6.20, Figure 6.21, Table 6.26, Table 6.27, Richard & Abraham 2013b, corrected for errors), and the increase to 2.82 was predominantly caused by a change in the species groups (Figure 6.21). Southern and northern Buller's albatrosses were grouped together for the estimation of vulnerability in the previous assessment, whereas they were split in the 2014 assessment.

The separation of the two Buller's albatross species was somewhat arbitrary, relying on a latitudinal cut off (all captures of Buller's albatross north of 40◦S being treated as northern Buller's albatross), and a seasonal cut-off (captures outside the breeding season of southern Buller's albatross treated as northern Buller's albatross). It is possible that other observed captures, particularly those occurring close to the Chatham Islands, may have been northern Buller's albatross. It may be possible to carry out genetic work on samples from captured specimens to clarify their taxonomic status. This would confirm assumptions made on attribution of captures to the two species.

The annual potential fatalities of southern Buller's albatross occurred in a range of fisheries, with estimated APFs of over 100 in hoki and squid trawl, and in small-vessel surface longline fisheries targeting southern bluefin tuna (Richard & Abraham 2014).

The population of southern Buller's albatross, breeding on The Snares and the Solander Islands, has sustained a long-term increase (Sagar & Stahl 2005). However, an apparent decline in the annual survival rate of breeding birds and in the recruitment of known-age birds has been found on The Snares in recent years, with the potential to lead to a decline in the overall abundance (Sagar 2014).

6.4.5.3.4 GIBSON'S ALBATROSS

Gibson's albatross were estimated in the 2013 assessment to be at "High" risk from commercial fisheries (Figure 6.20, Figure 6.21, Table 6.26, Table 6.27, Richard & Abraham 2013b, corrected for errors). In the 2014 assessment, their risk category increased to "Very High", and this species was here estimated to be the fourth most at-risk from commercial fisheries, with a median of 1.24 (95% c.i.: 0.69–2.43). The mean PBR_1 for this species was estimated to be 182 (95% c.i.: 98–285) and the mean APF to be 222 (95% c.i.: 161–307).

The increase in risk was due to the population size being revised downwards, and the disaggregation of royal albatrosses from Gibson's and Antipodean albatrosses for the estimation of vulnerability. Royal albatrosses do not get caught as often and separating them from the wandering albatrosses group led to an increase in vulnerability for Antipodean and Gibson's albatrosses. The disaggregation of the swordfish fishery from the small-vessel surface-longline fishery group may also have impacted the estimated APF.

Gibson's albatross have been well studied since 1991 on Adams Island, where approximately 95% of the species breeds. Monitoring of the population showed that during the period 2004–2006 there was a decrease in the number of breeding birds, in the annual survival and recruitment rate, and in nesting success. These changes may have been associated with an increase in the foraging range (Elliott & Walker 2014). In addition to captures within New Zealand waters, Gibson's albatross may also be caught in fisheries operating outside New Zealand's EEZ.

While there have been signs of recovery in recent years; improvements in recruitment, nesting success and survival (Elliott & Walker 2014), the conservation status of this species changed in 2013 from Nationally Vulnerable to Nationally Critical, according to the New Zealand Threat Classification System (Robertson et al. 2013).

6.4.5.3.5 FLESH-FOOTED SHEARWATER

The 2014 risk ratio of flesh-footed shearwater is similar to that of the 2013 assessment (Richard & Abraham 2013b), with an estimated median of 1.56 (95% c.i.: 0.63–3.42), after a number of updates, including a higher population size, a higher adult annual survival rate, and a change in the at-sea distribution. The mean PBR_1 for this species was estimated to be 521 (95% c.i.: 230–1200) and the mean APF to be 726 (95% c.i.: 495–1040), from 64 observed captures, including 30 and 27 in trawl and bottom-longline fisheries, respectively (Figure 6.20, Figure 6.21, Table 6.26, Table 6.27, Richard & Abraham 2013b, corrected for errors).

Flesh-footed shearwater have recently been added to the Threatened category, being classified as "Nationally Vulnerable", following a more recent survey finding a considerably lower number of breeding pairs than previously estimated, with approximately 10 000 pairs (Baker et al. 2010), from a previous estimate of between 25 000 to 50 000, noting that this estimate was based on colony visits rather than a comprehensive quantitative analysis (Taylor 2000). Moreover, long-term monitoring of the population breeding on Lord Howe Island, in eastern Australia, found that this population has been declining (Priddel et al. 2006). Waugh et al (2014) conducted further surveys at three main breeding colonies and their results indicated a probable decline for the population on Ohinau

Island, and stable populations at Lady Alice Island/Mauimua and Titi Island.

Some captures observed within the New Zealand EEZ might be of birds breeding outside New Zealand, which would lead to an overestimate of the number of Annual Potential Fatalities. On the other hand, this species might is also caught in recreational fisheries (Miskelly et al. 2012), foraging in the north-eastern region of New Zealand where there is considerable recreational fishing effort (Abraham et al. 2010a). Recreational fishing is not considered in this risk assessment.

6.4.5.3.6 NEW ZEALAND WHITE-CAPPED ALBATROSS

The risk category of New Zealand white-capped albatross has not changed from the last assessment, however the median risk ratio of 1.1 (95% c.i.: 0.59–2.02) in 2014 is less than half that in the 2013 assessment, 1.89 (95% c.i.: 0.71–7.32) (Figure 6.20, Figure 6.21, Table 6.26, Table 6.27, Richard & Abraham 2013b, corrected for errors). All updates led to a decrease in risk ratio (Figure 6.21), however the most important change was in the demographic parameters, with the number of annual breeding pairs revised upwards, from a mean of 77 000 to a mean of 95 700 (95% c.i.: 85 400–106 000), using a bootstrapped estimate from the recent aerial surveys of the population (Baker et al. 2014). Additionally, the uncertainty in the annual survival rate was more constrained. This change in demographic parameters led the risk ratio to decrease from a median 1.77 (95% c.i.: 0.68–6.78) to 1.11 (95% c.i.: 0.6–1.99). The change in at-sea distribution and in fishing effort in recent years only led to a minor decrease in risk ratio.

The updated APFs were estimated to be 4 410 (95% c.i.: 2 800–6 540), including 471 in trawl fisheries. The mean PBR_1 was estimated to be 4 040 (95% c.i.: 2 590–6 340). Around half of the estimated annual potential fatalities of white-capped albatross are predicted to occur in poorly observed inshore trawl fisheries (1 940 estimated annual potential fatalities), with over 400 estimated annual potential fatalities in each of squid, hoki and middle-depth trawl.

The New Zealand conservation status of New Zealand white-capped albatross is “Declining”. The trend in the population size is unclear, as annual aerial surveys since 2006 have shown a variable number of annual breeding pairs for this biennially breeding species (Baker et al. 2014).

White-capped albatross had very high capture rates in squid trawl fisheries. In the 1990–91 season, observers recorded captures rates of 27.9 white-capped albatross per 100 tows (Bartle 1991, Hilborn & Mangel 1997). With the elimination of the net sonde cable, the introduction of mandatory warp mitigation, and with an emphasis on practices such as better offal management, the capture rate of white-capped albatross in this fishery reduced to 4.1 (95% c.i.: 2.4 to 6.4) white-capped albatrosses per 100 tows (Abraham & Thompson 2011a). Despite this reduction in the capture rate, white-capped albatross continue to be caught in trawl nets, and there are still warp-captures, even in fisheries that use warp mitigation (Richard & Abraham 2014). Over the last three fishing years (2010-11 to 2012-13) the trawl warp or door has been recorded by observers as the source of mortality for white capped albatross in squid trawl fisheries (Table 6.30).

Table 6.30: Method of capture for observed captures of white capped albatross in squid trawl fisheries (http://data.dragonfly.co.nz/psc/ Data version v20140131).

	Method of capture						
Fishing year	Net	Warp or door	Mitigation	Other	Tangled	Unknown	Totals
2006-07	37	4			1	1	43
2007-08	27	10	1	1			39
2008-09	51	6	1	1		2	61
2009-10	14	3		3			20
2010-11	20	9		2			31
2011-12	22	13		1			36
2012-13	45	21				7	73
Totals	216	66	2	8	1	10	791

6.4.5.4 SOURCES OF UNCERTAINTY IN RISK ASSESSMENTS

There are several outstanding sources of uncertainty in modelling the effects of fisheries interactions on sea birds, especially for the complete assessment of risk to individual seabird populations.

6.4.5.4.1 SCARCITY OF INFORMATION ON CAPTURES AND BIOLOGICAL CHARACTERISTICS OF AFFECTED POPULATIONS

These sources of uncertainty can be explored within the analytical framework of the level 2 risk assessment (Richard et al 2011, Richard & Abraham 2013b, 2014), noting that the results of that exploration are constrained by the structure of that analysis. Richard & Abraham (2014) provided plots of such an exploration for 8 taxa (Figure 6.27). It can be concluded from this analysis that better estimates of average adult survival would lead to substantially more precise estimates of risk for a wide variety of taxa, including most of the species estimated to be at most risk. More precise estimates of risk would be available for black petrel, Salvin's albatross, New Zealand white-capped albatross, Chatham Island albatross, and Antipodean albatross if better estimates of potential fatalities were available, and better estimates of survival would be useful for all eight taxa. This analysis was not applied at this iteration of the risk assessment to the spatial distribution of seabirds and fisheries, although it is acknowledged that this is extremely important for the proper implementation of any spatial overlap method. Noting this limitation, this type of sensitivity analysis is a powerful way of assessing the priorities for collection of new information, including research.

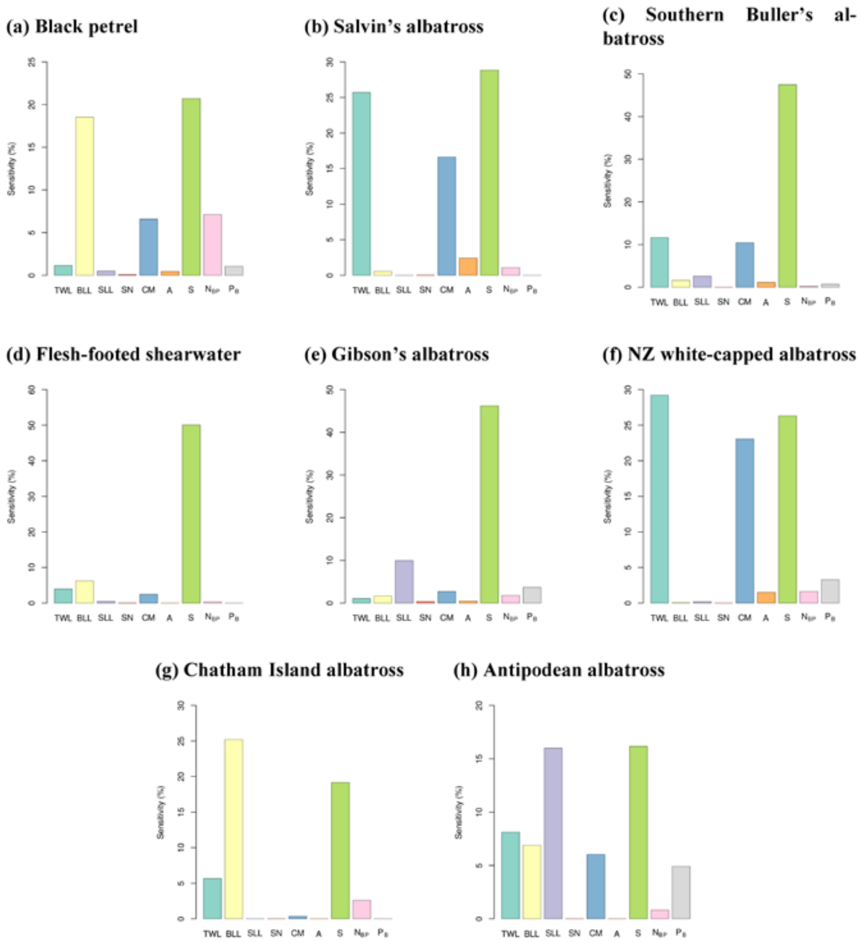


Figure 6.27: (reproduced from Richard & Abraham 2014) Sensitivity of the uncertainty in the risk ratio for the 8 seabird species with the highest risk ratio. For each seabird type, the sensitivity to the uncertainty in the following parameters is considered: annual potential fatalities in trawl, bottom-longline, surface-longline and set-net fisheries (TWL, BLL, SLL, SN, respectively); the cryptic multipliers (CM); age at first reproduction (A); adult survival (SA); the number of annual breeding pairs (N_{BP}); and the proportion of adults breeding (PB). The sensitivity is defined as the percentage of reduction in the 95% confidence interval of the risk ratio that occurs when the parameter is set to its arithmetic mean.

6.4.5.4.2 SCARCITY OF INFORMATION ON CRYPTIC MORTALITY

Cryptic mortality is particularly poorly understood but has substantial influence on the results of the risk assessment. Richard et al (2011) provided a description of the method used to incorporate cryptic mortality into their estimates of potential fatalities in the level-2 risk assessment (their appendix B authored by B. Sharp, MPI). This method builds on the published information from Brothers et al (2010) for longline fisheries and Watkins et al (2008) and Abraham (2010a) for trawl fisheries. Brothers et al (2010) observed almost 6000 seabirds attempting to take longline baits during line setting, of which 176 (3% of attempts) were seen to be caught. Of these, only 85 (48%) were retrieved during line hauling. They concluded that using only observed captures to estimate seabird fatalities grossly underestimates actual levels in pelagic longline fishing. Similarly, Watkins et al (2008) observed 2454 interactions between seabirds and trawl warps in the South African hake fishery over 189.8 hours of observation. About 11% of those interactions (263) involved birds, mostly albatrosses, being dragged under the water by the warps, and 30 of those submersions were observed to be fatal. Of the 30 birds observed killed on the warps, only two (both albatrosses) were hauled aboard and would have been counted as captures by an observer in New Zealand. Aerial collisions with the warps were about 8 times more common but appeared mostly to have little effect (although one white-chinned petrel suffered a broken wing which would almost certainly have fatal consequences).

Given the relatively small sample sizes in both of these trials, there is substantial (estimatable) uncertainty in the estimates from the trials themselves and additional (non-estimatable) uncertainty related to the extent to which these trials are representative of all fishing of a given type, particularly as both trials were undertaken overseas. The binomial 95% confidence range (calculated using the Clopper-Pearson “exact” method) for the ratio of total fatalities to observed captures in Brothers et al’s (2010) longline trial is 1.8–2.5 (mean 2.1), and that for Watkins et al’s trawl warp trial is 5–122 (mean 15.0 fatalities per observed capture). Abraham (2010a) estimated that there were 244 (95% c.i. 190–330) warp strikes by large birds for every one observed captured, and 6440 (3400–20 000) warp strikes by small birds for every one observed captured (although small birds tend to be caught in the net rather than by warps). There is also uncertainty in the relative frequencies and consequences of different types of encounters with trawl warps in New Zealand fisheries (Abraham 2010a, Richard et al 2011 Appendix B). Some of this uncertainty is included and propagated in the most recent risk assessment (Richard & Abraham 2013b).

A review of available information on cryptic mortality has been commissioned under CSP project INT2013-05 and supported by MPI project PRO2012-17. The final report was not available to be included at the time of this review.

6.4.5.4.3 MORTALITIES IN NON-COMMERCIAL FISHERIES.

Little is known about the nature and extent of incidental captures of seabirds in non-commercial fisheries, either in New Zealand or globally (Abraham et al 2010a). In New Zealand, participation in recreational fishing is high and 2.5% of the adult population are likely to be fishing in a given week (mostly using rod and line). Because of this high participation rate, even a low rate of interactions between individual fishers and seabirds could have population-level impacts. A boat ramp survey of 765 interviews at two locations during the summer of 2007–08 revealed that 47% of fishers recalled witnessing a bird being caught some time in the past. Twenty-one birds were reported caught on the day of the interview at a capture rate of 0.22 (95% c.i.: 0.13–0.34) birds per 100 hours of fishing. Observers on 57 charter trips recorded seabird captures at rate of 0.36 (0.09–0.66) birds per 100 fisher hours. The most frequently reported type of bird caught in rod and line fisheries were petrels and gulls. Captures of albatrosses, shags, gannets, penguins, and terns were also recalled.

The ramp surveys reported by Abraham et al (2010a) were limited and covered only two widely-separated parts of the New Zealand coastline. However, they also report two other pieces of information that suggest that non-commercial captures are likely to be very widespread. First, the Ornithological Society of New Zealand’s beach patrol scheme records seabird hookings and entanglements as a common occurrence throughout New Zealand. Second, returns of banded birds caught in fisheries (separating commercial and non-commercial fisheries is very difficult) are very widely distributed around the coast (Figure 6.28).

Noting that our understanding of seabird capture rates in amateur fisheries is very sketchy, it is possible to make first-order estimates of total captures using information on fishing effort. For example, in the north-eastern region where most of Abraham et al's (2010a) interviews were conducted, there were an estimated 4.8 (4.4–5.2) million fisher hours rod and line fishing from trailer boats in 2004–05 (Hartill et al 2007). Applying Abraham et al's (2010a) capture rate leads to an estimate of 11 500 (6600–17 200) captures per year in this area. Based on estimates of nationwide recreational fishing effort, this could increase to as many as 40 000 bird captures annually. Most birds captured by amateur fishers were reported to have been released unharmed (77% of the incidents recalled) and only three people reported incidents where the bird died. Because of likely recall biases and the qualitative nature of the survey, the fate of birds that are captured by amateur fishers remains unclear.

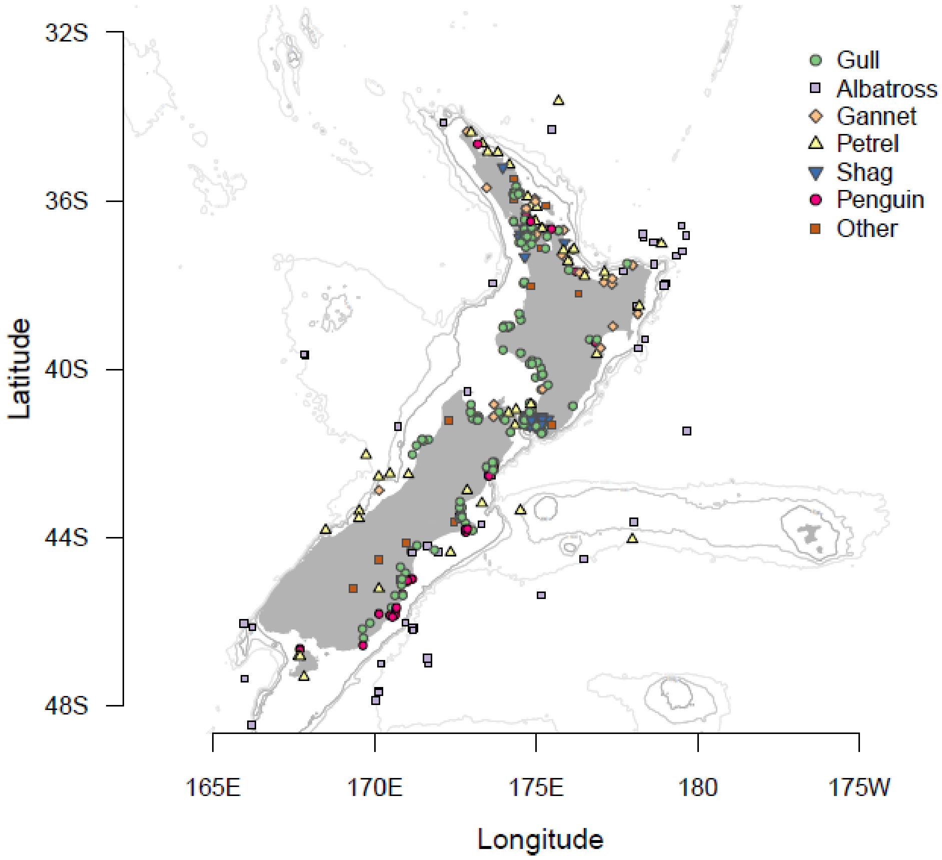


Figure 6.28: (from Abraham et al 2010a): Distribution of the reported capture locations for banded seabirds reported as being captured in fishing gear, 1952–2007. Note, band recovery locations are reported with low spatial precision and some of the inland locations may be correct.

Non-commercial fishers are allowed to use setnets in New Zealand and two studies suggest that these have an appreciable bycatch of seabirds. A study of captures in non-commercial setnets in Portobello Bay, Otago Harbour, between 1977 and 1985 (Lalas 1991) suggested that spotted shags were the most frequently caught taxa (82 recorded, compared with 14 Stewart Island shags and two little shags). Lalas (1991) suggested that up to 800 spotted shags (20% of the local population) may have been caught in the summer of 1981/82. A broader-scale study of yellow-eyed penguin mortality in setnets in southern New Zealand (Darby & Dawson 2000) suggested non-negligible captures of this species by non-commercial fishers, also reporting other seabirds like spotted shags and little blue penguin.

6.4.5.4.4 OUT OF ZONE MORTALITY.

Robertson et al (2003) mapped the distribution of the 25 breeding (mainly endemic) New Zealand seabird taxa they considered most at risk outside New Zealand waters. These ranged widely: 4 used the South Atlantic; 4 the Indian Ocean; 22 Australian waters and the Tasman Sea; 15 used the South Pacific Ocean as far afield as Chile and Peru; and 6 used the North Pacific Ocean as far north as the Bering Sea. These taxa therefore use the national waters of at least 18 countries. For example, the level-2 risk assessment described by Richard et al (2011) includes only that part of the range of each taxon contained within New Zealand waters, but many including commonly-caught seabirds like white-capped albatross and white-chinned petrel range much further and are vulnerable to fisheries in other parts of the world. For instance, fatalities of white-capped albatross outside the New Zealand EEZ greatly exceed fatalities within the zone (Baker et al 2007, Francis 2012, Table 6.31), and more than 10 000 white-chinned petrel are killed off South America each year (Phillips et al 2006), noting that reliable records are not available for most of the fisheries involved. Also note that white chinned petrels also breed on Prince Edward and Falkland Islands, South Georgia, Iles Crozet, and the Kerguelen group, so South American captures may be from other populations other than New Zealand's. Based on similar analyses, Moore & Zydelis (2008) concluded that a population-based, multi-gear and multi-national framework is required to identify the most significant threats to wide-ranging seabird populations and to prioritize mitigation efforts in the most problematic areas. To that end, the Agreement for the Conservation of Albatrosses and Petrels (ACAP) adopted a global prioritisation framework at the Fourth Session of the Meeting of the Parties (MoP4) in April 2012 (ACAP 2012).

Table 6.31: (from Francis 2012): Estimates of the number of white-capped albatrosses killed annually, by fishery. The first two columns are from Baker et al (2007b) (mid-point where a range was presented), including their assessment of reliability (L = low, M-H = medium-high, H = high). Updated estimates are from Watkins et al (2008, *) and Petersen et al (2009, **). Estimates not already corrected for cryptic mortality are either doubled to allow for this (***) or replaced by estimates of potential fatalities from Richard et al (2011, ***), noting that potential fatalities may considerably overestimate actual fatalities.

Fishery	From Baker et al 2007b		Updated	Incl. Cryptic mortality
South African demersal trawl	4 750	(L)	* 6650	6 650
Asian distant-water longline	1 255	(L)	–	*** 2 510
Namibian demersal trawl	910	(L)	* 1270	1 270
Namibian pelagic longline	180	(L)	** 195	*** 390
NZ hoki and squid trawl	513	(MH)	–	**** 4 920
NZ longline	60	(MH)	–	**** 199
Australian (line fisheries)	15	(MH)	–	*** 30
South African pelagic longline	570	(H)	** 570	*** 1 140
Total	8 210	–	–	17 110

6.4.5.4.5 OTHER SOURCES OF ANTHROPOGENIC MORTALITY.

Taylor (2000) listed a wide range of threats to New Zealand seabirds including introduced mammals, avian predators (weka), disease, loss of nesting habitat, competition for nest sites, coastal development, human disturbance, commercial and cultural harvesting, volcanic eruptions, pollution, plastics and marine debris, oil spills and exploration, heavy metals or chemical contaminants, global sea temperature changes, marine biotoxins, and fisheries interactions. Relatively little is known about most of these factors, but the parties to ACAP have agreed a formal prioritisation process to address and prioritise major threats (ACAP 2012). Croxall et al (2012) identified the main priorities as: protection of Important Bird Area (IBA) breeding, feeding, and aggregation sites; removal of invasive, especially predatory, alien species as part of habitat and species recovery initiatives. Lewison et al (2012) identified similar research priorities (in addition to direct fishing-related mortality), including: understanding spatial ecology; tropho-dynamics; response to global change; and management of anthropogenic impacts such as invasive species, contaminants, and protected areas. Non fishing-related threats to seabirds in New Zealand are largely the mandate of the Department of Conservation and a detailed description is beyond the scope of this document (although causes of mortality other than fishing are clearly relevant to the interpretation of risk assessment restricted to the direct effects of fishing). These threats are identified in DOC's Action Plan for Seabird Conservation in New Zealand (Taylor 2000) and various Threatened Species Recovery Plans.

6.4.5.4.6 FUTURE DEVELOPMENT OF THE RISK ASSESSMENT FRAMEWORK

The following steps were identified in the NPOA-Seabirds 2013 (MPI 2013) in order to improve the risk assessment framework that supports the implementation of the NPOA-Seabirds 2013:

- implementation of a framework and process to consolidate different risk assessment and population monitoring results into an integrated assessment, including:
    - checking the algorithmic level 2 assessment results for particular high risk species-fishery interactions, in light of other available data or identifiable structural biases on a case-by-case basis;
    - a mechanism to incorporate issues associated with seabird mortalities outside the EEZ and recreational fisheries risk in future assessments;
    - the use of species population models or census data to constrain input parameters or interpret estimates of risk;
- routine update of the integrated fisheries risk assessment with relevant new information; and
- periodic review and update of risk management priorities in light of current risk estimates.

MPI has committed to undertake a further two iterations of the seabird level two risk assessment in 2015 and 2016, under project PRO2014-06. This project will include another review workshop such as undertaken in 2013 to assess the risk assessment structure and input parameters. Additional analyses for the 2015 iteration of the risk assessment may include, but are not limited to:

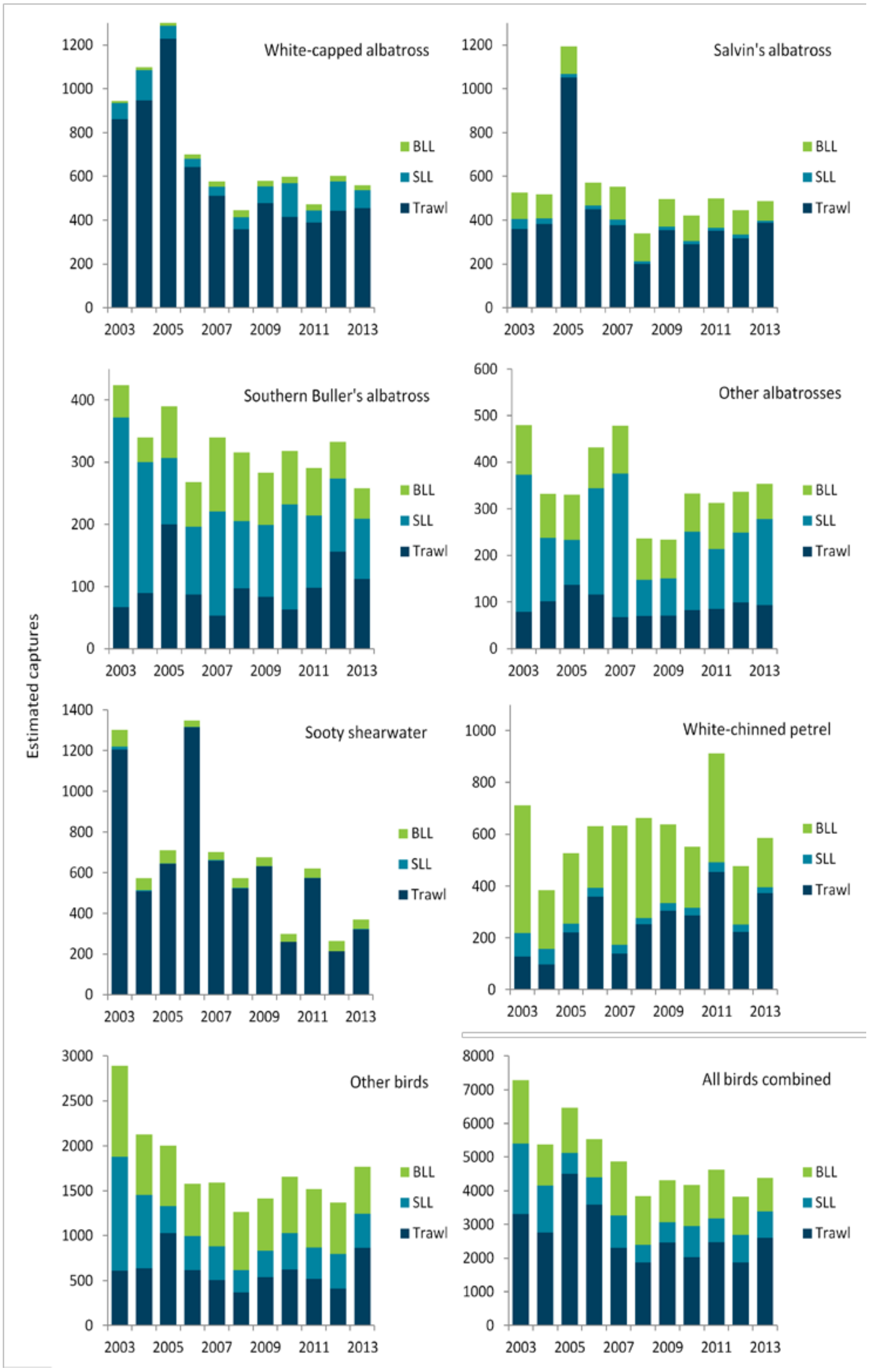
- Improving the distribution of uncertainty around N_{BPmin},
- Investigating the ability of the risk assessment to detect changes in vulnerability over time and determining the required level of coverage and observed captures to allow changes in vulnerability to be calculated,
- Simulations to test the ability of the risk assessment to detect/predict capture levels,
- Further consideration of the ρ factor, including the application of ρ where different information on abundance and overlap is used (i.e. black petrel) and determining whether and to what extent the use of N_{BPmin} leads to a bias in PBR_1.

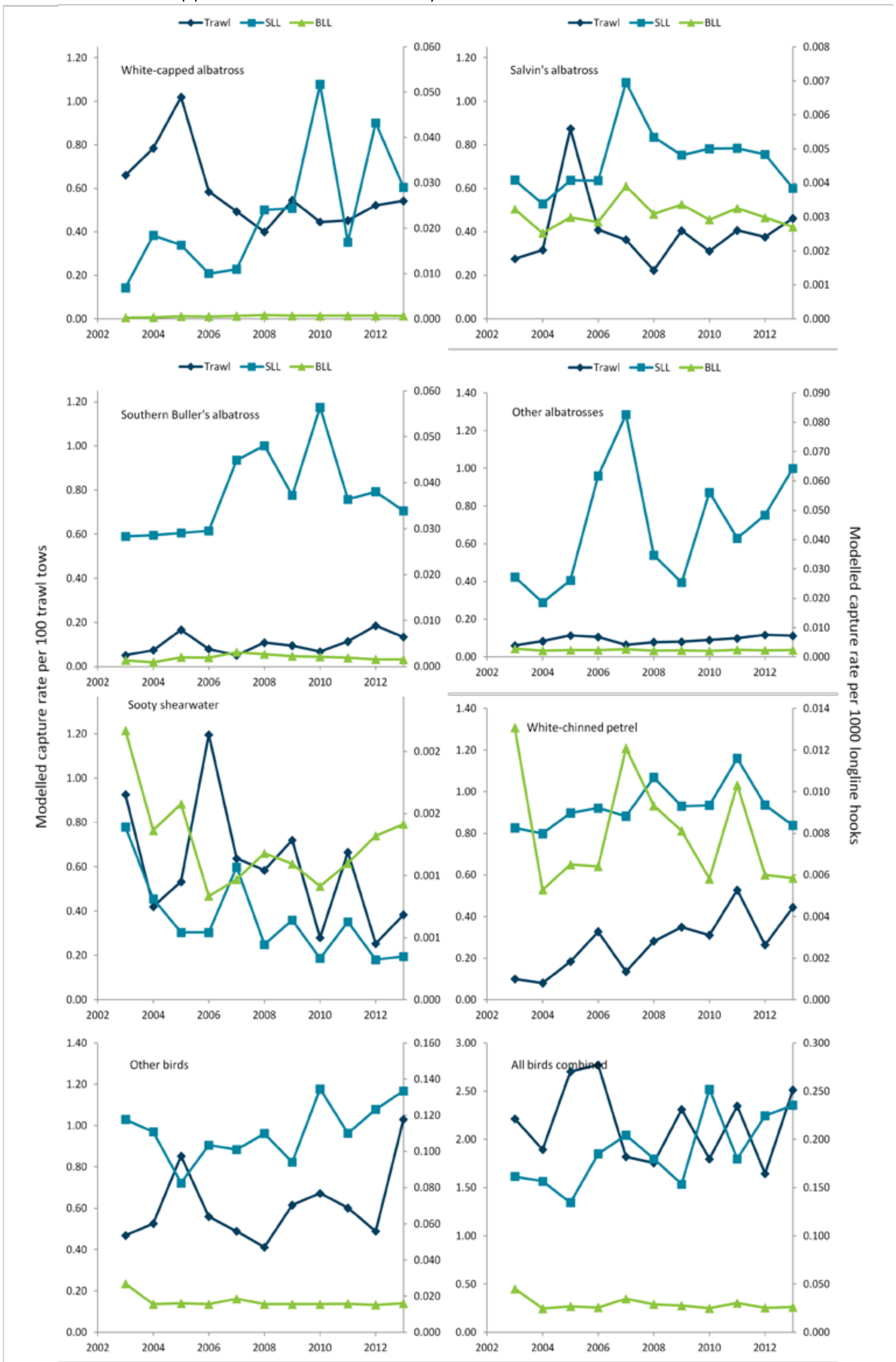
6.5 INDICATORS AND TRENDS

Population size	Multiple species and populations: see Taylor (2000)
Population trend	Multiple species and populations: see Taylor (2000)
Threat status	Multiple species and populations: see Robertson et al (2013)
Number of interactions[43]	In the 2012–13 October fishing year, there were an estimated 4378 seabird captures (excluding cryptic mortalities) across all trawl and longline fisheries (Data version v20140131). About 59% of the estimated captures across these fisheries (other fisheries such as set net are excluded) were in trawl fisheries, 18% in surface longline fisheries, and 23% in bottom longline fisheries:

Bird group	Trawl	Surface longline	Bottom longline	All these methods
White-capped albatross	454	83	21	558
Salvin's albatross	387	11	88	486
Southern Buller's albatross	112	97	49	258
Other albatrosses	94	184	76	354
White-chinned petrel	372	24	190	586
Sooty shearwater	321	1	46	368
Other birds	863	382	521	1766
All birds combined	2604	783	991	4378

[43] For more information, see: http://data.dragonfly.co.nz/psc/.

Trends in interactions	Captures of all birds combined show a decreasing trend between 2002–03 and 2012-13 (Data version v20140131) but there are substantial differences in trends between species and fisheries. Captures of white-capped albatross and sooty shearwater have decreased, especially in offshore trawl fisheries: 

Trends in interactions [Continued]	Capture rate trends (excluding cryptic mortalities) are described for the four fisheries estimated to account for most captures of a species (usually accounting for 70–80% of the total). Capture rates of white-capped albatross have fallen in trawl fisheries for hoki and squid but have remained steady in inshore trawl fisheries and increased in the southern bluefin tuna longline fishery. Capture rates for other albatross species for which specific estimates were made (Salvin's and southern Buller's) have fluctuated without obvious trend in trawl and bottom longline fisheries but increased in surface longline fisheries. Capture rates for white-chinned petrel have increased in the squid trawl fishery but have remained steady in longline fisheries. Capture rates of sooty shearwater have declined in the ling longline fishery but have fluctuated without apparent trend in other key fisheries. 

6.6 REFERENCES

Abraham, E R (2007) Summary of data collected during the southern squid fishery mincing trial. Research report prepared by Dragonfly for the Department of Conservation, Wellington, New Zealand. 39 p.

Abraham, E R (2009) Batching of waste to reduce seabird numbers behind trawl vessels. Unpublished report prepared for the Department of Conservation, Wellington, New Zealand.

Abraham, E R (2010a) Warp strike in New Zealand trawl fisheries, 2004–05 to 2008–00. New Zealand Aquatic Environment and Biodiversity Report No. 60. 29 p.

Abraham, E R (2010b) Mincing offal to reduce the attendance of seabirds at trawlers. Report prepared by Dragonfly for Department of Conservation, Wellington, New Zealand. 28 p.

Abraham, E R; Berkenbusch, K N; Richard, Y (2010a) The capture of seabirds and marine mammals in New Zealand non-commercial fisheries New Zealand Aquatic Environment and Biodiversity Report No. 64. 52 p.

Abraham, E R; Pierre, J P; Middleton, D A J; Cleal, J; Walker, N A; Waugh, S M (2009) Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel. Fisheries Research 95: 210–219

Abraham, E R; Thompson, F N (2009a) Capture of protected species in New Zealand trawl and longline fisheries, 1998–99 to 2006–07. New Zealand Aquatic Environment and Biodiversity Report No. 32.

Abraham, E R; Thompson, F N (2009b) Warp strike in New Zealand trawl fisheries, 2004–05 to 2006–07. New Zealand Aquatic Environment and Biodiversity Report No. 33. 21 p.

Abraham, E R; Thompson, F N (2010) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2006–07. Final Research Report for research project PRO2007-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Abraham, E R; Thompson, F N (2011a) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 79. 74 p.

Abraham, E R; Thompson, F N (2011b) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 80. 170 p.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Abraham, E R; Thompson, F N; Oliver, M D (2010b) Summary of the capture of seabirds, marine mammals and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. New Zealand Aquatic Environment and Biodiversity Report No. 45.

ACAP (2010). ACAP species assessment. Accessed from http://www.acap.aq.

ACAP (2011). Report of the Fourth Meeting of the Seabird Bycatch Working Group, Guayaquil, Ecuador, 22–24 August 2011. 94 p. AC6 Doc 14 Rev4.

ACAP (2012) ACAP Conservation Priorities. Fourth Meeting of the Parties, Lima, Peru, 23 – 27 April 2012, available at http://www.acap.aq/docman/english/meeting-of-the-parties/mop4/mop4-final-report. 13 p.

Amey, J; Sagar, P (2013). Salvin's albatross population trend at the Bounty Islands, 1997-2011. Report prepared for PRO2012-06 for the Department of Conservation, Wellington. 31 p.

Arcos, J M; Oro, D (1996) Changes in foraging range of Audouin's gulls Larus audouinii in relation to a trawler moratorium in the western Mediterranean. Waterbirds 19:128–131.

Astles, K L; Holloway, M G; Steffe, A; Green, M; Ganassin, C; Gibbs, P J (2006) An ecological method for qualitative risk assessment and its use in the management of fisheries in New South Wales, Australia. Fisheries Research 82: 290–303.

Ayers, D; Francis, M P; Griggs, L H; Baird, S J (2004) Fish bycatch in New Zealand tuna longline fisheries, 2000/01 and 2001/02. New Zealand Fisheries Assessment Report 2004/46. 47 p.

Baird, S J (1994) Nonfish Species and Fisheries Interactions Working Group Report. New Zealand Fisheries Assessment Working Group Report 94/1. MAF Fisheries, N.Z. Ministry of Agriculture and Fisheries, Wellington. 54 p.

Baird, S J (1995) Nonfish Species and Fisheries Interactions Working Group Report — April 1995. New Zealand Fisheries Assessment Working Group Report 95/1. MAF Fisheries, N.Z. Ministry of Agriculture and Fisheries, Wellington. 24 p.

Baird, S J (1996) Nonfish Species and Fisheries Interactions Working Group Report — May 1996. New Zealand Fisheries Assessment Working Group Report 96/1. Ministry of Fisheries, Wellington. 34 p.

Baird, S J (1997) Report on the incidental capture of nonfish species during fishing operations in New Zealand waters. (Unpublished report completed as part of the Ministry of Fisheries SANF01 contract.) 15 p plus appendices on New Zealand fur seal-trawl fishery interaction (54 p) and seabird-tuna longline fishery interaction (34 p). (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J (1998) Estimation of nonfish bycatch in commercial fisheries in New Zealand waters, 1990–91 to 1993–94. Final Research Report for Ministry of Fisheries Research Project ENV9701. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J (1999) Estimation of nonfish bycatch in commercial fisheries in New Zealand waters, 1997–98. Unpublished report completed for Objective 1 of Ministry of Fisheries Project ENV9801. 57 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J (2000a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1998–99. New Zealand Fisheries Assessment Report 2001/14 43 p.

Baird, S J (2000b) Incidental capture of seabirds in New Zealand tuna longline fisheries. In: Flint, E; Swift, K (Eds.), p. 126, Second Albatross Conference on the Biology and Conservation of Albatrosses and other Petrels, Honolulu, Hawaii, USA, 8–12 May 2000. Abstracts and Oral Presentations. Marine Ornithology 28: 125–152.

Baird, S J (2001a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1998–99. New Zealand Fisheries Assessment Report 2001/14. 43 p.

Baird, S J (Comp. & Ed.) (2001b) Report on the International Fishers' Forum on Solving the incidental Capture of Seabirds in Longline Fisheries, Auckland, New Zealand, 6–9 November 2000. Department of Conservation, Wellington, New Zealand. 63 p.

Baird, S J (2003) New Zealand breeding seabirds: human-induced mortality — a review. Draft report prepared for the Ministry of Fisheries Project ENV2000/09. 74 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. New Zealand Fisheries Assessment Report 2004/41. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. New Zealand Fisheries Assessment Report 2004/58. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. New Zealand Fisheries Assessment Report 2004/60. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. New Zealand Fisheries Assessment Report 2005/2. 50 p.

Baird, S J; Francis, M; Griggs, L H; Dean, H A (1998) Annual review of bycatch in southern bluefin and related tuna longline fisheries in the New Zealand 200 n. mile Exclusive Economic Zone. CCSBT-ERS/9806/31. (Third Meeting of the Ecologically Related Species Working Group, Tokyo, 9–13 June 1998.)

Baird, S J; Gilbert, D J (2010) Initial assessment of risk posed by commercial fisheries to seabirds breeding in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 50. 99 p.

Baird, S J; Gilbert, D J; Smith, M H (2006) Review of environmental risk assessment methodologies with relevance to seabirds and fisheries within New Zealand waters. Final Research Report for Ministry of Fisheries project ENV2005/01 Objective 3. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J; Griggs, L H (2004) Estimation of within-season chartered southern bluefin tuna (*Thunnus maccoyii*) longline seabird incidental captures, 2002. New Zealand Fisheries Assessment Report 2004/42. 15 p.

Baird, S J; Sanders, B M; Dean, H A; Griggs, L H (1999) Estimation of nonfish bycatch in commercial fisheries in New Zealand waters, 1990/91 to 1993/94. Final Research Report for Ministry of Fisheries Project ENV9701 Objective 1. 63 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J; Smith, M H (2008) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005–06. New Zealand Aquatic Environment and Biodiversity Report No. 18. 124 p.

Baker, B; Cunningham, R; Hedley, G; King, S (2008a) Data collection of demographic, distributional and trophic information on the Westland petrel to allow estimation of effects of fishing on population viability. Final Research Report prepared for the Ministry of Fisheries PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, B; Cunningham, R; Hedley, G; King, S (2011a) Data collection of demographic, distributional and trophic information on the Westland petrel to allow estimation of effects of fishing on population viability. Final Research Report prepared for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, B; Double, M (2007) Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability. Final Research Report prepared for the Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Double, M C; Gales, R; Tuck, G N; Abbott, C L; Ryan, P G; Petersen, S L; Robertson, C J R; Alderman, R; (2007a) A global assessment of the impact of fisheries related mortality on shy and white-capped albatrosses: conservation implications. Biological Conservation 137: 319–333.

Baker, B; Hedley, G; Cunningham, R (2010a) Data collection of demographic, distributional and trophic information on the flesh-footed shearwater to allow estimation of effects of fishing on population viability: 2009-10 Field Season. Final Research Report prepared for Ministry of Primary Industries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Hedley, G; Cunningham, R (in prep.) Data collection of demographic, distributional and trophic information on the flesh-footed shearwater to allow estimation of effects of fishing on population viability. 2010/11 Field Season. Draft Final Research Report prepared for the Ministry of Primary Industries project PRO2006-01.

Baker, B; Hedley, G; Waugh, S; Cunningham, R (2008b) Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability. Final Research Report prepared for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, B; Hedley, G; Waugh, S; Cunningham, R (2009a) Data collection of demographic, distributional and trophic information on the flesh-footed shearwater to allow estimation of effects of fishing on population viability: 2008-09 Field Season. Final Research Report prepared for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Cunningham, R (2009b) Data collection of demographic, distributional and trophic information on the white-capped albatross to allow estimation of effects of fishing on population viability - 2008 field season. Final Research Report for Ministry of Fisheries project PRO2006-01H. 13 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Cunningham, R (2010b) Data collection of demographic, distributional and trophic information on the white-capped albatross to allow estimation of effects of fishing on population viability - 2009 field season. Final Research Report for Ministry of Fisheries project PRO2006-01I. 13 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Cunningham, R (2011b) Data collection of demographic, distributional and trophic information on the white-capped albatross to allow estimation of effects of fishing on population viability — 2010 Field Season. Final Research Report for Ministry of Fisheries project PRO2006-01J. 15 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Cunningham, R (2013) White-capped albatross population estimate — 2011/12 and 2012/13. Final Report for Department of Conservation Contract 4431 & Project POP2012-05. 22 p.

Baker,B.; Jensz,K.; Cunningham, R. (2014b) White-capped albatross aerial survey 2014. Final Research Report for the Department of Conservation. Contract 4423/4524 (Unpublished report held by the Department of Conservation, Wellington.) Retrieved from http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/reports/pop2013-02-white-capped-albatross-survey-2014-final-report.pdf

Baker, G B; Jensz, K; Double, M; Cunningham, R (2007b) Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability. Final Research Report for Ministry of Fisheries project PRO2006-01. 12 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Double, M; Cunningham, R (2008c) Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability. Final Research Report for Ministry of Fisheries project PRO2006-01. 11 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Sagar, P (2012) Data collection of demographic, distributional and trophic information on Salvin's albatross to allow estimation of effects of fishing on population viability. Final Research Report for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baker, G B; Jensz, K; Sagar, P (2014a) 2013 Aerial survey of Salvin's albatross at the Bounty Islands. Final Report prepared for the Department of Conservation, Contract 4521.Barbraud, C.; Booth, A.; Taylor, G.A.; Waugh, S.M. In press. Survivorship in Fleshfooted Shearwater Puffinus carneipes at two sites in northern New Zealand. Marine Ornithology.

Bartle, J A (1991) Incidental capture of seabirds in the New Zealand subantarctic squid trawl fishery, 1990. Bird Conservation International 1: 351–359.

Bartumeus, F; Giuggioli, L; Louzao, M; Bretagnolle, V; Oro, D; Levin, S A (2010). Fishery discards impact on seabird movement patterns at regional scales. Current Biology 20: 215–222.

Bell, E.A. (2002) (cited in Sommer et al 2010): Grey petrels (Procellaria cinerea) on Antipodes Island, New Zealand: research feasibility, April to June 2001. Department of Conservation Science Internal Series 60. Department of Conservation,Wellington. 31 p.

Bell, E A; Sim, J L; Scofield, P; Francis, R I C C (2012) Population parameters of the black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island), 2009/10. Report for Conservation Services Programme Project POP2009-01, near-final (post-review) draft. 82 p. Department of Conservation, Wellington.

Bell, E A; Sim, J L; Scofield, P; Francis, R I C C; Landers, T (2013) At-sea distribution and population parameters of the black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island), 2012/13. Draft report on project POP2012/03 for DOC-CSP working group, August 2013. Department of Conservation, Wellington.

Brothers, N P (1991) Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. Biological Conservation 55: 255–268.

Brothers, N P; Cooper, J; Lokkeborg, S (1999) The incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation. FAO Fisheries Circular No. 937. 107 p.

Brothers, N P; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. PLoS ONE 5: e12491.

Bull, L S (2007) A review of methodologies for mitigating incidental catch of seabirds in New Zealand Fisheries. DOC Research & Development Series 263. Department of Conservation, Wellington. 57 p.

Bull, L S (2009) New mitigation measures reducing seabird by-catch in trawl fisheries. Fish and Fisheries 8: 31–56.

Campbell, J L; Gallagher, C (2007) Assessing the relative effects of fishing on the New Zealand marine environment through risk analysis. ICES Journal of Marine Science, 64: 256–270.

Carey, C (2005) Carefree's cunning contraption. Seafood New Zealand 13(6): 44–45.

Carroll, J; Charteris, M; Sagar P (2010) Population assessment of Salvin's albatrosses at the Snares Western Chain, 29 September – 14 October 2009. Final research report for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Charteris, M; Carroll, J; Sagar P (2009) Population assessment of Salvin's albatrosses at the Snares Western Chain, 29 September – 17 October 2008. Final research report for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Croxall, J P (2008) The role of science and advocacy in the conservation of Southern Ocean albatrosses at sea. Bird Conservation International 18: S13–29.

Croxall, J P; Butchart, S H M; Lascelles, B; Stattersfield, A J; Sullivan, B; Symes, A; Taylor, P (2012) Seabird conservation status, threats and priority actions: a global assessment. Bird Conservation International 22: 1−34.

Croxall, J P; Prince, P A; Rothery, P; Wood, A G (1998) Population changes in albatrosses at South Georgia. Pp 68–83. In: Robertson, G; Gales, R (Eds.) Albatross biology and conservation. Chipping Norton, Australia: Surrey Beatty & Sons.

Crysel, S (2002) Baffling birds brings benefits. Seafood New Zealand 10(10): 60–61.

Darby, J T; Dawson, S M (2000) Bycatch of yellow-eyed penguin (*Megadyptes antipodes*) in gillnets in New Zealand waters 1979–1997. Biological Conservation 93: 327–332.

Dillingham, P W; Fletcher, D (2011) Potential biological removal of albatrosses and petrels with minimal demographic information. Biological Conservation 144: 1885–1894.

Elliott, G.; Walker, K. (2014). Gibson's wandering albatross research, Adams Island 2014. Unpublished report prepared for the Department of Conservation, Wellington, New Zealand. Retrieved from http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservationservices/meetings/pop2013-03-gibsons-albatross-population-study-draft-final-report.pdf

Favero, M; Blanco, G; Garcia, G; Copello, S; Seco Pon, J P; Frere, E; Quintana, F; Yorio, P; Rabuffetti, F; Canete, G; Gandini, P (2010) Seabird mortality associated with ice trawlers in the Patagonian shelf: effect of discards on the occurrence of interactions with fishing gear. Animal Conservation 14:131–139.

Filippi, D; Waugh, S M; Nicol, S (2010) Revised spatial risk indicators for seabird interactions with longline fisheries in the western and central Pacific. Western and Central Pacific Fisheries Commission, Scientific Committee (2010) Paper EB-IP-01.

Fletcher, D; MacKenzie, D; Dillingham, P (2008) Modelling of impacts of fishing-related mortality on New Zealand seabird populations. Final Research Report for Ministry of Fisheries project ENV2005-08, 17 December 2008. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fletcher, W J (2005) The application of qualitative risk assessment methodology to prioritize issues for fisheries management. ICES Journal of Marine Science 62:1576–1587.

FAO (1999) International Plan of Action for reducing incidental catch of seabirds in longline fisheries. International Plan of Action for the conservation and management of sharks. International Plan of Action for the management of fishing capacity. Food & Agriculture Organisation of the United Nations, Rome. 26p.

FAO (2009) Fishing operations. 2. Best practices to reduce incidental catch of seabirds in capture fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 1, Suppl. 2. Rome, FAO. 2009. 49 p.

FAO (2010) Report of the Technical Consultation to Develop International Guidelines on Bycatch Management and Reduction of Discards, Rome, 6–10 December 2010. FAO Fisheries and Aquaculture Report No. 957. 41 p.

Francis, R I C C (2012) Fisheries risks to the population viability of white-capped albatross *Thalassarche steadi*. New Zealand Aquatic Environment and Biodiversity Report. No. 104. 24 p.

Francis, R I C C; Bell, E A (2010) Fisheries risks to population viability of black petrel (*Procellaria parkinsoni*). New Zealand Aquatic Environment and Biodiversity Report No. 51.

Francis, R I C C; Elliott, G; Walker, K (2013) Fisheries risks to the viability of Gibson's wandering albatross *Diomedea gibsoni*. New Zealand Aquatic Environment and Biodiversity Report.

Francis, R I C C; Sagar, P M (2012) Modelling the effect of fishing on southern Buller's albatross using a 60-year dataset, New Zealand Journal of Zoology 39:1, 3–17.

Francis, R I C C; Sagar, P M; Fu, D (2008) Status of the Snares Islands population of southern Buller's albatross. Final Research Report for Year 2 of Ministry of Fisheries Research Project

PRO200602. 138 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fraser, M J; Bell, M; Scofield, P; Robertson, C J R (2009a) Population assessment of Northern Buller's Albatross, Northern Royal Albatross, and Northern Giant Petrels at the Forty-Fours, 09–18 November 2008. Research Progress Report for Ministry of Fisheries Project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fraser, M J; Cameron, N; Scofield, P; Robertson, C J R (2010a) Population assessment of Northern Buller's Albatross and Northern Giant Petrels at the Forty-Fours, Chatham Islands, 1–8 December 2009. Final Research Report for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fraser, M J; Henderson, G; Robertson, C J R; Scofield, P (2011) Population dynamics of the Chatham Mollymawk at The Pyramid, 19 November–2 December 2010. Final Research Report for Ministry of Fisheries project, PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fraser, M J; Hunt, S; Scofield, P; Robertson, C J R (2009b) Population Dynamics of the Chatham Mollymawk at The Pyramid, 22 November to 07 December 2008. Final Research Report for Ministry of Fisheries project, PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fraser, M J; Palmer, D; Deppe, L; Scofield, P; Robertson, C J R (2010b) Population dynamics of the Chatham Mollymawk at The Pyramid, 20 November–14 December 2009. Final Research Report for Ministry of Fisheries project, PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Furness, R W (2003) Impacts of fisheries on seabird communities. Scientia Marina 67:33–45.

Furness, R W; Ensor, K; Hudson, A V (1992) The use of fishery waste by gull populations around the British Isles. Ardea 80: 105–113.

Grémillet, D; Pichegru, L; Kuntz, G, Woakes, A G; Wilkinson, S; Crawford, R J M; Ryan, P G (2008) A junk-food hypothesis for gannets feeding on fishery waste. Proceedings of the Royal Society of London B Biological Sciences 275: 1149–56.

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. New Zealand Fisheries Assessment Report 2007/26. 44 p.

Hilborn, R.; Mangel, M. (1997). The ecological detective: confronting models with data. Princeton University Press.

Hobday, A J; Smith, A; Webb, H; Daley, R; Wayte, S; Bulman, C; Dowdney, J; Williams, A; Sporcic, M; Dambacher, J; Fuller, M; Walker, T (2007) Ecological risk assessment for the effects of fishing: methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

Kirby, J; Hobday, A (2007) Ecological risk assessment for the effects of fishing the western and central Pacific Ocean: productivity-susceptibility analysis. Paper presented to the Scientific Committee of the Third Regular Session of the Western and Central Pacific Fisheries Commission, WCPFC-SC3-EB SWG/WP-1

Lalas, C (1991) Assessment of bird kills in set nets in Otago Harbour over a period of eight years (1977–1985). (Unpublished report held by Department of Conservation, Dunedin.)

Lewison, R L; Crowder, L B; Read, A J; Freeman, S A (2004) Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution 19: 598–604.

Lewison, R L; Oro, D; Godley, B J; Underhill, L; Bearhop, S; Wilson, R P; Ainley, D; Arcos, J M; Boersma, P D; Borboroglu, P G; Boulinier, T; Frederiksen, M; Genovart, M; González-Solís, J; Green, J A; Grémillet, D; Hamer, K C; Hilton, G M; Hyrenbach, K D; Martínez-Abraín, A; Montevecchi, W A; Phillips, R A; Ryan, P G; Sagar, P M; Sydeman, W J; Wanless, S; Watanuki, Y; Weimerskirch, H; Yorio, P (2012) Review: Research priorities for seabirds: improving conservation and management in the 21st century. Endangered Species Research 17: 93–121.

Lonergan, M (2011) Potential biological removal and other currently used management rules for marine mammal populations: a comparison. Marine Policy 35: 584–589.

Louzao, M; Arcos, J M; Guijarro, B; Valls, M; Oro, D (2011) Seabird-trawling interactions: factors affecting species-specific to regional community utilisation of fisheries waste. Fisheries Oceanography 20: 263–277.

Maunder, M N; Houston, D M; Dunn, A; Seddon, P J; Kendrick, T H (2007) Assessment to risk of yellow-eyed penguins *Megadyptes antipodes* from fisheries incidental mortality in New Zealand fisheries and definition of information requirements for managing fisheries related risk. Final Research Report for Ministry of Fisheries project ENV2005-13. 28 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Melvin, E F; Dietrich, K S; Fitzgerald, S; Cordoza, T (2010) Reducing seabird strikes with trawl cables in the pollock catcher-processor fleet in the eastern Bering Sea. Agreement on the Conservation of Albatrosses and Petrels, SBWG-3 Doc 14 Rev1, Hobart, Australia, 18 p

MFish-DOC (2004) National plan of action to reduce the incidental catch of seabirds in New Zealand fisheries. NZ Ministry of Fisheries and Department of Conservation, Wellington. 62 p.

Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery. Final Research Report for Ministry of Fisheries research project IPA2006/02. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Miskelly, C M; Dowding, J E; Elliott, G P; Hitchmough, R A; Powlesland, R G; Robertson, H A; Sagar, P M; Scofield, R P; Taylor, G A

(2008) Conservation status of New Zealand birds, 2008. Notornis 55: 117–135.

Moore, J E; Zydelis, R (2008) Quantifying seabird bycatch: where do we go from here? Animal Conservation 11: 257–259.

MPI (2013) National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand Fisheries. Ministry for Primary Industries. 63 p.

Newman, J; Scott, D; Bragg, C; McKechnie, S; Moller, H; Fletcher, D (2009) Estimating regional population size and annual harvest intensity of the sooty shearwater in New Zealand. New Zealand Journal of Zoology 36: 307–323.

Niel, C; Lebreton, J (2005) Using demographic invariants to detect overharvested bird populations from incomplete data. Conservation Biology 19: 826–835.

Oro, D; Cam, E; Pradel, R; Martinez-Abrain, A (2004) Influence of food availability on demography and local population dynamics in a long-live seabird. Proceedings of the Royal Society of London B Biological Sciences 271:387–396.

Oro, D; Furness, R W (2002) Influences of food availability and predation on survival of kittiwakes. Ecology 83:2516–2528.

Oro, D; Pradel, R; Lebreton, J D (1999) Food availability and nest predation influence life history traits in Audouin's gull, *Larus audouinii*. Oecologia 118:438–445.

Oro, D; Ruiz, X; Jover, L; Pedrocchi, V; Gonzalez-Solis, J (1997) Audouin's gull diet and adult time budget responses on changes in food availability induced by commercial fisheries. Ibis 139:631–637.

OSNZ (2010) Checklist of the birds of New Zealand and the Ross Dependency, Antarctica. Fourth Edition. Te Papa Press in association with the Ornithological Society of New Zealand Inc. Wellington.

Petersen, S L; Honig, M B; Ryan, P G; Underhill, L G (2009) Seabird bycatch in the pelagic longline fishery off southern Africa. African Journal of Marine Science 31: 191–204.

Phillips, R A; Silk, J R D; Croxall, J P; Afanasyev, V (2006) Year-round distribution of white-chinned petrels from South Georgia: relationships with oceanography and fisheries. Biological Conservation 129:336–347.

Pierre, J P; Abraham, E R; Cleal, J; Middleton, D A J (2012a) Reducing effects of trawl fishing on seabirds by limiting foraging opportunities provided by fishery waste. Emu 112: 244–254. CSIRO.

Pierre, J P; Abraham, E R; Middleton, D A J; Cleal, J; Bird, R; Walker, N A; Waugh, S M (2010) Reducing interactions between trawl fisheries and seabirds: responses to foraging patches provided by fish waste batches. Biological Conservation 143: 2779–2788.

Pierre, J P; Abraham, E R; Richard, Y (2012b) Concluding six years of research on seabird bycatch reduction through modified discharge management regimes: Is batch discharge better than ad-hoc discharge from trawl vessels? SBWG-4 Doc 14, Progress report on Agreement on the Conservation of Albatrosses and Petrels, Project Application 2010-04.

Poncet, S; Robertson, G; Phillips, R A; Lawton, K; Phalan, B; Trathan, P N; Croxall, J P (2006) Status and distribution of wandering, black-browed and grey-headed albatrosses breeding at South Georgia. Polar Biology 29: 772–781.

Priddel, D; Carlile, N; Fullagar, P; Hutton, I; O'Neill, L (2006) Decline in the distribution and abundance of flesh-footed shearwaters (Puffinus carneipes) on Lord Howe Island, Australia. Biological Conservation 128(3): 412–424.

Ramm, K C (2011) Conservation Services Programme Observer Report for the period 1 July 2008 to 30 June 2009. Available at www.doc.govt.nz/documents/science-and-technical/2008-09-csp-observer-report.pdf

Ramm, K C (2012) Conservation Services Programme Observer Report for 1 July 2009 to 30 June 2010. Available: www.doc.govt.nz/documents/conservation/marine-and-coastal/marine-conservation-services/csp-observer-report-2009-10.pdf

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from:http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Richard, Y; Abraham, E R (2013a) Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30 p.

Richard, Y; Abraham, E R (2013b) Risk of commercial fisheries to New Zealand seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 109. 58 p.

Richard, Y; Abraham, E R (2014) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2012-13. Draft New Zealand Aquatic Environment and Biodiversity Report.

Richard, Y; Abraham, E R; Filippi, D (2011) Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for Ministry of Fisheries projects IPA2009-19 and IPA 2009-20. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Richard, Y.; Pierre, J.P.; Abraham, E.R. (2014). Seasonality and temporal trends in counts of seabirds from pelagic tours off Kaikoura, New Zealand. Unpublished report held by the Encounter Foundation, Kaikoura, New Zealand.

Robertson, C J R (1998) (cited in Scofield 2011). Factors influencing the breeding performance of the Northern Royal Albatross. In: Albatross Biology and Conservation, Robertson, G; Gales, R (Eds.). Surrey Beatty & Sons: Chipping Norton. Pp 20–45.

Robertson, C J R; Bell, E A; Sinclair, N; Bell, B D (2003) Distribution of seabirds from New Zealand that overlap with fisheries worldwide. Science for Conservation 233. Department of Conservation, Wellington. 102 p.

Robertson, H A; Dowding, J E; Elliott, G P; Hitchmough, R A; Miskelly, C M; O'Donnell, C F J; Powlesland, R G; Sagar, P M; Scofield, R P; Taylor, G A (2013) Conservation status of New Zealand birds, 2012. New Zealand Threat Classification Series 4. Department of Conservation, Wellington. 22 p.

Romano, M D; Piatt, J F; Roby, D D (2006) Testing the junk-food hypothesis on marine birds: effects of prey type on growth and development. Waterbirds 29, 407–414.

Rowe, S J (2009) Conservation Services Programme Observer Report for the period 1 July 2004 to 30 June 2007. DOC Marine Conservation Services Series 1. Department of Conservation, Wellington. 97 p

Rowe, S J (2010) Conservation Services Programme Observer Report for the period 1 July 2007 to 30 June 2008. DOC Marine Conservation Services Series 4. Department of Conservation, Wellington. 97 p

Rowe, S J (2013) Level 1 risk assessment for incidental seabird mortality associated with fisheries in New Zealand's Exclusive Economic Zone. DOC Marine Conservation Services Series 10. Department of Conservation, Wellington. 58 p.

Sagar, P M; Carroll, J; Charteris, M; Thompson, D; Scofield, P (2011) Population assessment of Salvin's albatrosses at the Snares Western Chain, 25 September – 14 October 2010. Final Research Report for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Sagar, P M; Stahl, J C (2005) Increases in the numbers of breeding pairs in two populations of Buller's albatross (*Thalassarche bulleri bulleri*). Emu 105: 49–55.

Sagar, P M; Torres, L; Thompson, D (2010) Demography and distribution of Buller's Albatrosses *Thalassarche bulleri bulleri*: Final research report of the 2010 field season. NIWA Client Report: CHC2010-156, December 2010, prepared for Department of Conservation.

Sagar, P. (2014). Population studies of southern Buller's albatrosses on The Snares—population study of Buller's albatrosses. Report prepared for Department of Conservation, Ministry for Primary Industries, and Deepwater Group Limited.

Scofield, P (2011) Aerial photography of Northern Royal Albatrosses at the Chatham Islands, 2006–2010. Final Research Report for Ministry of Fisheries project, PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Scofield, P; Fraser, M J; Robertson, C J R (2008a) Population Dynamics of the Chatham Mollymawk at The Pyramid, 19-29 November 2007. Final Research Report for Ministry of Fisheries project, PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Scofield, P; Fraser, M J; Robertson, C J R (2008b) Population assessment of Northern Buller's Albatross, Northern Royal Albatross, and Northern Giant Petrels at the Forty-Fours, 13–19 November 2007. Final Research Report for Ministry of Fisheries project, PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Sharp, B (2009) A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ. (Unpublished report held by the Ministry for Primary Industries, dated May 2009).

Sharp, B; Parker, S; Smith, N (2009) An impact assessment framework for bottom fishing methods in the CCAMLR area. CAMMLR Science, 15 June 2009.

Sharp, B R, Waugh, S M; Walker, N A (2011). A risk assessment framework for incidental seabird mortality associated with commercial fishing in the New Zealand EEZ. Unpublished report held by the Ministry for Primary Industries, Wellington.

Sommer, E; Bell, B; Boyle, D (2008) Antipodes Island white-chinned petrel trip report, 2008. Final Research Report for Ministry of Fisheries project PRO2006-01. (Unpublished report held by Ministry for Primary Industries, Wellington.) 15 p.

Sommer, E; Boyle, D; Baer, J, Fraser, M, Palmer, D, Sagar, P (2010) Antipodes Island white-chinned petrel and grey petrel field work report, 2009–10. Final Research Report for Ministry of Fisheries project PRO2006-01, Wellington. 13p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Sommer, E; Boyle, D; Fraser, M (2009) Antipodes white-chinned petrel and grey petrel trip report, 2009. Final Research Report for Ministry of Fisheries project PRO2006-01, (Unpublished report held by Ministryfor Primary Industries, Wellington.) 19 p.

Soykan, C U; Moore, J E; Zydelis, R; Crowder, L B; Safina, C; Lewison, R L (2008) Why study bycatch? An introduction to the Theme Section on fisheries bycatch. Endangered Species Research 5: 91–102.

Sullivan, B J; Brickle, P; Reid, T A; Bone, D G; Middleton, D A J (2006a) Mitigation of seabird mortality on factory trawlers: Trials of three devices to reduce warp cable strikes. Polar Biology 29: 745–753.

Sullivan, B J; Reid, T A; Bugoni, L (2006b) Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biological Conservation 131: 495–504.

Taylor, G A (2000) Action plan for seabird conservation in New Zealand. Part A, threatened seabirds. Threatened Species Occasional Publication No. 16. Department of Conservation, Wellington. 234 p.

Thompson, F N; Abraham, E R (2009) Six monthly summary of the capture of protected species in New Zealand commercial fisheries, summer 2007–08. New Zealand Aquatic Environment and Biodiversity Report No. 35.

Tuck, G N; Phillips, R A; Small, C; Thomson, R B; Klaer, N; Taylor, F; Wanless, R; Arrizabalaga, H (2011) An assessment of seabird–fishery interactions in the Atlantic Ocean. ICES Journal of Marine Science 68: 1628–1637.

Tuck, G N; Polacheck, T; Croxall, J P; Weimerskirch, H; Ryan, P; Nel, D; Wayte, S; Bulman, C M (2004) Modelling the impact of fishery incidental mortality on three populations of wandering albatross. Pp 149–241 in Tuck, G N (Ed.) A comprehensive study of the ecological impacts of the worldwide pelagic longline industry: Southern Hemisphere studies. Melbourne, Australia: CSIRO.

Vié, J-C; Hilton-Taylor, C; Stuart, S N (Eds.) (2009) Wildlife in a changing world – an analysis of the 2008 IUCN Red List of Threatened Species. Gland, Switzerland: IUCN. 180 p.

Wade, P R (1998). Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science. 14: 1–37.

Wagner, E L; Boersma, P D (2011) Effects of fisheries on seabird community ecology. Reviews in Fisheries Science 19: 157–167.

Walker, K; Elliott, G (1999) Population changes and ecology of the wandering albatross *Diomedia exulans gibsoni* at the Auckland Islands. Emu 99: 239–247

Walker, K; Elliott, G (2009) Gibson's wandering albatross research Adams Island 2009. 11 p. (Unpublished report produced for the Department of Conservation.)

Walker, N.; Smith, N.; Sharp, B.; Cryer, M. (2014). A qualitative review of New Zealand's 2013 level two risk assessment for seabirds. New Zealand Fisheries Science Review 2015/1. 58 p.

Watkins, B P; Petersen, S L; Ryan, P G (2008) Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters. Animal Conservation 11: 247–254.

Waugh, S M; Baker, G B; Gales, R; Croxall, J P (2008a) CCAMLR process of risk assessment to minimise the effects of longline fishing mortality on seabirds. Marine Policy 32: 442–454.

Waugh, S M; Filippi D (2009) Ecological risk assessment for seabirds in New Zealand fisheries: primary components of ecological risk assessment methodology and calculating vulnerability and productivity for species. Research Progress Report for Ministry of Fisheries Research Project IPA2009-19. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Waugh S M; Filippi, D; Walker, N A; Kirby, D S (2008b) Updated preliminary results of an ecological risk assessment for seabirds and marine mammals with risk of fisheries interactions. Western Central Pacific Fisheries Commission Scientific Committee 4th Regular Session, August 2008, Port Moresby, Papua New Guinea. WCPFC-SC4-2008/EB-WP-2.

Waugh, S M; Taylor, G (2012) Annual Report on Project POP2011-02 Flesh-footed Shearwaters - population study trial and at-sea distribution. Project POP2011-02, Report to the Department of Conservation, Wellington.

Waugh, S M; Tennyson, A J D; Taylor, G A; Wilson, K (2013) Population sizes of shearwaters (Puffinus spp.) breeding in New Zealand, with recommendations for monitoring. Tuhinga 24: 159–204.

Waugh, S.M; Jamieson, S.E; Stahl, J-C; Filippi, D.P; Taylor, G.A; Booth, A (2014) Flesh-footed shearwater – population study and foraging areas. Project POP2011-02, Report to the Department of Conservation, Wellington.

Webber, D. (2014) Independent review of the seabird risk assessment. Unpublished report held by the Ministry for Primary Industries, Wellington.

WGSE (2011) Report of the International Council for the Exploration of the Sea (ICES) Working Group on Seabird Ecology (WGSE), 1–4 November 2011, Madeira, Portugal. ICES CM 2011/SSGEF:07. 73 p.

Wienecke, B; Robertson, G (2002) Seabird and seal-fisheries interactions in the Australian Patagonian toothfish *Dissostichus eleginoides* trawl fishery. Fisheries Research 54:253–265.

Wood, C (2006) (cited in Baker et al 2011b). Westland petrel (*Procellaria westlandica*) colony and burrow distribution survey 2003–2005. Unpublished report held by Department of Conservation, Wellington, New Zealand.

THEME 2: NON-PROTECTED BYCATCH

7 FISH AND INVERTEBRATE BYCATCH

Scope of chapter

This chapter outlines the main non-protected bycatch species (fish and invertebrates) and annual levels and trends in bycatch and discards in New Zealand's major offshore fisheries. This may also include some protected species. Research in this field was conducted fishery by fishery and this summary of current knowledge, while grouping the fisheries by method, continues to reflect that strategy. New research published in 2013 analysed individual species bycatch over time for each of the Tier 1 Deepwater fisheries and this approach is expected to continue, and be gradually refined. A new section is planned for inclusion in the 2015 AEBAR to address spatial patterns in fish and invertebrate bycatch and discards, with summaries by fishery and standardised areas.

The fisheries summarised are as follows:

Trawl fisheries:	Longline fisheries:	Other fisheries
Arrow squid	Ling (bottom)	Albacore tuna troll
Hoki/hake/ling	Tuna (surface)	Skipjack tuna purse seine
Jack mackerel		
Southern blue whiting		
Orange roughy		
Oreo		
Scampi		

Area

All areas and fisheries

Focal localities

Trawl fisheries
Arrow squid: Auckland Islands and Stewart/Snares Shelf (80–300 m).
Hoki/hake/ling: Chatham Rise, West Coast South Island, Campbell Plateau, Puysegur Bank, and Cook Strait (200–800 m).
Jack mackerel: West Coast of the North and South Islands, Chatham Rise, and Stewart-Snares Shelf (0–300 m).
Southern blue whiting: Campbell Plateau and Bounty Plateau (250–600 m).
Orange roughy: The entire New Zealand region (700–1200 m).
Oreos: South Chatham Rise, Pukaki Rise, Bounty Plateau, and Southland (700–1200 m).
Scampi: East coasts of the North and South Islands, Chatham Rise, and Auckland Islands (300–450 m).

Longline fisheries
Ling (bottom): Chatham Rise, Bounty Plateau, and Campbell Plateau (150–600 m).
Tuna (surface): East coast of the North Island and west coast of the South Island.

Other fisheries
Albacore tuna troll: West coasts of the North and South Islands.
Skipjack tuna purse seine: Northern North Island

Key issues

- Under-utilisation (including shark finning) of high volume, low value bycatch species, especially rattails, spiny dogfish, deepsea sharks, blue sharks, porbeagle sharks, and swimming crabs. However, from 1 October 2014, it will be illegal for a commercial fisher to remove the fins from any shark and discard the body of the shark at sea in New Zealand.
- Potential for further reduction of discards by discretionary fishing practices such as has been occurring in recent years with increasing use of meal plants and mid-water nets, where practicable.
- Unseen mortality in longline fisheries due to predation by large fish and sharks, marine mammals, seabirds, and sea lice.
- Lack of bycatch and discards information for most inshore (0–200 m) fisheries because of low observer coverage, and reporting requirements prior to 1 October

	2007 which saw most catch and effort data aggregated per day and by statistical area (Catch Effort and Landing Return). Collection of more detailed fishing event catch and effort data for smaller trawl (6–28 m), longline, and setnet vessels began on 1 October 2007.
Emerging issues	• Trends of increased rates and levels of bycatch and discarding in several categories of catch, especially non-QMS fish species and invertebrates. • The effect on bycatch rates in the ling longline fishery of a change to heavier fishing gear (including integrated weights) as used in the Antarctic toothfish fishery. • Increasing trawl distance/time in the squid, scampi, and orange roughy fisheries due to changes in fishing gear or reduction of target species catch rates—leading to greater bycatch levels in some categories.
MPI Research (current)	DAE201002 (bycatch and discards in deepwater fisheries) DEE201004 (ecological risk assessment in deepwater fisheries) DEE201005A (environmental indicators in deepwater fisheries) HMS201301 (bycatch in tuna longline fisheries) ENV201301 (model based estimates of fish bycatch)
NZ Government Research (current)	None
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture.
Related chapters/issues	Chondrichthyans (sharks, rays, and chimaeras)

Note: This chapter has been updated for the AEBAR 2014

7.1 CONTEXT

Management of non-protected species bycatch aligns with Fisheries 2030 Objective 6: *Manage impacts of fishing and aquaculture*.

DEEPWATER TRAWL AND BOTTOM LONGLINE FISHERIES

The management of non-protected species bycatch in the deepwater and middle-depth fisheries was described in the National Fisheries Plan for Deepwater and Middle-depth Fisheries (the National Deepwater Plan). Under the National Deepwater Plan, the objective most relevant for management of non-protected species bycatch is Management Objective 2.4: *Identify and avoid or minimise adverse effects of deepwater and middle-depth fisheries on incidental bycatch species*. Specific objectives for the management of non-protected species bycatch will be outlined in the fishery-specific chapters of the National Deepwater Plan. Estimation of non-protected species bycatch was carried out for each of the Tier-1 Deepwater fisheries on an annual rotational basis, with each of the following fisheries updated about every 4–5 years:

- arrow squid
- ling bottom longline
- hoki/hake/ling trawl
- jack mackerel trawl
- southern blue whiting trawl
- orange roughy/oreo trawl
- scampi trawl

SURFACE LONGLINE, TROLL, AND PURSE-SEINE FISHERIES

Non-protected fish species bycatch in the fisheries for Highly Migratory Species (HMS) was addressed in the HMS fish plan. Tuna fisheries incidental bycatch was examined, with updates every 2–3 years planned. Some data on bycatch in the Albacore tuna troll fishery and the skipjack tuna purse seine fishery were also available.

INSHORE FISHERIES

The three National Fisheries Plans for Inshore species (finfish, shellfish and freshwater fisheries) also included objectives which address non-protected species bycatch, but research on these objectives has yet to be conducted. However, summaries of the main bycatch species have occasionally been included in reports from fisheries characterisation projects, for example school shark, red gurnard, and elephantfish (Starr et al 2010a, b, c, Starr & Kendrick 2012, Starr & Kendrick 2013).

7.2 GLOBAL UNDERSTANDING

Bycatch of unwanted, low value species and discarding of these and of target species that are damaged or too small to process are significant issues in many fisheries worldwide. Few, if any, fisheries are completely without bycatch and this issue has been the subject of many studies and international meetings. Saila (1983) made the first comprehensive global assessment and estimated, albeit with very poor information, that at least 6.7 million tonnes was discarded each year. Alverson et al (1994) extended that work and estimated the global bycatch at 27.0 (range 17.9–39.5) million tonnes each year. An update by Kelleher (2005) suggested global bycatch of about 8% of the global catch, or 7.3 million tonnes, in 1999–2001.

Tropical shrimp trawl fisheries typically have the highest levels of unwanted bycatch, with an average discard rate of 62% (Kelleher 2005), accounting for about one-quarter to one-third of global bycatch. Discard rates in demersal trawl fisheries targeting finfish are much lower but, because they are so widespread, make a considerable contribution to global discards. Tuna longline fisheries have the next largest contribution and tend to have greater unwanted bycatch than other line fisheries (Kelleher 2005).

The estimated global level of discards reduced considerably since the Alverson et al (1994) estimate, but differences in the methodology and definition of bycatch used (see Kelleher 2005, Davies et al 2009) make it difficult to quantify the decline. The main reasons for the decline in bycatch may be due to a combination of higher retention rates, better fisheries management, and improved fishing methods.

Bycatch and discard estimation is frequently very coarse, and estimates of rates based on occasional surveys are often scaled up to represent entire fisheries and applied across years, or even to other fisheries (e.g., Bellido et al 2011). Data from dedicated fisheries observers are also frequently used for individual fisheries, and these are considered to provide the most accurate results, providing that discarding is not illegal (leading to bias due to "observer effects", Fernandes et al 2011). Ratio estimators similar to those applied in New Zealand fisheries are frequently used to raise observed bycatch and discard rates to the wider fishery, and the methods used in New Zealand fisheries are broadly similar to those used elsewhere (e.g., Fernandes et al 2011, Borges et al 2005).

Discard data are increasingly incorporated into fisheries stock assessments and management decision-making, especially with the move towards an Ecosystem Approach to Fisheries (EAF) (Bellido et al 2011), and as third party fishery certification schemes more closely examine the effects of fishing on the ecosystem. These data were also used to assess impacts on non-target species (e.g., Pope et al 2000, Casini et al 2003).

7.3 STATE OF KNOWLEDGE IN NEW ZEALAND

7.3.1 OVERVIEW

Estimation of annual bycatch and discard levels of non-protected species in selected New Zealand fisheries have been undertaken at regular intervals since 1998 (Table 7.1).

Table 7.1: Summary of research into bycatch and discards in New Zealand fisheries. [Continued on next page]

Trawl fisheries	Report
Arrow squid trawl	Anderson et al (2000) Anderson (2004b) Ballara & Anderson (2009) Anderson (2013a) Anderson (2013b)
Hoki trawl	Clark et al (2000) Anderson et al (2001) Anderson & Smith (2005) Ballara et al (2010) Anderson (2013b) Ballara et al (in prep.)
Hake trawl	Ballara et al (2010) Anderson (2013b) Ballara et al (in prep.)
Ling trawl	Ballara et al (2010) Anderson (2013b) Ballara et al (in prep.)
Jack mackerel trawl	Anderson et al (2000) Anderson (2004b) Anderson (2007) Anderson (2013b)
Southern blue whiting trawl	Clark et al (2000) Anderson (2004a) Anderson (2009b) Anderson (2013b)
Orange roughy trawl	Clark et al (2000) Anderson et al (2001) Anderson & Clark (2003) Anderson (2009a) Anderson (2011) Anderson (2013b)
Oreo trawl	Clark et al (2000) Anderson (2004a) Anderson (2011) Anderson (2013b)

Table 7.1 [Continued]: Summary of research into bycatch and discards in New Zealand fisheries.

Scampi trawl	Clark et al (2000) Anderson (2004a) Ballara & Anderson (2009) Anderson (2012) Anderson (2013b)

Other fisheries	Report
Albacore tuna troll	Griggs et al (2014)
Skipjack tuna purse seine	Anon (2013)

TRAWL AND BOTTOM LONGLINE FISHERIES

The estimation process for the trawl and bottom longline fisheries used rates of bycatch and discards in various categories, i.e., in most cases “all QMS species combined”, “all non-QMS species combined”, “all invertebrate species combined”,. It also used fishery strata in the observed fraction of the fishery, and effort statistics from the wider fishery, to calculate annual bycatch and discard levels. This ratio-based approach estimates precision by incorporating a multi-step bootstrap algorithm which takes into account the effect of correlation between trawls in the same observed trip and stratum. Estimates of the annual bycatch of a wide range of individual species were also made in the most recent analysis of the arrow squid fishery (Anderson 2013a), and also for all the Deepwater Tier 1 fisheries (Anderson 2013b).

In some cases the apparent increase or decrease in bycatch of a species is likely to be due to other factors including the introduction of new species to the QMS, new species-specific 3-letter codes to replace generic codes, and improvements in species identification over time, e.g., the increase in recorded bycatch of floppy tubular sponge in the hoki/hake/ling trawl fishery reflects the improved identification of sponges in more recent years, and use of the species specific code for giant spider crab (GSC) instead of unspecified crabs (CRB) in the hoki/hake/ling trawl fishery. Some codes may also have been misused, e.g., in the arrow squid fishery, the increase in recorded bycatch of smooth red swimming crab (*Nectocarcinus bennetti*) appears to be at the expense of bycatch of the similar-looking paddle crab (*Ovalipes catharus*) with the seemingly generic species code (PAD).

The approach used in these analyses relied heavily on an appropriate level and spread of observer effort being achieved, and this was examined in detail in each report. Although details of bycatch and discards were recorded directly by vessel skippers for all fishing events through catch effort forms, these data were generally inadequate for precise measurement of annual totals as the forms list only the top five catch species, discards were not well recorded, and they generally lacked the accuracy and precision of observer data. Despite these inadequacies annual bycatch totals were usually derived from catch effort data, but only as secondary estimates.

SURFACE LONGLINE FISHERIES

The estimation process used for surface longline fisheries was similar to that used for trawl and bottom longline fisheries, with each species assessed separately. In this case CPUE was calculated as the number of fish observed caught per 1000 hooks set stratified by fishing year, fleet (Foreign Licenced, Foreign Chartered, and Domestic), and area. CPUE was expressed using a ratio of means estimator (see Bradford 2002, Ayers et al 2004). The total number of each species caught in each stratum was estimated by scaling up the CPUE to the total number of hooks set. These numbers were then summed across strata to give total annual catch estimates. An analytical estimator was used to calculate variance, using an adjustment to account for correlation between variance and the mean of the effort variable (after Thompson 1992).

TROLL AND PURSE SEINE FISHERIES

Fish bycatch research in these fisheries is limited to annual summaries of observer recorded species catches, without any attempts to raise observed catch rates to the total commercial fishery.

INSHORE FISHERIES

Some bycatch information is available from some fishery characterisation studies (see Section 7.1) but there were no detailed analyses of bycatch and discards from inshore fishing principally because of the lack of observer data. Most of the analyses of bycatch and discards for offshore fisheries were reliant on observer data, e.g., Anderson 2012, 2013a, and similar analyses for inshore fisheries are not possible. Past observer coverage of inshore fisheries was low (e.g., fewer than 2% of tows observed in 2009–10, Ramm 2012) and coverage was mainly focused on monitoring the Hector’s and Maui’s dolphin Threat Management Plan. There are also practical and logistical problems with placing observers on smaller inshore vessels, and other options are being explored for the monitoring of these fisheries. This includes electronic monitoring using various configurations of video cameras, gear sensors, and position recording. Some progress has been made, but there remain some issues to surmount before electronic monitoring can provide all the information required to estimate fish and invertebrate bycatch. However for SNA 1 MPI has committed to 100% observer or camera coverage for all trawl vessels by October 1, 2015[44], therefore information should improve quickest in this fishery.

Detailed fishing event data for inshore fishing, e.g., tow-by-tow catch and effort, were not collected before 1 October 2007 unless the vessel was using the Trawl Catch Effort and Processing Return (TCEPR) used by deepwater vessels (over 28 m). Before 1 October 2007, smaller trawl (6–28 m), longline, and setnet vessels used the Catch Effort and Landing Return (CELR) to collect daily summary catch-effort and landings data by statistical area. From 1 October 2007 onwards, detailed data for each fishing event were collected using the new Trawl Catch and Effort Return (TCER), and this may support a more detailed analyses of bycatch in inshore fisheries.

7.3.2 ARROW SQUID TRAWL FISHERY

Since 1990–91 the level of observer coverage in this fishery was 6–53% of the total annual catch, and was relatively high, 28–40% from 2006–07 to 2010–11 due to the management measures imposed for the protection of New Zealand sealions (*Phocarctos hookeri*)[45]. This coverage was spread across the fleet and annually 10–68% of all vessels targeting arrow squid were observed, with this fraction increasing over time. Observers covered the full size range of vessels operating in the fishery, although the smallest vessels were slightly undersampled and the largest oversampled.

The observer effort was mostly focussed on the main arrow squid fisheries around the Auckland Islands and Stewart-Snares Shelf, but the smaller fisheries on the Puysegur Bank and off Banks Peninsula were also covered, although less consistently. Observer coverage was more focussed on the central period of the arrow squid season, February to April, than the fleet was in general – with fishing in January and May slightly undersampled.

Appropriate stratification for the analyses was determined using linear mixed-effect models (LMEs) to identify key factors influencing variability in the observed rates of bycatch and discarding. This approach addressed the significant vessel-to-vessel and trip-to-trip differences in bycatch and discard rates in this fishery by treating the trip variable as a random effect (whereby the trip associated with each record was assumed to be randomly selected from a population of trips) and treated other variables as fixed effects. This process consistently identified the separate fishery areas (Auckland Islands, Stewart-Snares Shelf, Puysegur Bank, Banks Peninsula) as having the greatest influence on bycatch and discard rates (with trawl duration of secondary importance) and so fishery area was used in all cases to stratify the calculation of annual levels.

Since 1990–91, over 470 bycatch species or species groups were identified by observers in this fishery, most being non-commercial species (including invertebrate species) caught in low numbers. Arrow squid accounted for about 80% of the total estimated catch recorded by observers. The main bycatch species or species groups were the QMS species barracouta (8.5%), silver warehou (2.5%), spiny dogfish (1.7%), and jack mackerel (1.1%); and of these only spiny dogfish were mostly discarded (Figure 7.1).

Of the other (non-squid) invertebrate groups crabs (0.8%), in particular smooth red swimming crab (*Nectocarcinus bennetti*) (0.5%), were caught in the greatest amounts and were mostly discarded. Smaller amounts of octopus and squid, sponges, cnidarians, and echinoderms were also often caught and discarded.

When combined into broader taxonomic groups, bony fish (excluding rattails, tuna, flatfish, and eels) contributed the most bycatch (16.5% of the total catch), followed by sharks and dogfishes (1.9%), crustaceans (0.8%), and rattails (0.2%). The combined bycatch of all other fish (tuna, rays and skates, chimaeras, flatfish, and eels) accounted for a further 0.5% of the total catch.

[44] http://www.fish.govt.nz/en-nz/Consultations/SNA1+management+decision.htm

[45] Operational plan to manage the incidental capture of New Zealand sea lions in the Southern Squid Trawl Fishery (SQU6T); Ministry for Primary Industries, 1 October 2012. ISBN Online: 978-0-478-42003-6; ISSN Online: 2253-3923

More than 75% of the sharks and dogfishes, rattails, and eels were discarded, whereas about half the flatfish were retained, as were most of the tuna, rays and skates, chimaeras, and other fish not in any of these groups. The fish species discarded in the greatest amounts were spiny dogfish, redbait, rattails, and silver dory. Of the invertebrates, virtually all the echinoderms, other squids, sponges, cnidarians, and polychaetes were discarded, but crustaceans, octopuses, and other molluscs were often retained.

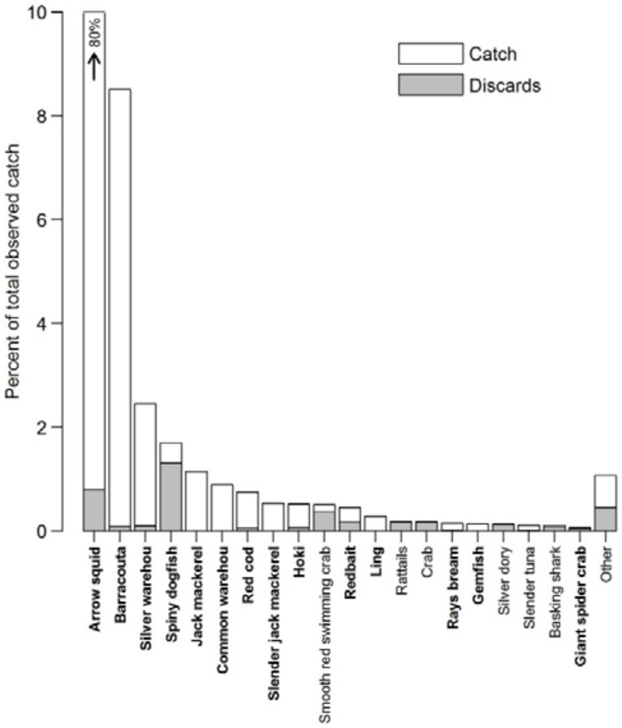


Figure 7.1: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the arrow squid fishery, and the percentage discarded, 1 October 1990 to 30 September 2011 (Anderson 2013a). The "Other" category is the sum of all bycatch species representing less than 0.05% of the total catch. QMS species are shown in bold.

Total annual bycatch in the arrow squid fishery was 4500–25 000 t, with low levels in the early 1990s and after 2007–08, and a peak in the early 2000s (Figure 7.2). The large majority of the bycatch comprised QMS species, with less than 1000 t of non-QMS species and invertebrate species bycatch in most years.

TRENDS IN ESTIMATED BYCATCH BY SPECIES FROM THE ARROW SQUID TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were barracouta (*Thyrsites atun*, BAR), silver warehou (*Seriolella punctata*, SWA), and spiny dogfish (*Squalus acanthias*, SPD).
- Of the 101 bycatch species examined, the catch of 15 decreased and 54 increased over time.
- The species that showed the greatest decline were paddle crabs (PAD), jack mackerels (*Trachurus* spp., JMA), and slender jack mackerel (*Trachurus murphyi*, JMM) (Figure 7.3).
- The species that showed the greatest increase were giant spider crab (*Jacquinotia edwardsii*, GSC), smooth red swimming crab (NCB) (a species mainly limited to the Auckland Islands and adjacent regions of the Campbell Plateau), and silver dory (*Cyttus novaezealandiae*, SDO) (Figure 7.3).

Estimated total annual discards ranged from just over 200 t in 1995–96 to about 5500 in 2001–02 and, like bycatch, peaked in the early 1990s and were at relatively low levels after 2006–07 (Figure 7.4). The majority of discards were QMS species (about 62% for all years), followed by non-QMS species (19%), invertebrate species (11%), and arrow squid (7%).

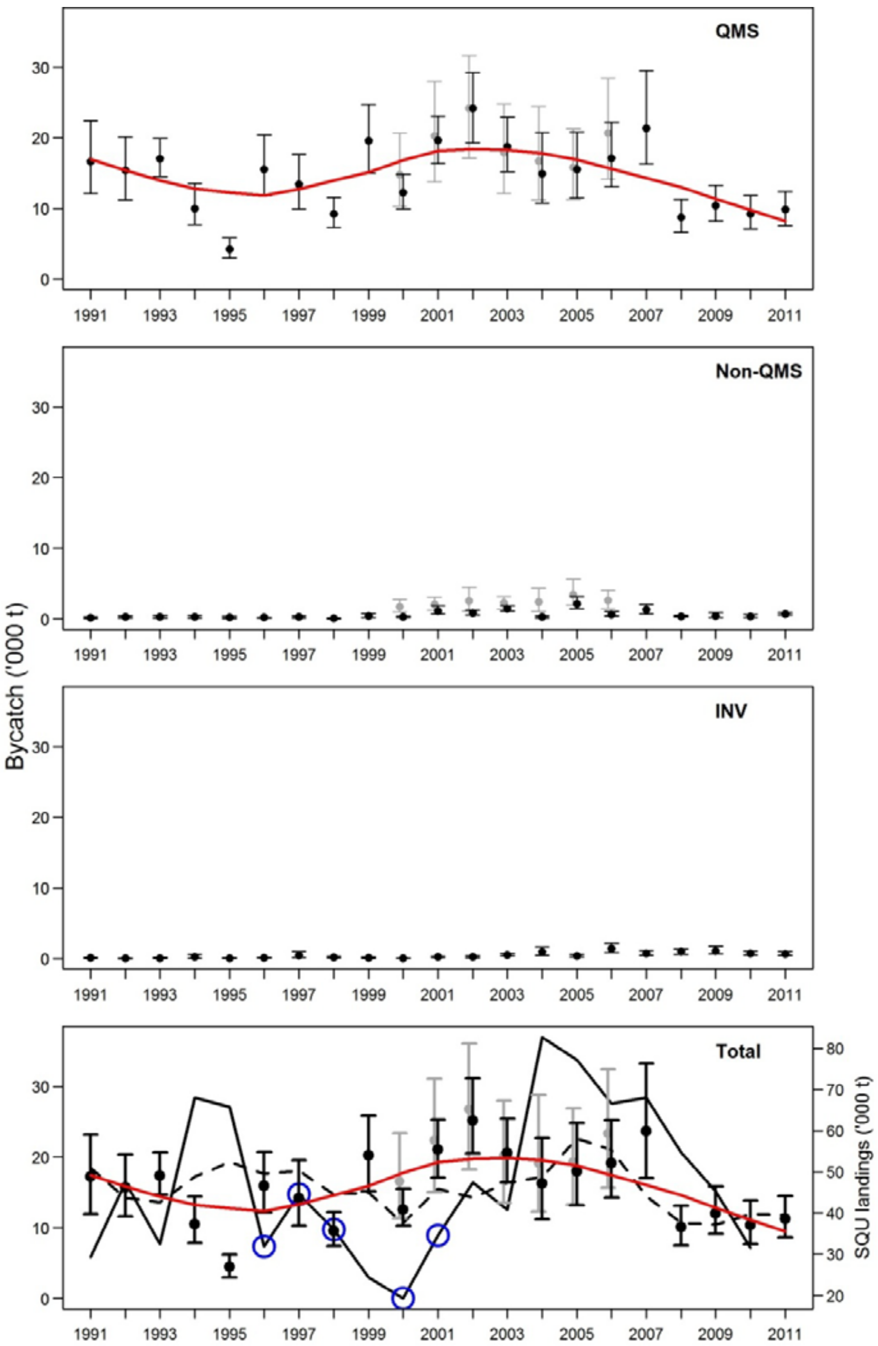


Figure 7.2: Annual estimates of bycatch in the arrow squid trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2010–11. Also shown (in grey) are estimates of bycatch in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual bycatch. In the bottom panel the solid black line shows the total annual reported trawl-caught landings of arrow squid (Ministry for Primary Industries 2013a), with circles indicating years in which the fishery closed early after reaching the sea lion FRML; and the dashed line shows annual effort (scaled to have mean equal to that of total bycatch).

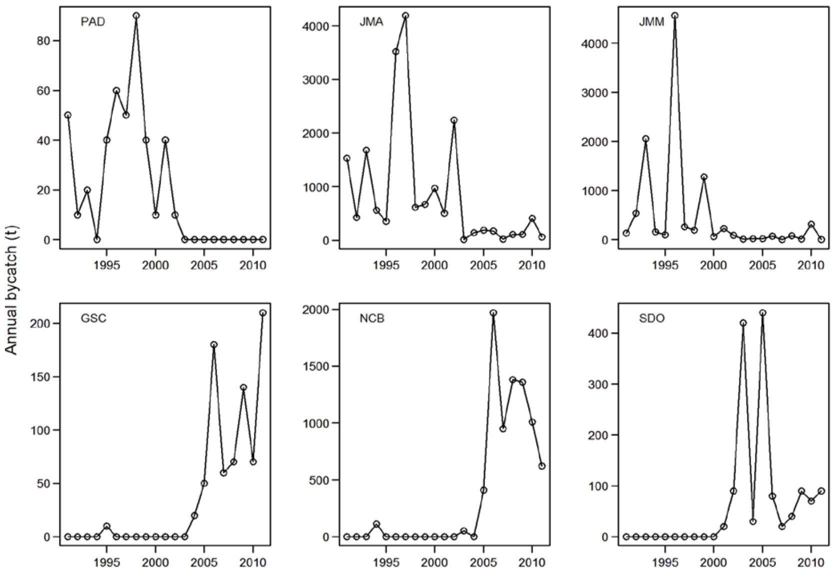


Figure 7.3: Annual bycatch estimates in the arrow squid trawl fishery for the species which had the greatest catch decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes (from Anderson 2013b).

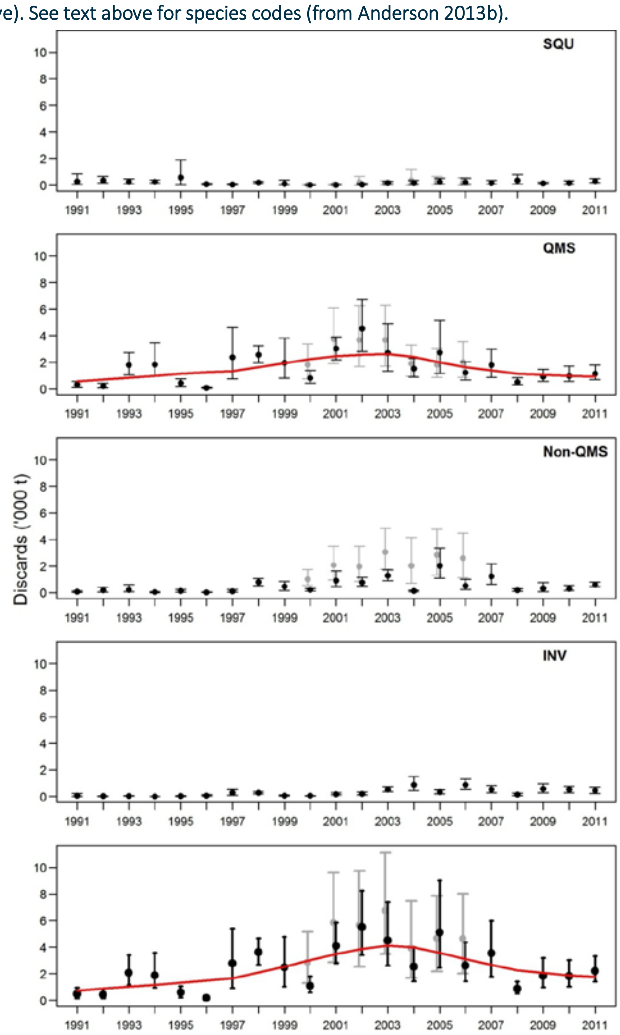


Figure 7.4: Annual estimates of discards in the arrow squid trawl fishery, for arrow squid (SQU), QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2010–11. Also shown (in grey) are estimates of discards in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual discards.

7.3.3 HOKI/HAKE/LING TRAWL FISHERY

Earlier reports were limited to the hoki target fishery and only the most recent report considered bycatch and discards for the fishery as defined by the three target species combined—but hoki was dominant in this fishery, accounting for over 90% of the catch (Ballara et al 2010).

Observer coverage in the hoki, hake, and ling trawl fishery between 2000–01 and 2006–07 was 11–21% of the annual target fishery catch, and 78 separate vessels were observed, covering the full range of vessel sizes. The annual number of observed tows decreased from 3580 in 2000–01 to 1999 in 2006–07. Coverage was spread over the geographical range of this fishery, with high sampling throughout the west coast South Island (WCSI) and Chatham Rise fishing grounds and, less frequently, in the Sub-Antarctic. Lower levels of sampling were achieved in the Cook Strait and Puysegur fisheries, and coverage was lower still around the North Island although this area accounted for very little of the overall catch. Good observer coverage was achieved during the hoki spawning season (July to early September), but coverage outside of this period was variable and under-representative in some months in some years, especially in the Sub-Antarctic, Chatham Rise and Puysegur fisheries.

Hoki, hake, and ling accounted for 87% (77%, 6%, and 4% respectively) of the total observed catch from trawls targeting hoki, hake, and ling between 2000–01 and 2006–07. The remaining 13% comprised a large range of species, in particular javelinfish (2.1%), silver warehou (1.7%), rattails (1.4%), and spiny dogfish (1.1%) (Figure 7.5). In total, over 470 species or species groups were identified by observers, the majority of which are non-commercial species caught in low numbers. Chondrichthyans in general, often unspecified but including spiny dogfish and basking shark, accounted for much of the non-commercial catch. Echinoderms, squids, crustaceans, and other unidentified invertebrates were also well represented in the bycatch of this fishery.

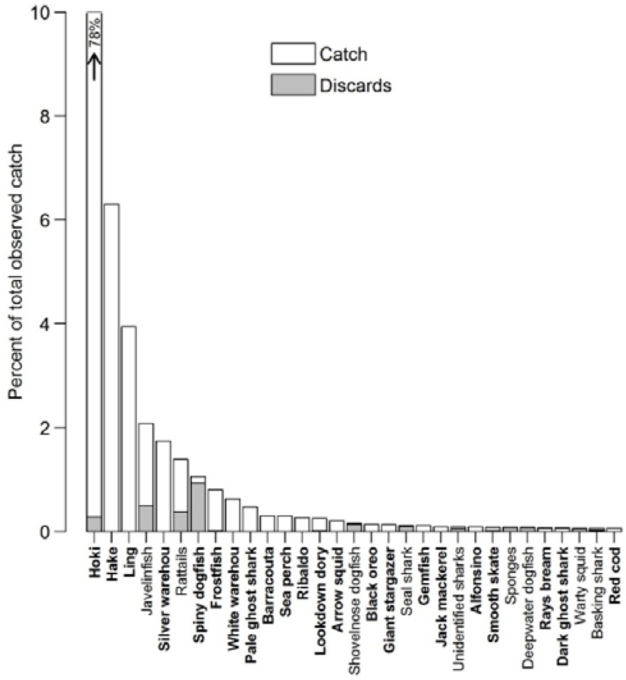


Figure 7.5: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the hoki/hake/ling 2000–01 to 2006–07 fishery, and the percentage discarded. QMS species are shown in bold.

Total bycatch in the hoki, hake, and ling fishery between 2000–01 and 2006–07 was 36 000–58 000 t per year (compared to the combined total landed catch of hoki, hake, and ling of 130 000–238 000 t). Estimates of total bycatch for 1990–91 to 1998–99 from earlier projects (for the hoki target fishery alone), were 15 000–60 000 t (Figure 7.6). Overall, total bycatch increased during the 1990s to a peak in the early 2000s, then declined slowly. Annual bycatch for the 1990–01 to 2006–07 period was also estimated for commercial species (i.e. QMS species and species which were generally retained (more than 75%) and which comprised 0.1% or more of the total observed catch) and non-commercial species, rather than QMS and non-QMS species. Roughly similar amounts of these two categories were caught overall, and each showed a similar pattern over time to total bycatch.

TRENDS IN BYCATCH BY SPECIES FROM THE HOKI, HAKE, AND LING TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were silver warehou (SWA), javelinfish (JAV), and unspecified rattails (Macrouridae, RAT).
- Of the 342 bycatch species examined, 44 had a decrease in catch over time and 102 an increase in catch.
- The species that showed the greatest decline included: skates (SKA), although this result is likely to be mainly due to better identification of rough skates (*Zearaja nasuta*, RSK) and smooth skates (*Dipturus innominata*, SSK) after their introduction into the QMS in October 2003; slender jack mackerel (JMM) (a species not found south of the Stewart-Snares shelf), and dogfishes (*Etmopterus* spp., ETM) (Figure 7.7).
- The species that showed the greatest increase were alfonsino (*Beryx splendens*, BYS) (a species not found south of the Chatham Rise), scabbardfish (*Benthodesmus* spp., BEN), and floppy tubular sponge (*Hyalascus* sp., HYA), although these were not well identified before 2007–08 (Figure 7.7).

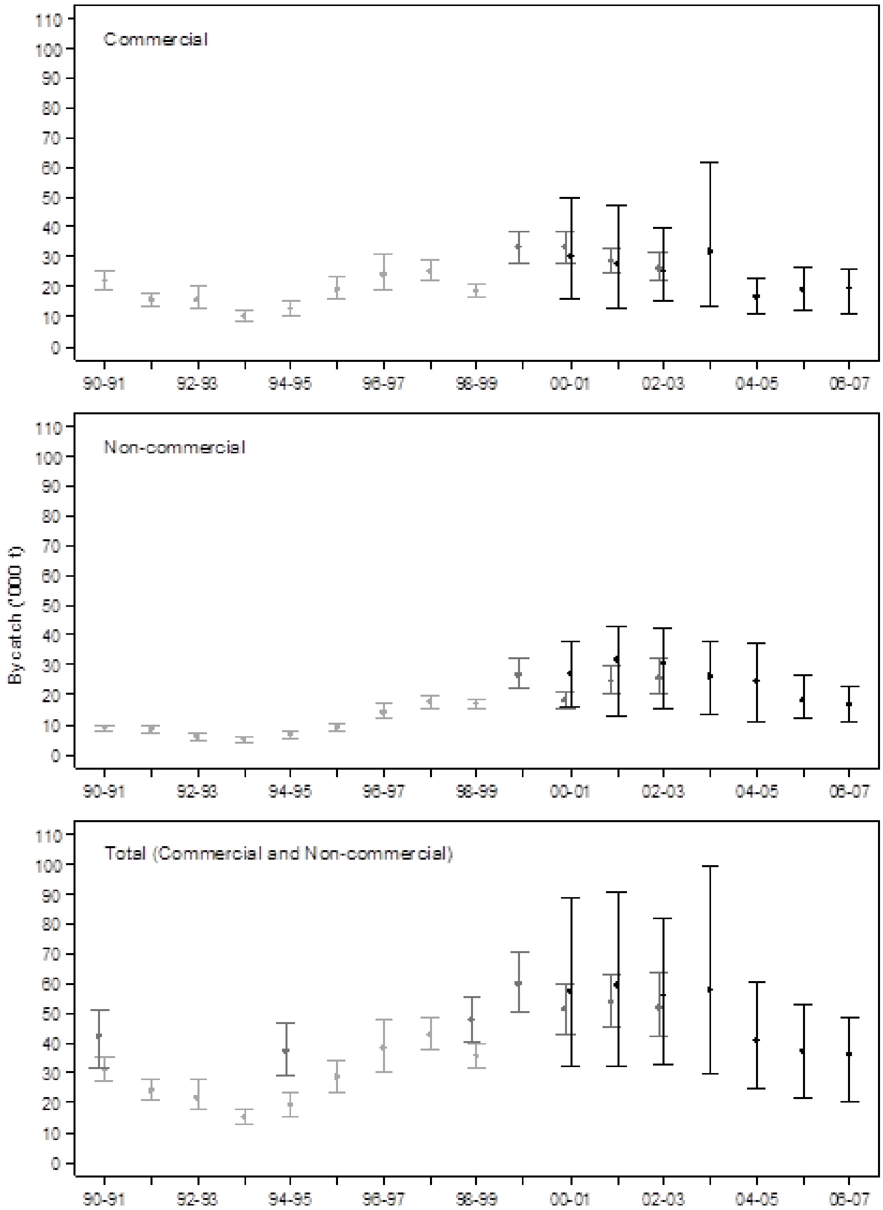


Figure 7.6: Annual estimates of fish bycatch in the target hoki, hake and ling trawl fishery, calculated for commercial species, non-commercial species, and overall for 2000–01 to 2006–07 (black). Also shown (in light grey) are the equivalent bycatch estimates calculated for 1990–91 to 1998–99 by Anderson et al (2001), and for the years 1990–91, 1994–95, 1998–99 and 1999–2000 to 2002–03 by Anderson & Smith (2005), (in dark grey). Error bars show the 95% confidence intervals.

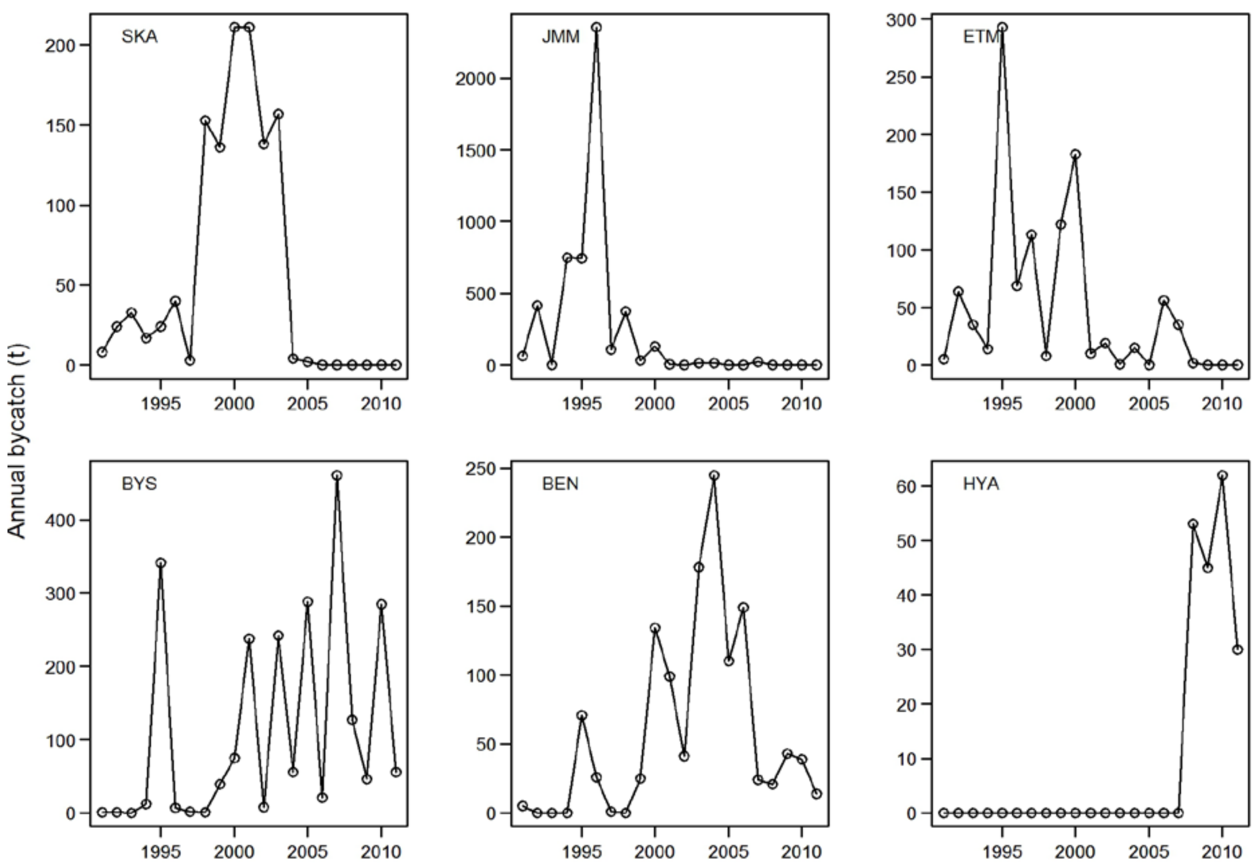


Figure 7.7: Annual bycatch estimates in the hoki, hake, and ling trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discard estimates for 2000–01 to 2006–07 were 5500–29 000 t per year with the main species discarded including spiny dogfish, rattails, javelinfish, hoki, and shovelnose dogfish. Total annual discards for 1990–91 to 1998–99 were 6600–17 900 t, and overall there was no obvious trend in total discards (Figure 7.8). The target species (hoki, hake, and ling) made up 9.7% of total observed discards. Discard rates were strongly influenced by the use of meal plants on fishing vessels; discards of non-commercial species on factory vessels without meal plants were up to twice the level of discards for vessels with meal plants. The use of meal plants, especially for species such as javelinfish and other rattails, was more prevalent in recent years.

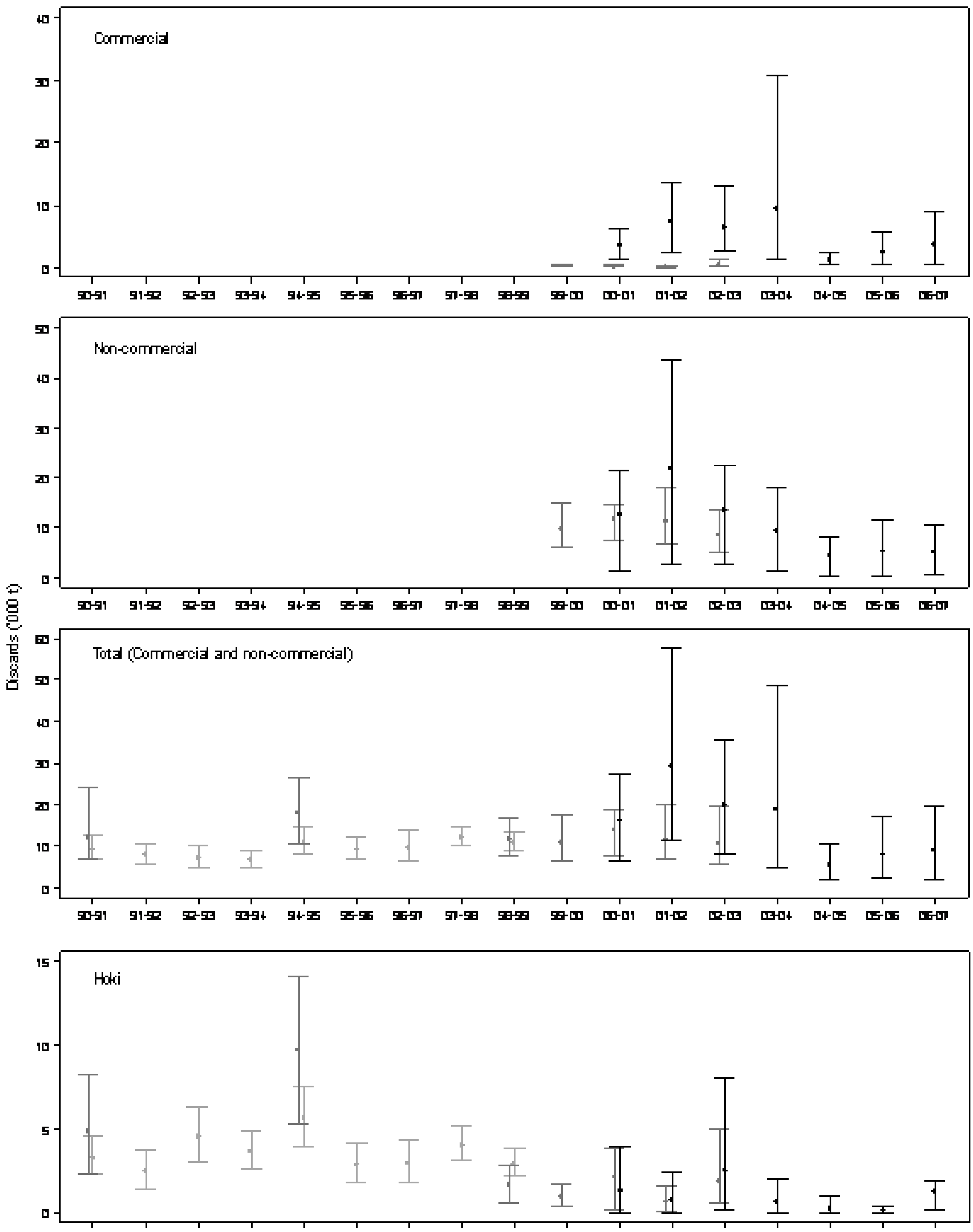


Figure 7.8: Annual estimates of fish discards in the target hoki, hake, and ling trawl fishery, calculated for commercial species, non-commercial species, hoki, and overall for the period 2000–01 to 2006–07 (black). Also shown (in light grey) are the equivalent discard estimates calculated for the period 1990–91 to 1998–99 by Anderson et al (2001), and for 1990–91, 1994–95, 1998–99 and 1999–2000 to 2002–03 by Anderson & Smith (2005), (in dark grey). Error bars show the 95% confidence intervals.

7.3.4 JACK MACKEREL TRAWL FISHERY

Estimates of annual bycatch in this fishery are available for 1990–91 to 2004–05 (Anderson 2007), with this fishery due for reassessment in 2014–15. The annual level of observer coverage in this fishery was 8–27% of the target fishery catch but was usually 15–20%. For the most recent period examined in detail, 2001–02 to 2004–05, the majority of the observer effort was focussed on the main fishery, off the west coasts of the North and South Islands, with some additional coverage on the Stewart/Snares Shelf and Chatham Rise fisheries. However, in 2003–04 and 2004–05, there was a total of only 12 trawls observed outside of the western fishery. During this time the fishery was dominated by seven large trawlers and observers were able to complete a trip on each vessel in most years. The fishery runs year round, and although there were long periods in each year when commercial fishing effort was not observed, coverage encompassed all seasons for the four years combined. More recently observer coverage was relatively high (31–82% from 2006–07 to 2011–12) and should remain so given the commitment of MPI to mandatory observer coverage on foreign charter vessels, which took over 90% of the catch in this fishery since 2002–03 (Ministry for Primary Industries 2013b).

Jack mackerel species were 70% of the total estimated catch from all trawls targeting jack mackerel from 2001–02 to 2004–05. The remaining 30% mostly comprised other commercial species; especially barracouta (15.6%), blue mackerel (4.8%), frostfish (3.1%), and redbait (2.7%) (Figure 7.9). Overall about 130 species or species groups were identified by observers, and about half of these were non-commercial, non-QMS species caught in low numbers. The species most discarded was the spiny dogfish (which became a QMS species in October 2004), which comprised about 0.5% of the total catch. The bycatch of non-QMS invertebrate species has yet to be closely studied in this fishery, but species of squid, salps, and jellyfish were the most common species recorded by observers during this period.

Total bycatch in the jack mackerel trawl fishery from 2001–02 to 2004–05 was 7700–11 900 t. Estimates of total bycatch for 1990–91 to 2003–04 from earlier projects were 5400–15 500 t (Figure 7.10). After an abrupt increase in the late 1990s, annual bycatch steadily decreased to a level comparable to that of the 1990–91 to 1996–97 period. This bycatch almost entirely consisted of commercial (mainly QMS) species.

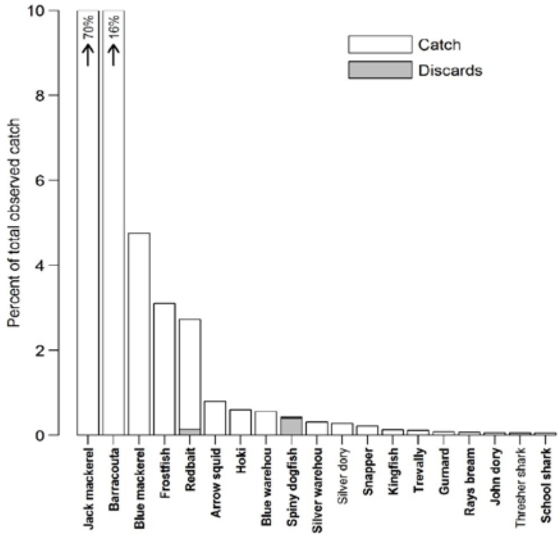


Figure 7.9: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the jack mackerel fishery, 2001–02 to 2004–05, and the percentage discarded. QMS species are shown in bold.

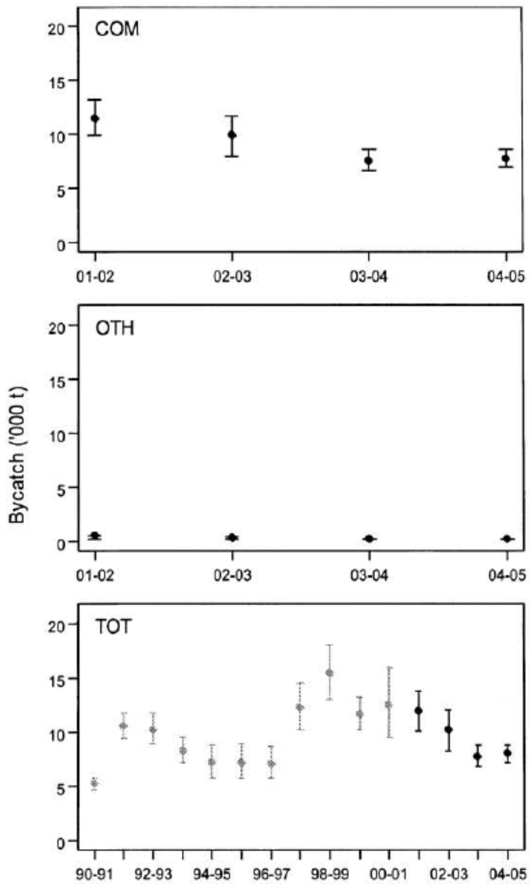


Figure 7.10: Annual estimates of fish bycatch in the target jack mackerel trawl fishery for the 2001–02 to 2004–05 fishing years (in black), calculated for commercial species (COM), non-commercial species (OTH), and overall (TOT). Also shown (in grey) are estimates of overall bycatch calculated for 1990–91 to 2000–01 by Anderson et al (2000) and Anderson (2004a). Error bars show the 95% confidence intervals.

TRENDS IN BYCATCH BY SPECIES FROM THE JACK MACKEREL TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were barracouta (BAR), blue mackerel (*Scomber australasicus*, EMA), and frostfish (*Lepidopus caudatus*, FRO).
- Of the 114 bycatch species examined, 32 had a decrease in catch over time and 18 an increase in catch.
- The species that showed the greatest decline were dark ghost shark (GSH, introduced to the QMS in October 1998; the code has sometimes erroneously been used for pale ghost shark, GSP), carpet shark (*Cephaloscyllium isabellum*, CAR), and red cod (*Pseudophycis bachus*, RCO) (Figure 7.11).
- The species that showed the greatest increase were pilchard (*Sardinops sagax*, PIL) (a species present only in the west coast jack mackerel fishery), greenback jack mackerel (*Trachurus declivis*, JMD), and yellowtail jack mackerel (*T. novaezelandiae*, JMN). Although part of the target species group, the latter two species are included to enable examination of changes in the relative catches of the constituent species under the JMA code. (Figure 7.11).

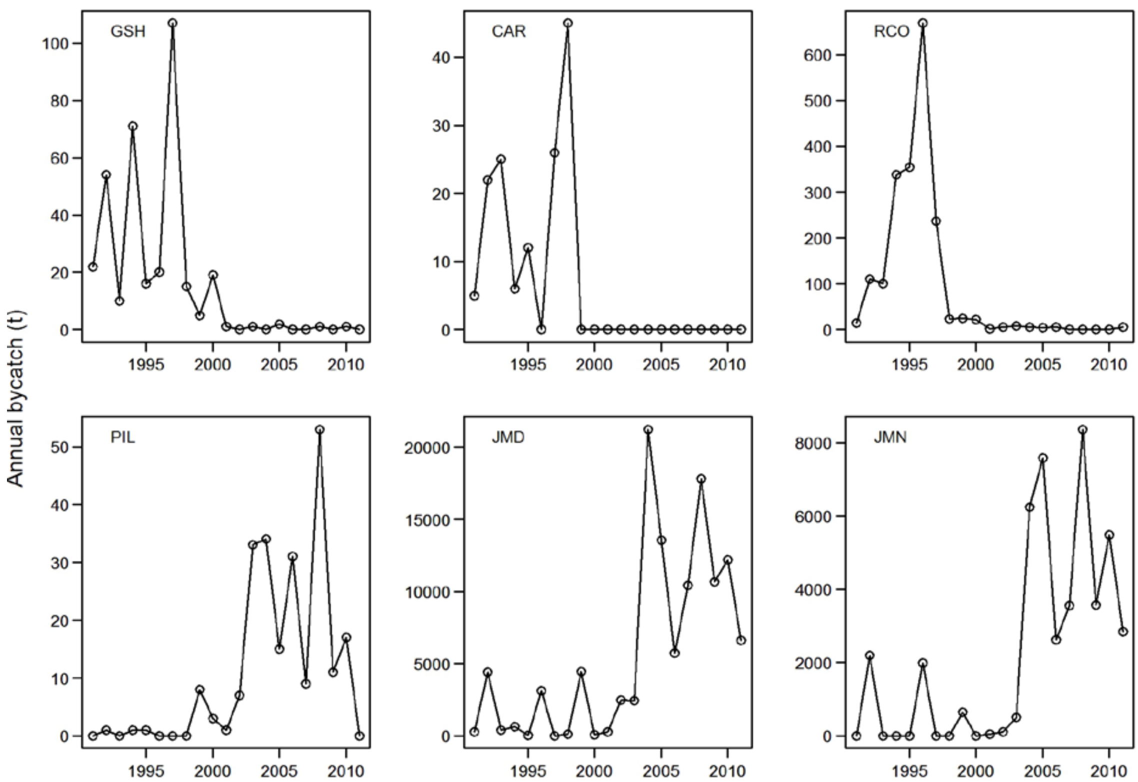


Figure 7.11: Annual bycatch estimates in the jack mackerel trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discards decreased between 2001–02 and 2004–05, continuing a trend that began in 1998–99, to a level of only 90–100 t per year. This is about 5% of the level of 1997–98 (1850 t), when annual discards were at their greatest, and is lower than in any year since 1990–91 (Figure 7.12). Discards of the target species were about 200–400 t per year prior to 1998–99 but thereafter decreased to only about 10 t per year, mainly due to the absence of recorded losses of large quantities of fish through rips in the net or intentional releases of fish during landing. Discards were composed of roughly equal amounts of commercial and non-commercial species in the recent study, although commercial species discards were substantially greater in 2001–02.

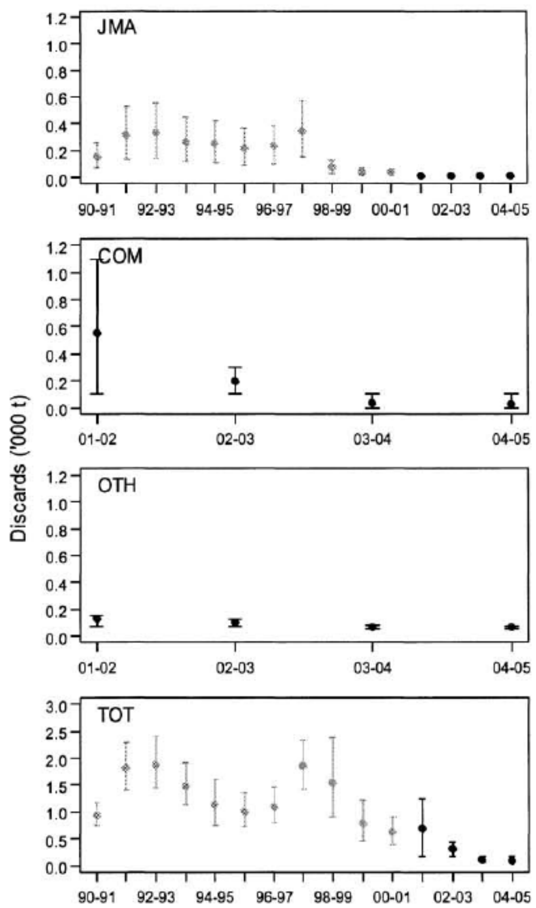


Figure 7.12: Annual estimates of fish discards in the target jack mackerel trawl fishery for the 2001–02 to 2004–05 fishing years (in black), calculated for jack mackerel (JMA), commercial species (COM), non-commercial species (OTH), and overall (TOT). Also shown (in grey) are estimates of jack mackerel and overall discards calculated for 1990–91 to 2000–01 by Anderson et al (2000) and Anderson (2004a). Error bars show the 95% confidence intervals.

7.3.5 SOUTHERN BLUE WHITING TRAWL FISHERY

In a study that covered data from 2002–03 to 2006–07, the ratio estimator used to calculate bycatch and discard rates in this fishery was based on trawl duration (Anderson 2009b). Linear mixed-effect models (LMEs) identified fishing depth as the key variable influencing bycatch rates and discard rates in this fishery, and regression tree methods were used to optimise the number of levels of this variable in order to stratify the calculation of annual bycatch and discard totals in each catch category.

The key categories of catch/discards examined were; southern blue whiting, other QMS species combined, commercial species combined (as defined above for hoki/hake/ling), non-commercial species combined, and three commonly caught individual species, hake, hoki, and ling.

The level of observer coverage represented was 22–53% of the target fishery catch from 2002–03 to 2006–07 and similar levels were reported from 1990–91 to 2001–02. The spread of observer data, across a range of variables, had no obvious shortcomings, due to a combination of the highly restricted distribution of the southern blue whiting fishery over space and time of year, a stable and uniform fleet composition, and a high level of observer effort.

Southern blue whiting were more than 99% of the total estimated catch from all observed trawls targeting southern blue whiting from 2002–03 to 2006–07. About half the remaining total catch was made up of ling (0.2%), hake (0.1%), and hoki (0.1%) (Figure 7.13). These three species, along with other QMS species, comprised over 80% of the total bycatch. In all, over 120 species or species groups were identified by observers, most were non-commercial species caught in low numbers. Porbeagle sharks (introduced into the QMS in 2004), javelinfish and other rattails, and silverside, accounted for much of the remaining bycatch. Invertebrate species (mainly sponges, crabs, and echinoderms) were also recorded by observers, but no taxon accounted for more than 0.01% of the total observed catch.

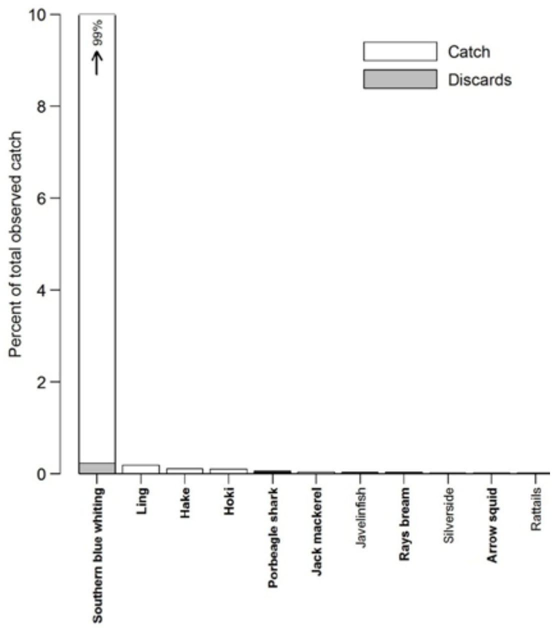


Figure 7.13: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the southern blue whiting fishery, 2002–03 to 2006–07, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch estimates from 2002–03 to 2006–07 was 40–390 t, compared with approximate target species catches in the same period of about 22 000 to 42 000 t. This bycatch was split between commercial species (55%) and non-commercial species (45%), although QMS species accounted for about 80% of the total bycatch during this period. Total annual bycatch decreased during the period, to an all-time low of 40 t in 2006–07. Total annual bycatch estimates for 1990–91 to 2001–02, from earlier reports, were mostly 60–500 t but reached nearly 1500 t in 1991–92 (Figure 7.14). This year immediately preceded the introduction of southern blue whiting into the QMS, and effort and the catch was exceptionally high.

TRENDS IN BYCATCH BY SPECIES FROM THE SOUTHERN BLUE WHITING TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were ling (*Genypterus blacodes*, LIN), hoki (*Macruronus novaezelandiae*, HOK), and hake (*Merluccius australis*, HAK).
- Of the 65 bycatch species examined, 12 had a decrease in catch over time and 4 an increase in catch.
- The species that had the greatest decline were hoki (HOK), moonfish (*Lampris guttatus*, MOO) (a species mainly found north of the southern blue whiting grounds), and dark ghost shark (*Hydrolagus novaezealandiae*, GSH; the code has sometimes erroneously been used for pale ghost shark, GSP) (Figure 7.15).
- The species that showed the greatest increase were ray's bream (*Brama brama*, RBM), opah (*Lampris immaculatus*, PAH), and silverside (*Argentina elongate*, SSI) (Figure 7.15).

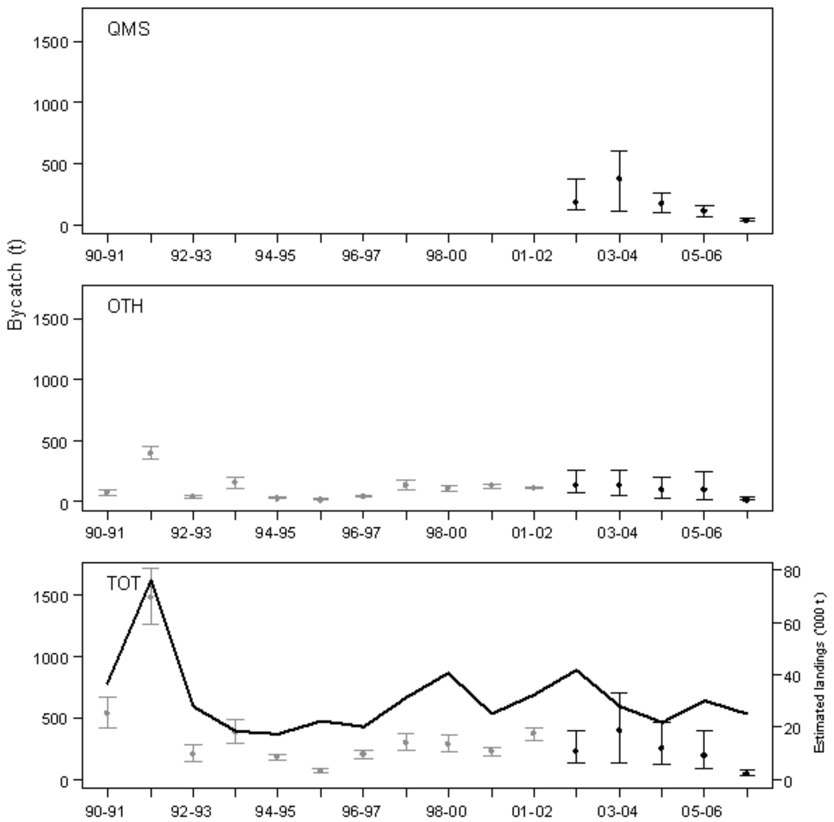


Figure 7.14: Annual estimates of fish bycatch in the southern blue whiting trawl fishery, calculated for QMS species, non-commercial species (OTH), and overall (TOT) for 2002–03 to 2006–07 (in black). Also shown (in grey) are estimates of bycatch in each category (excluding QMS) for 1990–91 to 2001–02 (Anderson 2004a). Error bars show the 95% confidence intervals. Note: the 98–00 fishing year encompasses the 18 months between September 1998 and March 2000, the transitional period between a change from an Oct–Sep to Apr–Mar fishing year. The dark line in the bottom panel shows the total annual estimated landings of SBW (Ministry for Primary Industries 2013a).

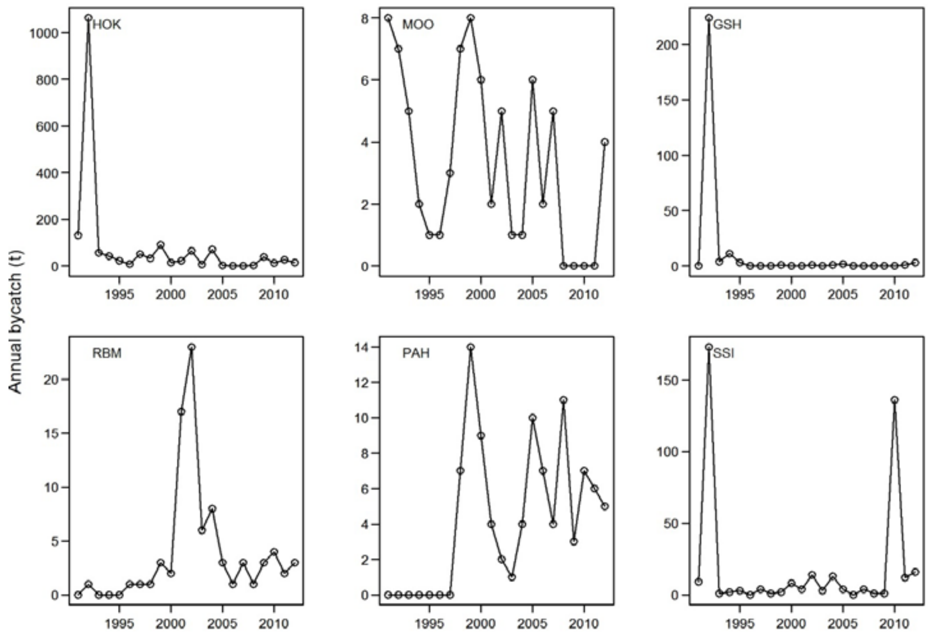


Figure 7.15: Annual bycatch estimates in the southern blue whiting trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

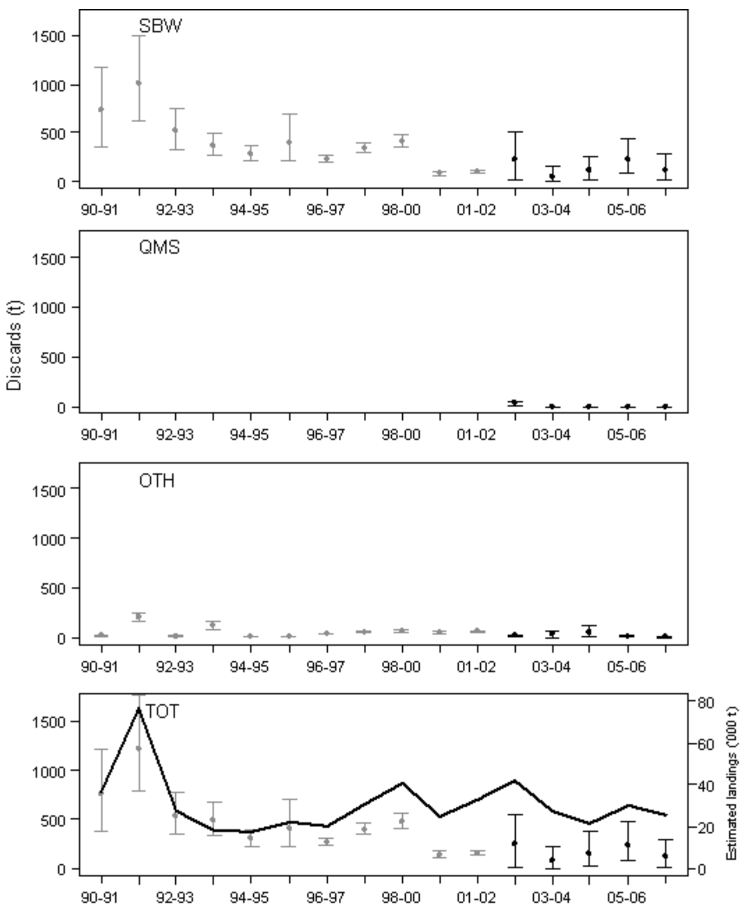


Figure 7.16: Annual estimates of fish discards in the southern blue whiting trawl fishery, calculated for the target species (SBW), QMS species, non-commercial species (OTH), and overall (TOT) for 2002–03 to 2006–07 (in black). Also shown (in grey) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2001–02 by Anderson (2004a). Error bars show the 95% confidence intervals. The dark line shows the total annual estimated landings of SBW (Ministry for Primary Industries 2013a).

Total annual discard estimates from 2002–03 to 2006–07 were 90–250 t per year. Discard amounts sometimes exceeded bycatch due to the large contribution of the target species (50–230 t per year) to total discards – the result usually of fish losses during recovery of the trawl. Discarding of commercial species was virtually non-existent in most years and discards of non-commercial species amounted to only 10–50 t per year. The main species discarded were southern blue whiting, rattails and porbeagle sharks. Total annual discard estimates for 1990–91 to 2001–02, from earlier reports, were mostly 140–750 t but were about 1200 t in 1991–92 (Figure 7.16). Discards of southern blue whiting (and therefore total discards) decreased substantially at the end of the 1990s and remained at low levels, below 250 t per year, up to 2006–07.

7.3.6 ORANGE ROUGHY TRAWL FISHERY

A detailed analysis of this fishery from 1990–91 to 2008–09, used the ratio estimator to calculate bycatch and discard rates based on the number of trawls (Anderson 2011). Linear mixed-effect models (LMEs) identified trawl duration as the key variable influencing bycatch rates and discard rates in this fishery, and regression tree methods were used to optimise the number of levels of this variable in order to stratify the calculation of annual bycatch and discard totals in each catch category.

The key categories of catch/discards examined were; orange roughy, other QMS species (excluding oreos) combined, commercial species combined (as defined above for hoki/hake/ling), and non-commercial species combined.

The level of observer coverage in this fishery was high over the entire period of the fishery—more than 10% (in terms of the total fishery catch) in all but one year, and over 50% in some years. Observer coverage was not evenly spread across all parameters of the orange roughy fishery, the most widespread of any New Zealand fishery, with notable undersampling of smaller vessels, the east coast fisheries in QMAs ORH 2A, ORH 2B, and ORH 3A, and some of the earlier years of the period.

Since 2005–06, orange roughy has been about 84% of the total observed catch. Much of the remainder of the total catch (about 10%) comprised oreo species: mainly smooth oreo (8%), and black oreo (2.1%). Rattails (various species, 0.8%) and shovelnose spiny dogfish (*Deania calcea*, 0.6%) were the species most adversely affected by this fishery, with over 90% discarded (Figure 7.17). Other fish species frequently caught and usually discarded included deepwater dogfishes (family Squalidae), especially *Etmopterus* species, the most common was probably Baxter's dogfish (*Etmoptertus baxteri*), slickheads, and morid cods, especially Johnson's cod (*Halargyreus johnsonii*) and ribaldo. In total, over 250 bycatch species or species groups were observed, most were non-commercial species, including invertebrate species, caught in low numbers. Squid (mostly warty squid, *Onykia* spp.) were the largest component of invertebrate catch, followed by various groups of coral, echinoderms (mainly starfish), and crustaceans (mainly king crabs, family Lithodidae).

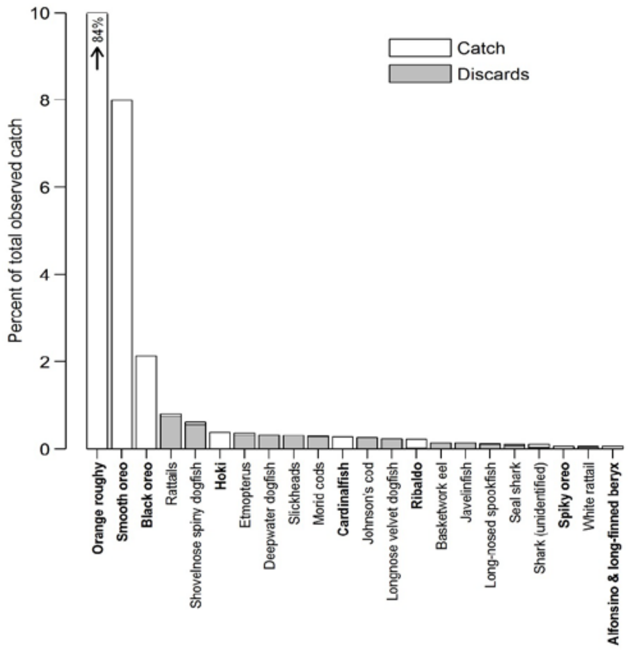


Figure 7.17: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the orange roughy fishery, 1990–91 to 2008–09 and the percentage discarded. QMS species are shown in bold.

Total annual bycatch in the orange roughy fishery since 1990–91 was 2300–27 000 t, and declined over time alongside the decline in catch and effort in this fishery to be less than 4000 t in each of the last four years estimated, 2005–06 to 2008–09 (Figure 7.18). Bycatch mostly comprised commercial species, with non-commercial species accounting for only 5–10% of the total bycatch in the recent period.

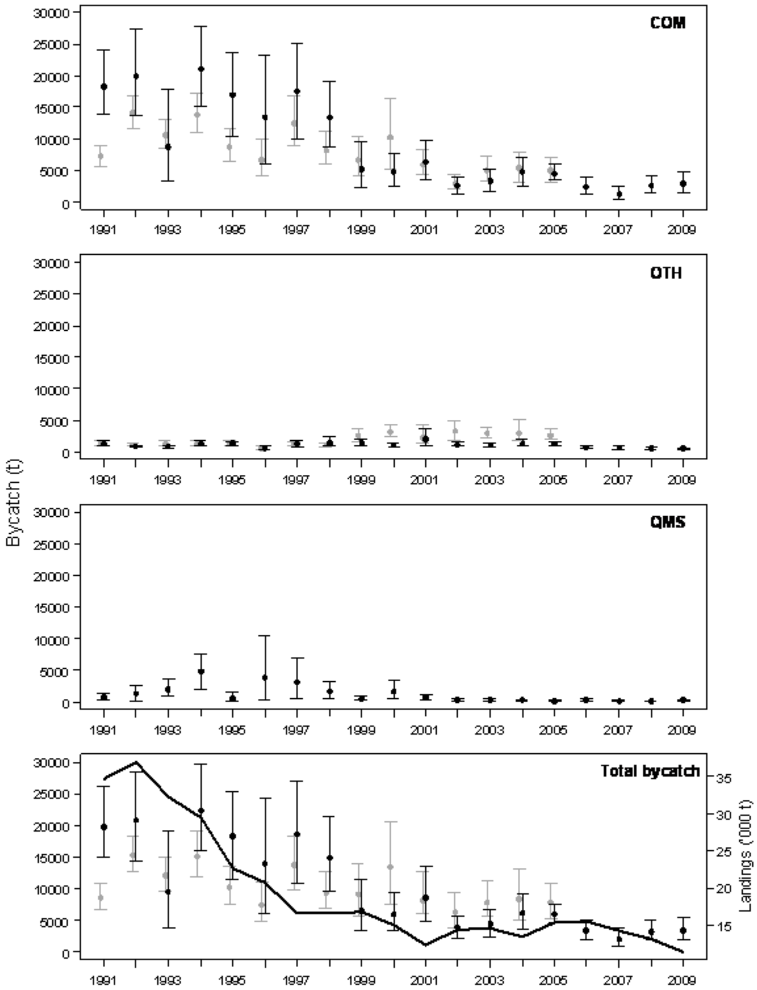


Figure 7.18: Annual estimates of fish bycatch in the orange roughy trawl fishery, calculated for commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are earlier estimates of bycatch in each category (excluding QMS) calculated for 1990–91 to 2004–05 (Anderson et al 2001, Anderson 2009a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of orange roughy (O. Anderson & M. Dunn (NIWA), unpublished data).

TRENDS IN BYCATCH BY SPECIES FROM THE ORANGE ROUGHY TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were smooth oreo (*Pseudocyttus maculatus*, SSO), black oreo (*Allocyttus niger*, BOE), and black cardinalfish (*Epigonus telescopus*, CDL).
- Of the 206 bycatch species examined, 29 had a decrease in catch over time and 51 an increase in catch.
- The species that showed the greatest decline were alfonsinos (*Beryx* spp., BYX) (generally not found south of the Chatham Rise; the specific code BYS is also frequently used), spiny dogfish (SPD), and oreos (*Oreosomatidae*, OEO; individual species codes may have been more frequently after 1994–95) (Figure 7.19).
- The species that showed the greatest increase were bushy hard coral (*Goniocorella dumosa*, GDU; a species probably not well identified before 2005–06), longnose velvet dogfish (*Centroscymnus crepidater*, CYP), and morid cods (*Moridae*, MOD) (Figure 7.19).

Estimated total annual discards also decreased over time, from about 3400 t in 1990–91 to about 300 t in 2007–08 (Figure 7.20), and since about 2000 were almost entirely non-commercial, non-QMS species. Large discards of orange roughy and other commercial species, more prevalent early in the fishery, were often due to fish lost from torn nets during hauling.

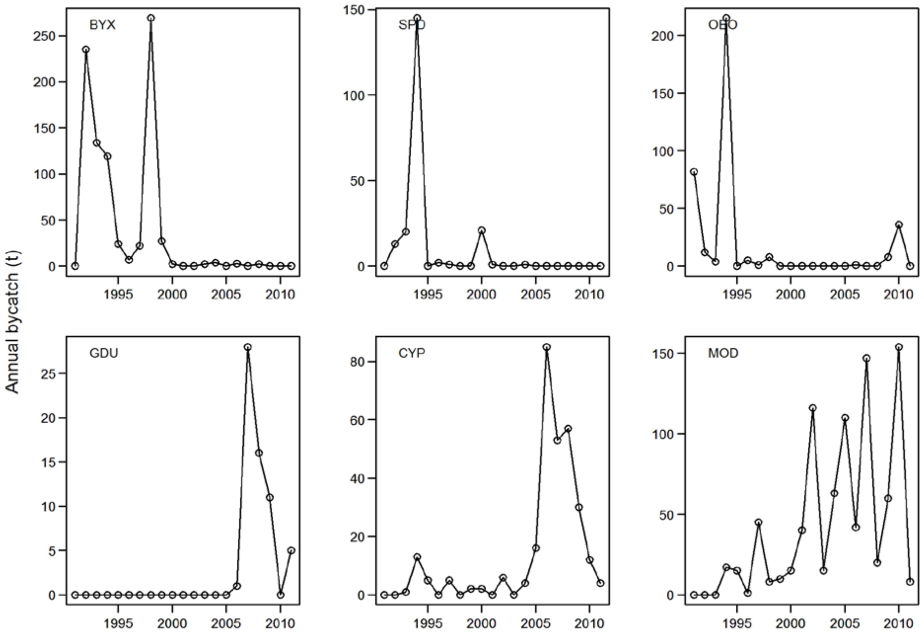


Figure 7.19: Annual bycatch estimates in the orange roughy trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

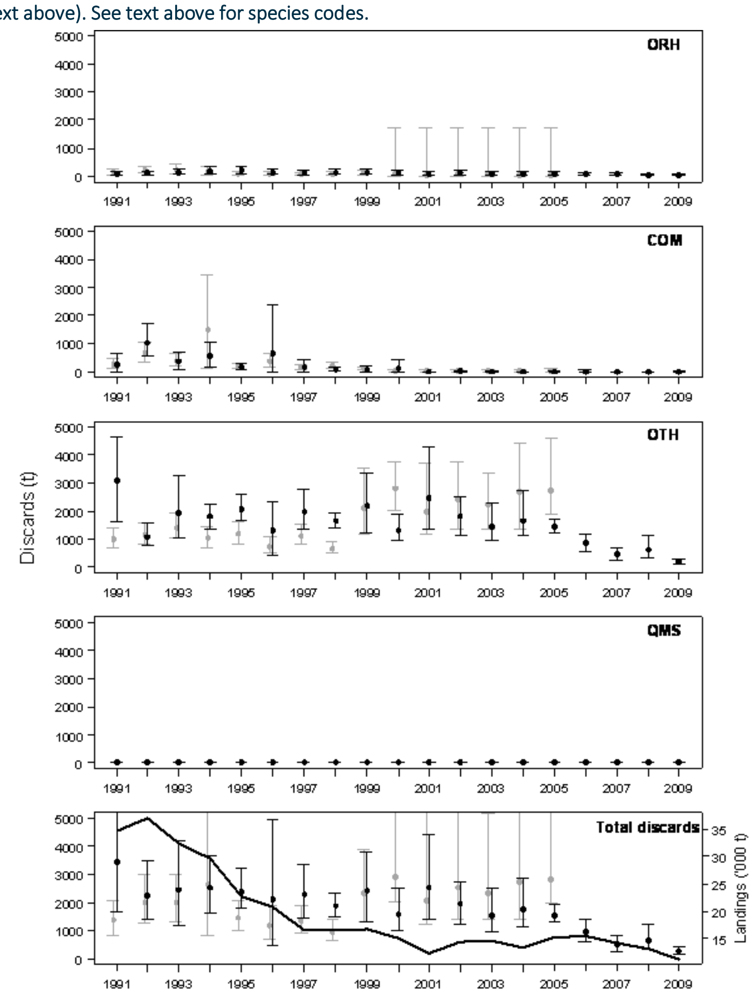


Figure 7.20: Annual estimates of fish discards in the orange roughy trawl fishery, calculated for the target species (ORH), commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2004–05 (Anderson et al 2001, Anderson 2009a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of orange roughy (O. Anderson & M. Dunn (NIWA), unpublished data).

7.3.7 OREO TRAWL FISHERY

A detailed analysis of this fishery from 1990–91 to 2008–09, used the ratio estimator to calculate bycatch and discard rates in the oreo fishery based on the number of trawls (Anderson 2011). Linear mixed-effect models (LMEs) identified trawl duration as the key variable influencing bycatch rates and discard rates in this fishery, and regression tree methods were used to optimise the number of levels of this variable in order to stratify the calculation of annual bycatch and discard totals in each catch category. The key categories of catch/discards examined were; oreos, other QMS species (excluding oreos) combined, commercial species combined (as defined above for hoki/hake/ling), and non-commercial species combined.

The oreo fishery was strongly linked to the orange roughy fishery, and only about 15% of the observed trips examined in the study predominantly targeted oreos, and nearly 30% of the observed trawls targeting oreos were from trips which predominantly targeted orange roughy. The coverage of the oreo fishery was therefore partly determined by the operations of the orange roughy fishery.

The annual number of observed trawls in the oreo fishery ranged from 30 in 1991–92 to 1006 in 2006–07 and the number of vessels observed ranged from 2 to 12. The level of coverage remained at a relatively consistent level after the mid-1990s, despite a decrease in the total catch and effort. Observer coverage was mostly restricted to the main fisheries on the South Chatham Rise and further south. Within this region, few locations were not covered by observers during the 19 years examined, but in the smaller fisheries, on the North Chatham Rise, Louisville Ridge, and the east coast from Kaikoura to East Cape, coverage was minimal. The match of observer coverage to commercial effort was relatively good, especially compared with the orange roughy fishery. Some oversampling on the south Chatham Rise occurred in some periods, e.g., 2001–2005 and 2008–09, and undersampling in the Pukaki/Bounty fisheries in 2005–06 and 2008–09, but elsewhere, and at other times, the spread of coverage was nearly ideal. The full range of vessel sizes (mainly between 300 t and 3000 t) was covered by observers, although small vessels were underrepresented and large vessels overrepresented. The fleet reduced in recent years and the remaining vessels were observed more regularly, with 30–60% of the fleet hosting observers annually since 2002–03.

Oreo species accounted for about 92% of the total estimated catch from all observed trawls targeting oreos after 1 October 2002. Orange roughy (3.5%) was the main bycatch species, with no other species or group of species accounting for more than 0.6% of the total catch. Hoki were the next most common bycatch species, followed by rattails, deepwater dogfish (especially Baxter's dogfish and seal shark (*Dalatias licha*)), slickheads, and basketwork eel (*Diastobranchus capensis*), all of which were usually discarded (Figure 7.21). Ling were also frequently caught, but only comprised about 0.25% of the total catch. In total, over 250 species or species groups were identified by observers in the target fishery, including numerous invertebrates. As in the orange roughy fishery, corals, squids and octopuses, king crabs, and echinoderms were the main groups caught. Coral, in particular, was a substantial part of the bycatch, accounting for almost 0.4% of the total catch.

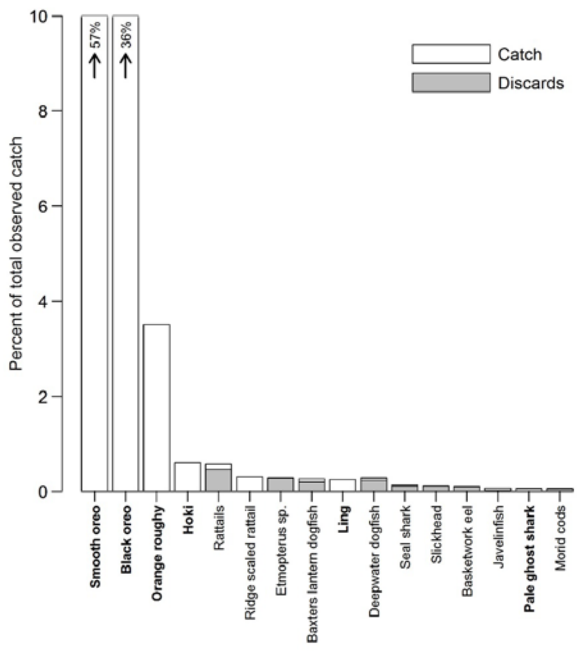


Figure 7.21: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the oreo fishery, 1990–91 to 2008–09, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch in the oreo fishery since 1990–91 was 270–2200 t and, apart from some higher levels in the late 1990s, showed no obvious trends (Figure 7.22). Bycatch was split almost evenly between commercial and non-commercial species overall, although after 2002 about 60% of the bycatch comprised commercial species.

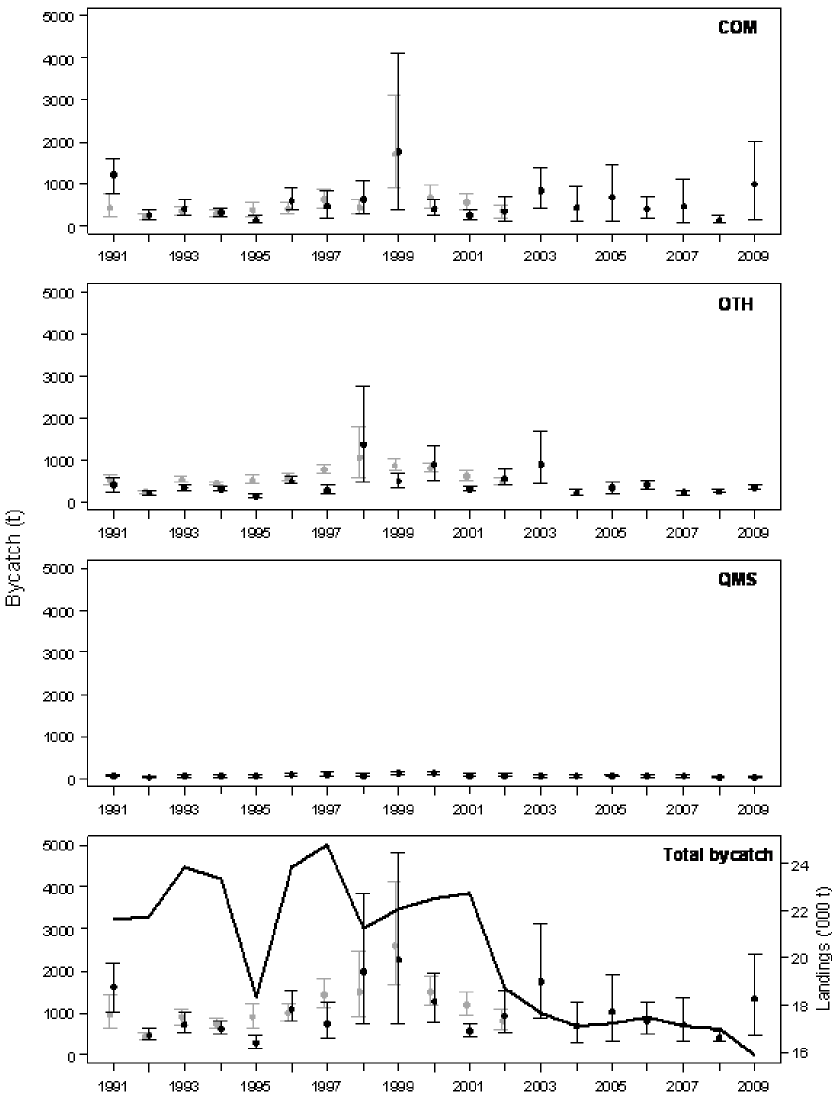


Figure 7.22: Annual estimates of fish bycatch in the oreo trawl fishery, calculated for commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of bycatch in each category (excluding QMS) calculated for 1990–91 to 2001–02 (Anderson 2004a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of oreos (Ministry for Primary Industries 2013a).

TRENDS IN BYCATCH BY SPECIES FROM THE OREO TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were orange roughy (*Hoplostethus atlanticus*, ORH), unspecified shark (SHA), and hoki (HOK).
- Of the 110 bycatch species examined, 3 had a decrease in catch over time and 27 an increase in catch.
- The species that showed the greatest decline were dark ghost shark (GSH) and unspecified shark (SHA), although both trends may be influenced by improving taxonomic resolution over time; and ling (LIN) (Figure 7.23).
- The species that showed the greatest increase were pale ghost shark (GSP), Baxter's lantern dogfish (*Etmopterus baxteri*, ETB), and ridge-scaled rattail (*Macrourus carinatus*, MCA) (Figure 7.23).

Discards in the oreo fishery remained relatively stable over time, ranging from about 260 t to 750 t per year, with higher levels in the late 1990s than in the early 1990s or 2000s (Figure 7.24). Discards mainly comprised non-commercial, non-QMS species, but also included a significant component of the target species in most years.

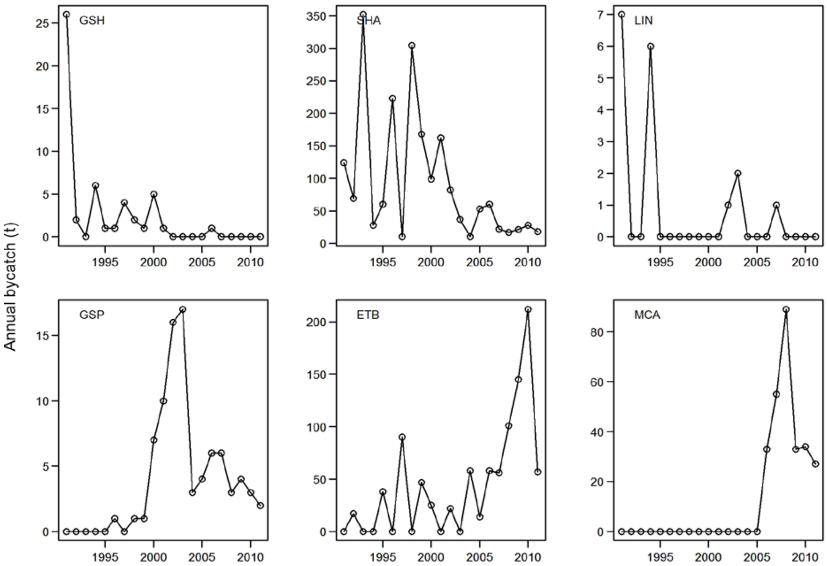


Figure 7.23: Annual bycatch estimates in the oreo trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1). See text above for species codes.

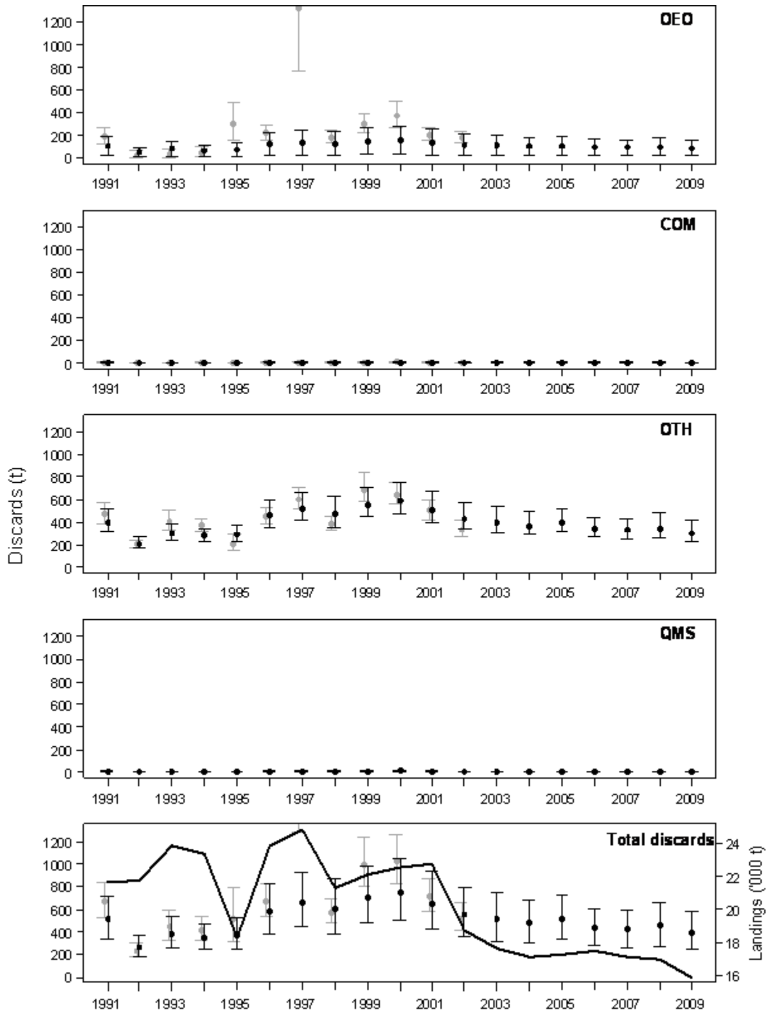


Figure 7.24: Annual estimates of fish discards in the oreo trawl fishery, calculated for the target species (OEO), commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2001–02 (Anderson 2004a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of oreos (Ministry for Primary Industries 2013a).

7.3.8 SCAMPI TRAWL FISHERY

A detailed analysis of this fishery from 1990–91 to 2009–10 used the ratio estimator to calculate bycatch and discard rates in the scampi fishery based on the number of trawls (Anderson 2012). Linear mixed-effect models (LMEs) identified fishery area as the key variable influencing bycatch rates and discard rates.

The key categories of catch/discards examined were; all QMS species combined, all non-QMS species combined, all invertebrate species combined, javelinfish, and all other rattail species combined.

Observer coverage in the scampi fishery has been relatively low compared with most of the other fisheries assessed. The long-term level of observer coverage in the orange roughy, oreo, arrow squid, southern blue whiting, and ling longline fisheries is greater than 18% of the target fishery catch (and over 40% for southern blue whiting) whereas in the scampi fishery (and also in the jack mackerel fishery) long-term coverage has only been about 11–12%. However, annual coverage in the scampi fishery was greater than 10% in most years and fell below 5% only once (in 2000–01).

The annual number of observed trawls in the fishery ranged from 142 to 797, but has been over 300 trawls in most years. The number of vessels observed in each year ranged from 3 to 8 (equivalent to 33–66% of the fleet) and was very constant—5 or 6 vessels in most years. Analysis of the spread of observer effort compared with that of the scampi fishery as a whole, across a range of variables, indicated that this coverage was reasonably well spread. Although some less important regions of the fishery received little or no coverage (e.g. the central Chatham Rise, where commercial scampi fishing has only recently developed, and west coast South Island), the main scampi fisheries were consistently sampled throughout the period examined. Vessels were mostly of a similar size, and the small amount of effort by larger vessels was adequately covered, as was the full depth range of the fishery and (despite highly intermittent sampling in several years) all periods of the year.

Over 450 bycatch species or species groups were observed in the scampi target fishery catch, most being non-commercial species, including invertebrate species, caught in low numbers. Scampi accounted for only about 17% of the total estimated catch from all observed trawls targeting scampi since 1 October 1990. The main bycatch species or species groups were javelinfish (16%), other (unidentified) rattails (13%), sea perch (*Helicolenus* spp., 8.4%), ling (7.5%), and hoki (6.1%). The first three of these bycatch groups were mostly discarded (Figure 7.25). Of the other invertebrate groups, unidentified crabs (1.1%) and unidentified starfish (0.8%) were caught in the greatest amounts. When combined into broader taxonomic groups, bony fish (excluding rattails) contributed the most to total bycatch (40%), followed by rattails (29%), rays and skates (3.5%), sharks and dogfish (2.3%), crustaceans (2.2%), chimaeras (2.0%), echinoderms (1.6%), and cnidarians (0.6%). A large percentage of the bycatch in these groups was discarded, and was less than 85% only for bony fish (excluding rattails) (33%), rays and skates (67%), and chimaeras (28%).

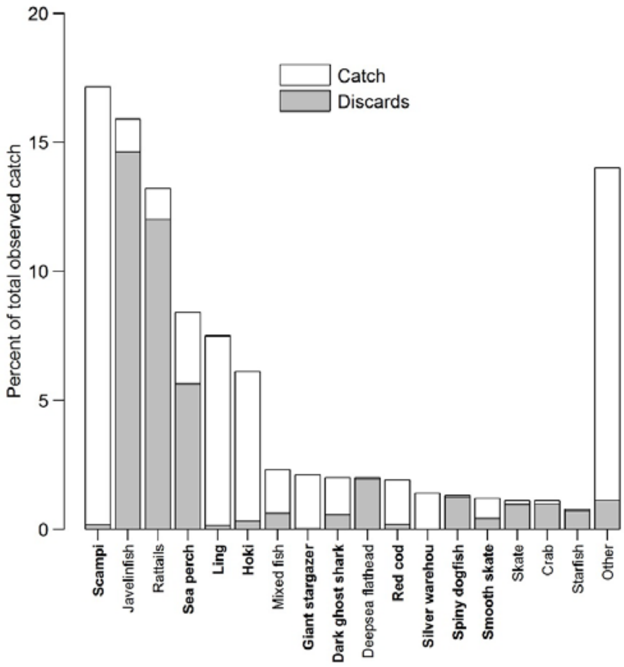


Figure 7.25: Percentage of the total catch contributed by the main bycatch species (those representing 1% or more of the total catch) in the observed portion of the scampi fishery, 1990–91 to 2009–10, and the percentage discarded. The "Other" category is the sum of all other bycatch species (fish and invertebrates) representing less than 1% of the total catch. QMS species are shown in bold.

Total annual bycatch since 1990–91 ranged from about 2100 t to 9200 t and, although highly variable, showed a significant decline over the past 20 years – driven mainly by a decline in the bycatch of QMS species (Figure 7.26). Annual bycatch has generally been an even mixture of QMS and non-QMS species, with invertebrate species (although showing a significant increase over time) accounting for only about 7% of the total bycatch for the whole period. Rattails (split evenly between javelinfish and all other species combined) accounted for 30–80% of the annual non-QMS bycatch. Comparison of bycatch rates with relative biomass estimates from trawl surveys to test for similarity of trends over time was possible for the Chatham Rise and Auckland Islands fishery areas, but these were inconclusive.

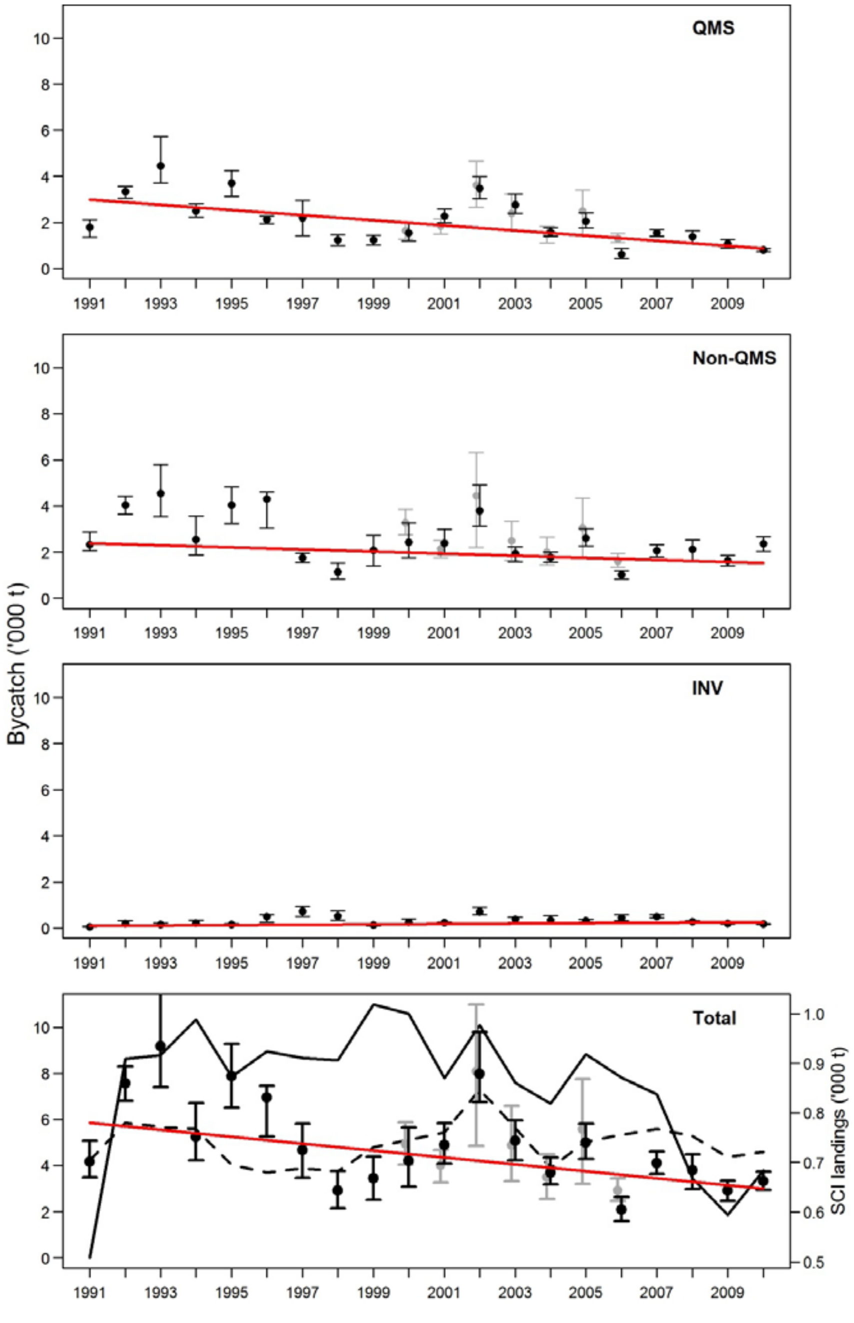


Figure 7.26: Annual estimates of bycatch in the scampi trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2009–10. Also shown (in grey) are estimates of bycatch in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The straight lines show the fit of a weighted regression to annual bycatch. In the bottom panel the solid black line shows the total annual reported landings of scampi (Ministry for Primary Industries 2013a) and the dashed line shows annual effort (scaled to have mean equal to that of total bycatch).

TRENDS IN BYCATCH BY SPECIES FROM THE SCAMPI TRAWL FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were javelinfish (*Lepidorhynchus denticulatus*, JAV), unspecified rattails (*Macrouridae*, RAT), and sea perch (*Helicolenus* spp., SPE).
- Of the 250 bycatch species examined, 49 had a decrease in catch over time and 59 an increase in catch.
- The species that showed the greatest decline were skates (*Rajidae* and *Arhynchobatidae*, SKA; although identification of skates beyond this generic code may have improved after 2002–03), bluenose (*Hyperoglyphe antarctica*, BNS) (a species not present at the Auckland Islands) and alfonsino (*Beryx* spp., BYX) (species not found south of the Chatham Rise; the use of the specific code BYS may have increased) (Figure 7.27).
- The species that showed the greatest increase were common roughy (*Paratrachichthys trailli*, RHY), jackknife prawn (*Haliporoides sibogae*, HIS), and spiny masking crab (*Teratomaia richardsoni*, SMK) (Figure 7.27).

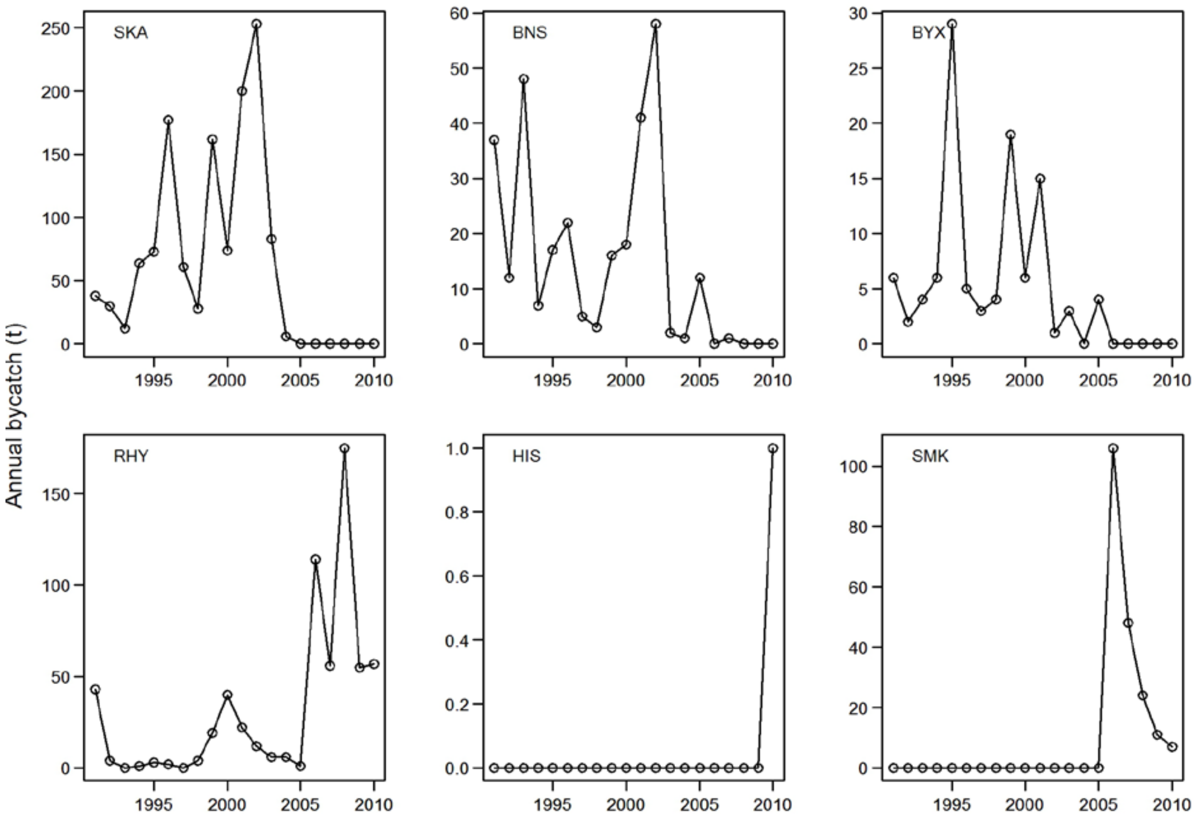


Figure 7.27: Annual bycatch estimates in the scampi trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discards ranged from 6790 t in 1995–96 to 1430 t in 2005–06 and, although there was a general decrease since 2001–02, there was no significant trend in overall discard levels since 1990–91 (Figure 7.28). Discards were dominated by non-QMS species (overall about 75%) followed by QMS species (16%) and invertebrates (9%). Rattail species accounted for nearly 60% of the non-QMS discards and about 45% of all discards.

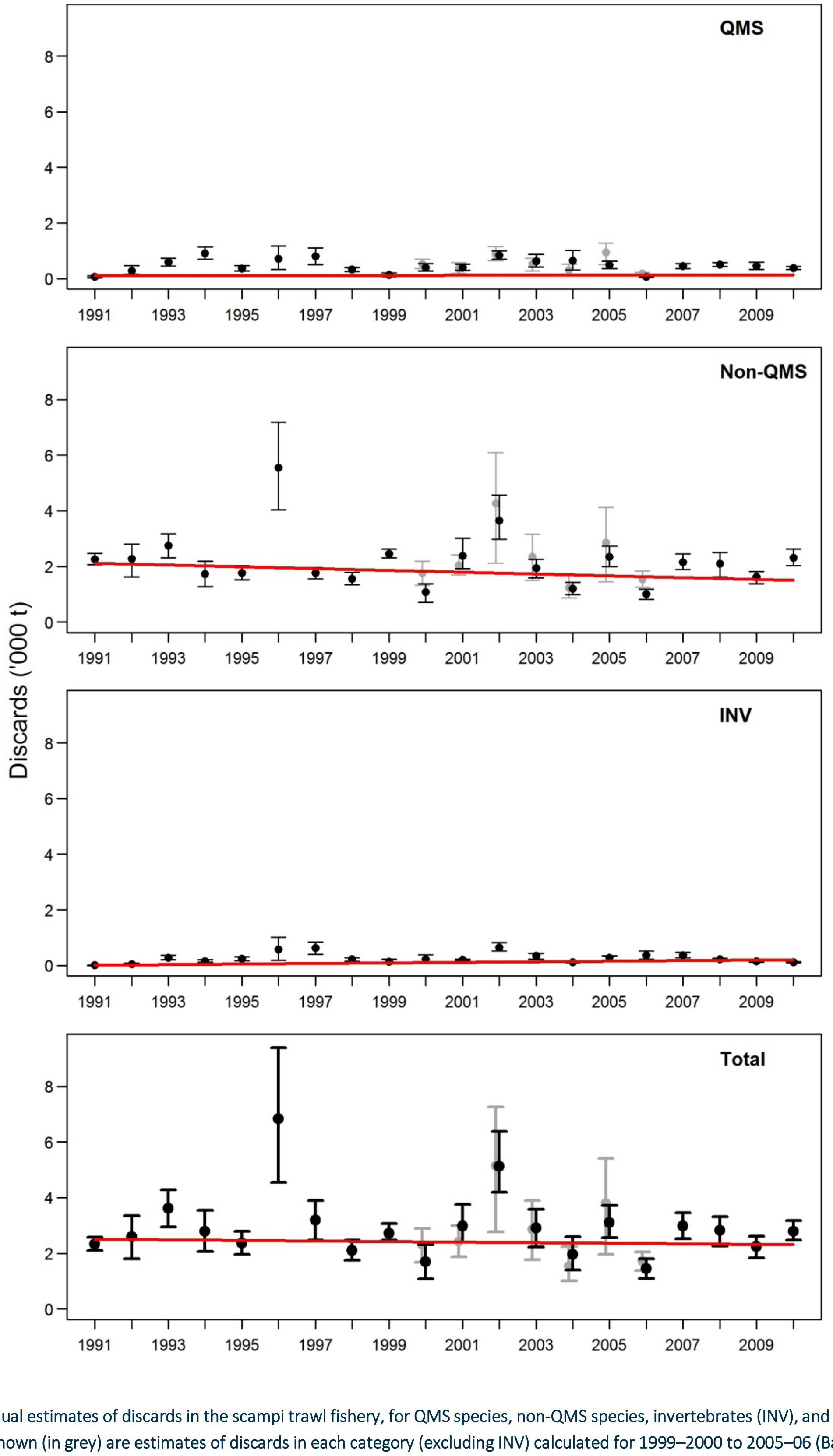


Figure 7.28: Annual estimates of discards in the scampi trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2009–10. Also shown (in grey) are estimates of discards in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The straight lines show the fit of the weighted regression to annual discards.

7.3.9 LING LONGLINE FISHERY

The first analysis of bycatch and discards in this fishery covered the period from 1990–91 to 1997–98 (Anderson et al 2000), and the second analysis covered the years up to 2005–06 (Anderson 2008). To enable a comparison of estimates between studies, which used slightly different methodologies, the 1994–95 fishing year was re-assessed in the 2008 analysis. In addition to estimating the bycatch of all quota species combined, and all non-quota species combined, in the 2008 analysis annual bycatch was estimated separately for three commonly caught individual species, spiny dogfish, red cod, and ribaldo. Comparative estimates of only total annual bycatch are available from the first analysis for 1990–91 to 1997–98.

The ratio estimator used in these analyses to calculate bycatch and discard rates was based on the number of hooks set. The ratios were applied to hook number totals calculated from commercial catch-effort data to make annual estimates for the target fishery as a whole.

Regression tree methods were used to minimise the number of levels of season and area variables used to stratify data for the calculation of annual discard bycatch totals in all categories with minimal loss of explanatory power. This reduced the number of areas in each category from eight down to between two and four, and split the year into three or four periods. The area variables created in this way tended to have more explanatory power.

Between 1998–99 and 2005–06 only 9% of the vessels operating in this fishery were observed (14 vessels in all) but these tended to be the main operators (including most of the larger autoliners) and accounted for between 7.7% and 52.5% of the annual target ling catch and 7.8% to 61% of the annual number of longlines set during these years. The annual number of observed sets was 324–1605 compared with the total target fishery effort of 2500–4150 sets. Observer coverage before 1998–99 was very low, exceeding 5% of the annual target ling catch only in 1994–95 and 1996–97.

Ling were 68% of the total estimated catch from all observed sets targeting ling between 1998–99 and 2005–06, and spiny dogfish (much of which was discarded) about a further 14% (Figure 7.29). About half of the remaining 18% of the catch comprised other commercial species; especially red cod (*Pseudophycis bachus*), (2.3%), ribaldo (*Mora moro*) (2.2%), rough skates (*Zearaja nasuta*, 1.9%), smooth skates (*Dipturus innominatus*) (1.8%), and sea perch (*Helicolenus* spp.) (1.2%). Altogether, 93% of the observed catch was comprised of QMS species, representing 40 of the 96 species in the QMS prior to 1 October 2007. Over 130 species or species groups were identified by observers, the majority being non-commercial species caught in low numbers, especially black cod (*Paranotothenia magellanicus*) and Chondrichthyans, often unspecified but including shovelnose spiny dogfish (*Deania calcea*), *Etmopterus* species, and seal sharks (*Dalatias licha*). A large number of echinoderms, especially starfish (of which almost 200 000 were observed caught during the period), anemones, crustaceans, and other invertebrates were also recorded by observers.

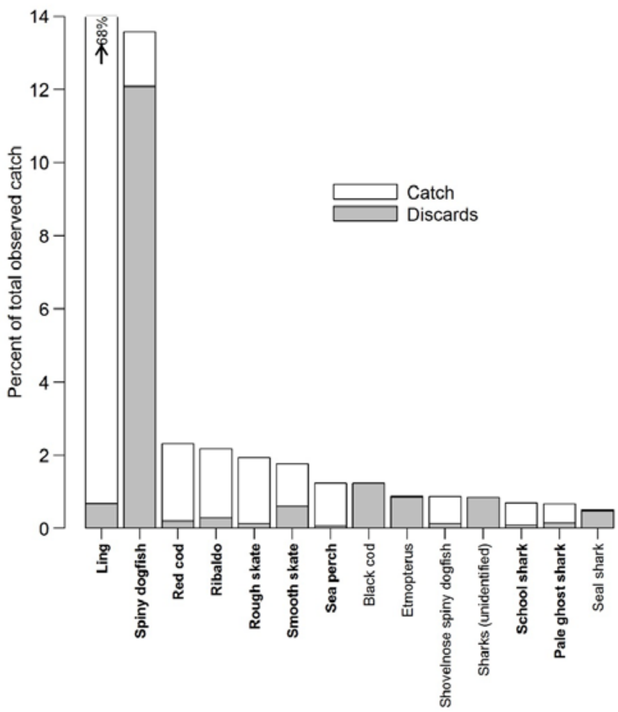


Figure 7.29: Percentage of the total catch contributed by the main bycatch species (those representing 0.5% or more of the total catch) in the observed portion of the ling longline fishery, 1998–99 to 2005–06 and the percentage discarded. QMS species are shown in bold.

Total annual bycatch estimates for 1998–99 to 2005–06 were 2200–3700 t, compared with approximate target species catches in the same period of 3500–8700 t. A large part of this bycatch (40–50%) comprised a single species, spiny dogfish, and 80% of the bycatch were quota species (Figure 7.30 and Figure 7.31). Bycatch levels decreased during the period, in line with decreasing effort in the fishery. Total bycatch estimates for the years before 1998–99 was 880–3900 t. Differences in methodology between the two studies, coupled with generally low observer coverage, resulted in significantly different estimates of total bycatch for 1994–95.

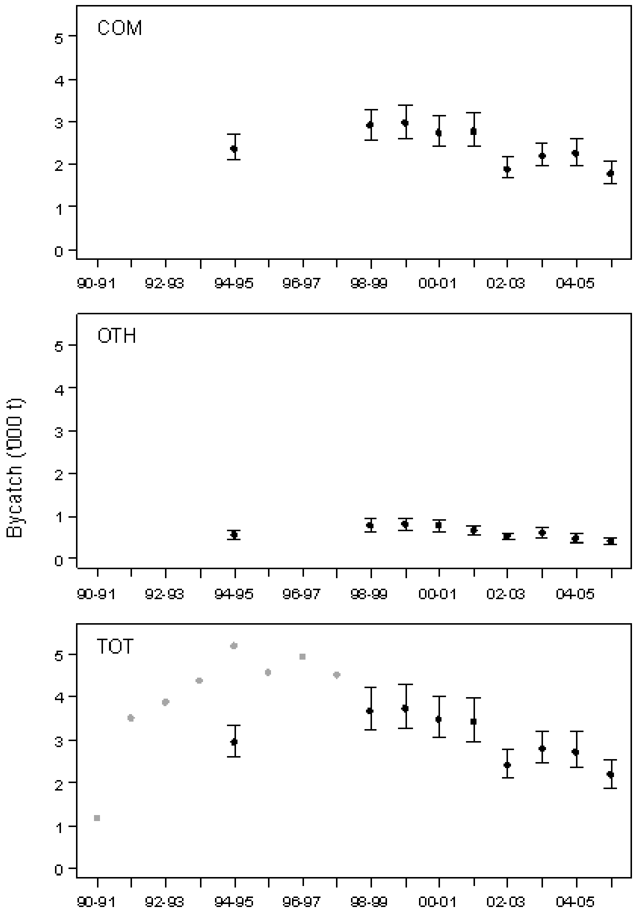


Figure 7.30: Annual estimates of fish bycatch in the target ling longline fishery, calculated for commercial (QMS) species (COM), non-commercial (non-QMS) species (OTH), and overall (TOT) for the years 1994–95 and 1998–99 to 2005–06 (in black). Also shown (in grey) are estimates of total bycatch calculated for the period 1990–91 to 1997–98 by Anderson et al (2000). Error bars show the 95% confidence intervals.

TRENDS IN BYCATCH BY SPECIES FROM THE LING BOTTOM LONGLINE FISHERY

Anderson (2013b) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2010–11. The following conclusions were made:

- The most commonly caught bycatch species were spiny dogfish (SPD), ribaldo (*Mora moro*, RIB), and smooth skate (*Dipturus innominatus*, SSK).
- Of the 103 bycatch species examined, 5 had a decrease in catch over time and 35 had an increase in catch.
- The species that had the greatest decline were skates (SKA, although identification of skates beyond this generic code may have improved after 2002–03), Antarctic rock cods (*Nototheniidae*, NOT), and conger eels (*Conger* spp., CON) (Figure 7.32).
- The species that had the greatest increase were leafscale gulper shark (*Centrophorus squamosus*, CSQ), rough skate (*Zearaja nasuta*, RSK), and hairy conger (*Bassanago hirsutus*, HCO) (Figure 7.32).

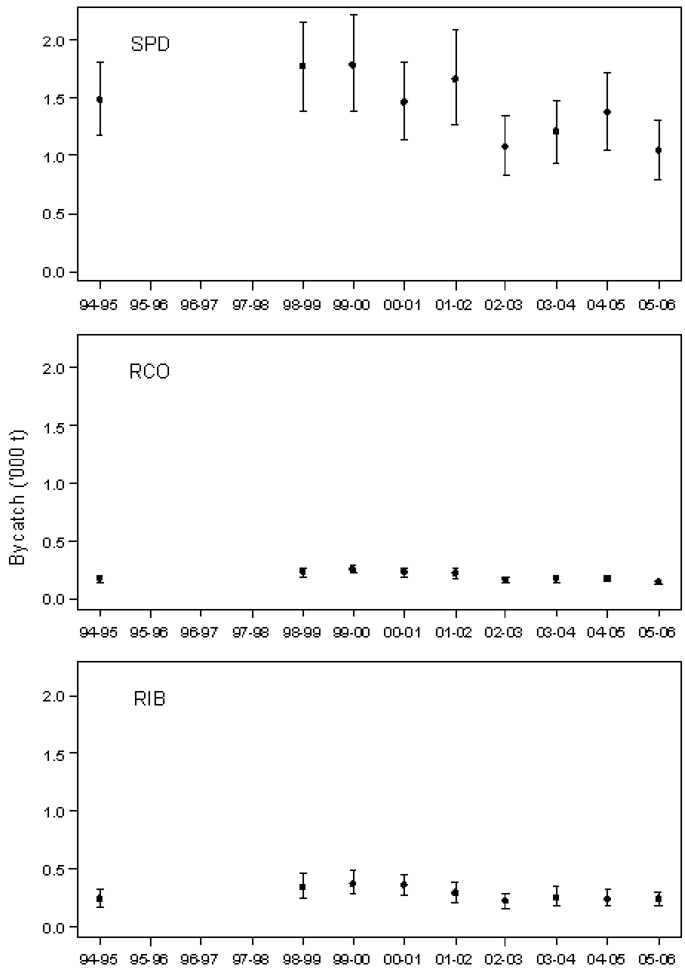


Figure 7.31: Annual estimates of the bycatch of spiny dogfish (SPD), red cod (RCO), and ribaldo (RIB) in the target ling longline fishery for the years 1994–95 and 1998–99 to 2005–06. Error bars show the 95% confidence intervals.

Total annual discard estimates for 1998–99 to 2005–06 were 1400–2400 t, and generally decreased during the period (Figure 7.33). About 70–75% of these discarded fish were quota species, and 60–70% spiny dogfish, the remainder being non-quota, generally non-commercial, species. Ling were discarded in small amounts (40–90 t per

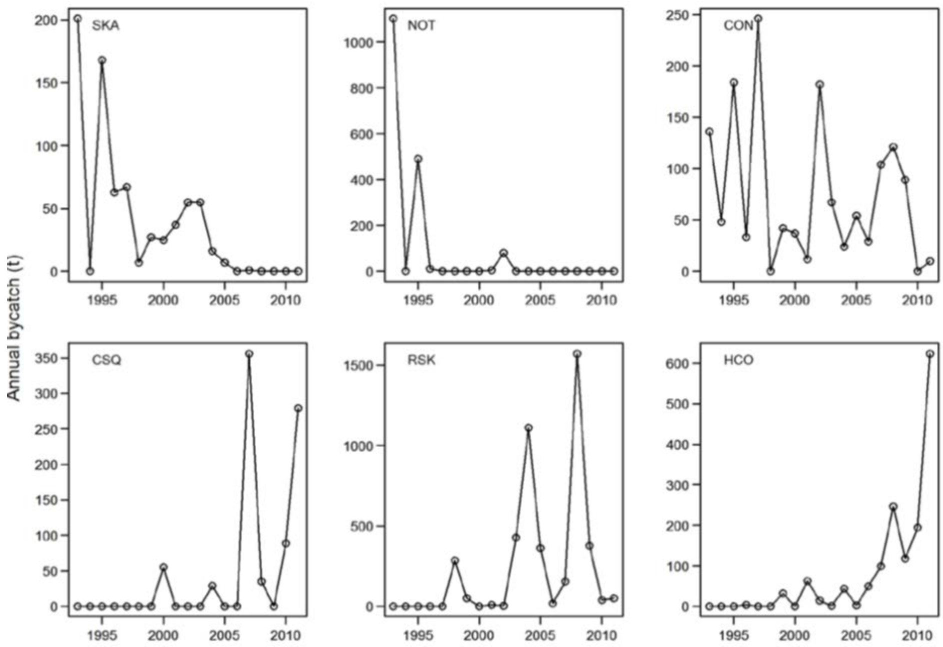


Figure 7.32: Annual bycatch estimates in the ling longline fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1). See text above for species codes.

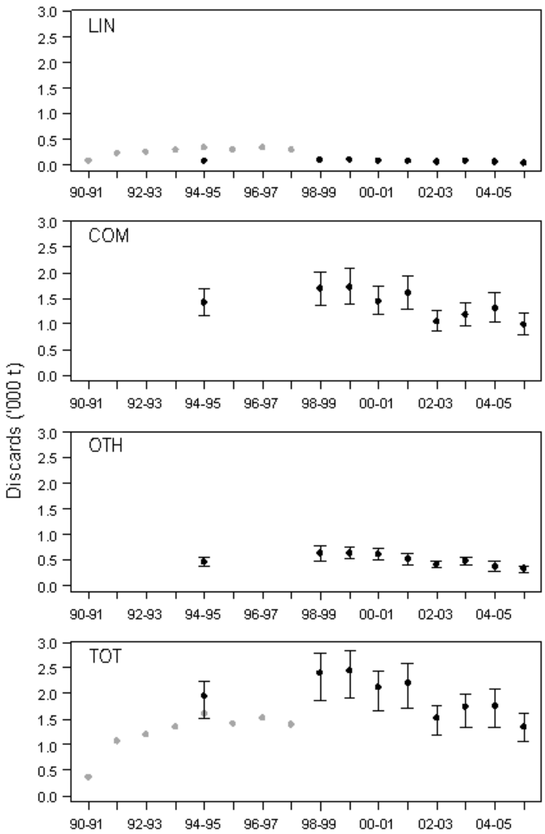


Figure 7.33: Annual estimates of fish discards in the target ling longline fishery, calculated for ling (LIN), commercial (QMS) species (COM), non-commercial (non-QMS) species (OTH), and overall (TOT) for the years 1994–95 and 1998–99 to 2005–06 (in black). Also shown (in grey) are estimates of the ling and total discards calculated for 1990–91 to 1997–98 by Anderson et al (2000). Error bars show the 95% confidence intervals.

year), these discards generally being attributable to fish being lost on retrieval or predated by marine mammals and birds. Estimated annual discards were generally lower for the earlier period (1990–91 to 1997–98) and were 350–1600 t. Total discard estimates for 1994–95 were similar for the two studies.

7.3.10 TUNA LONGLINE FISHERY

The New Zealand tuna longline fishery was dominated by the foreign licensed vessels during the 1980s, but is now comprised of chartered Japanese vessels and New Zealand domestic vessels. The domestic fishing fleet dominated the fishery since 1993–94 (Figure 7.34).

The Japanese charter fleet mainly targeted southern bluefin tuna off the west coast South island (WCSI), and domestic vessels targeted southern bluefin tuna and bigeye tuna and the fishery was concentrated on the east coast of the North Island (ECNI) with some fishing for southern bluefin tuna on the WCSI.

A detailed analysis of fish bycatch in tuna longline fisheries covered the 2006−07 to 2009−10 fishing years (Griggs & Baird 2013)

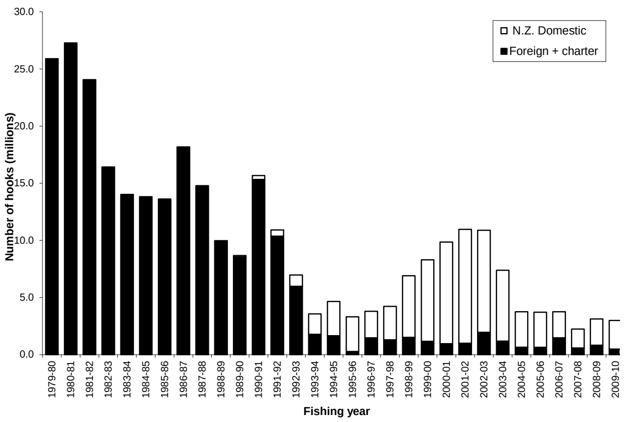


Figure 7.34: Effort (hooks set) in the tuna longline fishery. Black bars are Foreign and Charter vessels, white bars are NZ domestic vessels.

During 2006–07 to 2009–10, 111 074 fish and invertebrates from at least 62 species or species groups were observed. Most species were rarely observed, with only 37 species (or species groups) exceeding 100 observations between 1988–89 and 2009–10. The most commonly observed species over all years were blue shark, albacore tuna, and Ray's bream, these three making up nearly 70% of the catch by numbers. Blue shark and Ray's bream were the most abundant and second most abundant species in each of the four fishing years 2006–07 to 2009–10 (Table 7.2). Other important non-target species were albacore, lancetfish, bigscale pomfret, dealfish, porbeagle shark, swordfish, moonfish, mako shark, deepwater dogfish, sunfish, and oilfish. The catch composition varied with fleet and area fished.

QMS bycatch species caught were blue shark, mako shark, porbeagle shark, school shark, moonfish, Ray's bream, and swordfish. Swordfish was also sometimes targeted.

Table 7.2: Species composition of observed tuna longline catches. Number of fish observed are shown for 2006–07 to 2009–10 and all fish observed since 1988–89. Top 30 species.

	Species	Scientific Name	2006–07 to 2009–10	Total number
1	Blue shark	*Prionace glauca*	38 162	182 628
2	Albacore tuna	*Thunnus alalunga*	9 854	101 316
3	Rays bream	*Brama brama*	25 277	98 205
4	Southern bluefin tuna	*Thunnus maccoyii*	10 373	43 291
5	Porbeagle shark	*Lamna nasus*	2 235	19 011
6	Dealfish	*Trachipterus trachypterus*	2 304	17 185
7	Lancetfish	*Alepisaurus ferox & A. brevirostris*	5 661	14 383
8	Moonfish	*Lampris guttatus*	1 683	9 134
9	Deepwater dogfish	Squaliformes	1 600	9 112
10	Swordfish	*Xiphias gladius*	2 213	8 286
11	Big scale pomfret	*Taractichthys longipinnis*	2 954	7 818
12	Oilfish	*Ruvettus pretiosus*	711	7 542
13	Mako shark	*Isurus oxyrinchus*	1 676	6 162
14	Rudderfish	*Centrolophus niger*	373	4 907
15	Butterfly tuna	*Gasterochisma melampus*	617	4 469
16	Escolar	*Lepidocybium flavobrunneum*	643	4 422
17	Bigeye tuna	*Thunnus obesus*	1 240	4 390
18	School shark	*Galeorhinus galeus*	419	3 620
19	Yellowfin tuna	*Thunnus albacares*	97	3 342
20	Sunfish	*Mola mola*	1 000	2 755
21	Pelagic stingray	*Pteroplatytrygon violacea*	585	2 398
22	Hoki	*Macruronus novaezelandiae*	265	2 021
23	Thresher shark	*Alopias vulpinus*	169	1 400
24	Skipjack tuna	*Katsuwonus pelamis*	38	1 151
25	Dolphinfish	*Coryphaena hippurus*	134	608
26	Flathead pomfret	*Taractes asper*	158	516
27	Striped marlin	*Tetrapturus audax*	59	468
28	Black barracouta	*Nesiarchus nasutus*	51	386
29	Barracouta	*Thyrsites atun*	10	357
30	Pacific bluefin tuna	*Thunnus orientalis*	34	222

Most blue, porbeagle, mako, and school sharks were processed in some way, either being finned or retained for their flesh, but there were significant fleet differences. Blue sharks were mainly just finned. Most albacore, swordfish, yellowfin tuna, moonfish and Ray's bream were retained. Most bigscale pomfret, escolar, oilfish and rudderfish were discarded, with some year and fleet differences. Almost all deepwater dogfish, dealfish, and lancetfish were discarded.

7.3.11 ALBACORE TUNA TROLL FISHERY

This fishery was carried out by small domestic vessels fishing over the summer months mainly on the west coast of the North and South Island, especially WCSI.

Observers began to go to sea on troll vessels in 2007. The first two years were a trial period with one trip observed in each year. Targets were set in 2009. Coverage was 0.5–1.5% of days fished for the 2009−10 to 2012−13 fishing years.

Albacore was 94.4% of the observed catch over the past seven years, followed by Ray's bream (2.7%), Skipjack tuna (1.7%), and small numbers (less than 1%) of a few other species (Table 7.3).

Table 7.3: Species composition of observed albacore troll catches, 2006–07 to 2012–13.

Species	Scientific name	Number of fish caught							
		2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	Total of 7 years
Albacore tuna	*Thunnus alalunga*	1 684	1 776	1 755	5 403	4 905	2 772	3 881	22 176
Rays bream	*Brama brama*		18	12	537	35	7	15	624
Skipjack tuna	*Katsuwonus pelamis*	1	2	26	20	359	2		410
Barracouta	*Thyrsites atun*			1		24	13	23	61
Kahawai	*Arripis trutta*			6		3	14	14	37
Kingfish	*Seriola lalandi*			2	4	4			10
Dolphinfish	*Coryphaena hippurus*				1				1
Mako shark	*Isurus oxyrinchus*						1	1	2
Unidentified		2			174				176

7.3.12 SKIPJACK TUNA PURSE SEINE FISHERY

Skipjack tuna was 98.5% of the catch observed on purse seine vessels in New Zealand waters (Anon 2013).

Catch composition from six observed purse seine trips operating within New Zealand fisheries waters in 2011 and 2012 can be seen in Table 7.4.

Table 7.4: Catch composition from six observed purse seine trips operating within New Zealand fisheries waters in 2011 and 2012. [Continued on next page]

Common name	Scientific name	Observed catch (2011 & 2012)	
		weight (kg)	% of total
Skipjack tuna	*Katsuwonus pelamis*	4 360 758	98.50
Jack mackerel	*Trachurus* spp.	37 207	0.84
Blue mackerel	*Scomber australasicus*	17 760	0.40
Sunfish	*Mola mola*	4 516	0.10
Spine-tailed devil ray	*Mobula japanica*	1 990	0.04
Striped marlin	*Tetrapturus audax*	1 320	0.03
Frigate tuna	*Auxis thazard*	1 090	0.02
Albacore tuna	*Thunnus alalunga*	683	0.02

Table 7.4 [Continued]: Catch composition from six observed purse seine trips operating within New Zealand fisheries waters in 2011 and 2012.

Common name	Scientific name	Observed catch (2011 & 2012)	
		weight (kg)	% of total
Jellyfish	Scyphozoa	459	0.01
Mako shark	*Isurus oxyrinchus*	418	0.01
Thresher shark	*Alopias vulpinus*	275	0.01
Swordfish	*Xiphias gladius*	150	<0.01
Hammerhead shark	*Sphyrna zygaena*	145	<0.01
Bronze whaler shark	*Carcharhinus brachyurus*	80	<0.01
Ray's bream	*Brama brama*	80	<0.01
Frostfish	*Lepidopus caudatus*	74	<0.01
Flying fish	Exocoetidae	71	<0.01
Slender tuna	*Allothunnus fallai*	50	<0.01
Porcupine fish	*Allomycterus pilatus*	47	<0.01
Moonfish	*Lampris guttatus*	40	<0.01
Stingray	Dasyatidae	40	<0.01
Blue shark	*Prionace glauca*	30	<0.01
Discfish	*Diretmus argenteus*	25	<0.01
Snapper	*Pagrus auratus*	15	<0.01
Electric ray	*Torpedo fairchildi*	14	<0.01
Pufferfish	*Sphoeroides pachygaster*	9	<0.01
Octopus	Octopoda	7	<0.01
Squid	Teuthoidea	7	<0.01
Garfish	*Hyporhamphus ihi*	5	<0.01
Starfish	Asteroidea & ophiuroidea	3	<0.01
Salp	*Doliolum* spp.	3	<0.01
Paper nautilus	*Argonauta nodosa*	2	<0.01
Pelagic ray	*Pteroplatytrygon violacea*	2	<0.01
John dory	*Zeus faber*	2	<0.01
Leatherjacket	*Meuschenia scaber*	2	<0.01
Rudderfish	*Centrolophus niger*	2	<0.01
Smooth skate	*Dipturus innominatus*	2	<0.01
Gurnard	*Chelidonichthys kumu*	1	<0.01
Jack mackerel	*Trachurus murphyi*	1	<0.01
Natant decapod	Decapoda	1	<0.01
Pipefish	Syngnathidae	1	<0.01

7.4 INDICATORS AND TRENDS

A standard measure that can be used to indicate the degree of wastefulness in a fishery is the level of annual discards as a fraction of the catch of the target species. The most recent mean estimates are provided in Table 7.5 for those fisheries where the necessary data were available. The largest mean discard fraction was from the scampi trawl fishery where 2.5 kg of bycatch was discarded for every kilogram of scampi caught.

Comparison of estimates of total discards over time from all the deepwater trawl fisheries (Figure 7.35) shows the substantial total discards from the large hoki/hake/ling fisheries (2013–14 hoki total TACC of 150 000 t) even though the relative amounts of discards from these fisheries are low (see Table 7.5). This also shows the large size of discards from the scampi fishery (2013–14 scampi total TACC of 1224 t) and the arrow squid fishery (2013–14 arrow squid total trawl TACC of 77 120 t).

Some general trends were identified in some fisheries, especially those examined in recent MPI projects where the determination of trends in the rates and levels of bycatch over time was an explicit objective (Table 7.6).

Table 7.5: Fishery efficiency. Kilograms of discards per kilogram of target species catch. The numbers are the most recent mean estimate, from published reports.

Fishery	Discards/target species catch (kg)
Arrow squid trawl	0.02–0.07
Ling longline	0.35
Hoki/hake/ling trawl	0.03
Jack mackerel trawl	0.011
Southern blue whiting trawl	0.005
Orange roughy trawl	0.03–0.06
Oreo trawl	0.02–0.03
Scampi trawl	2.5

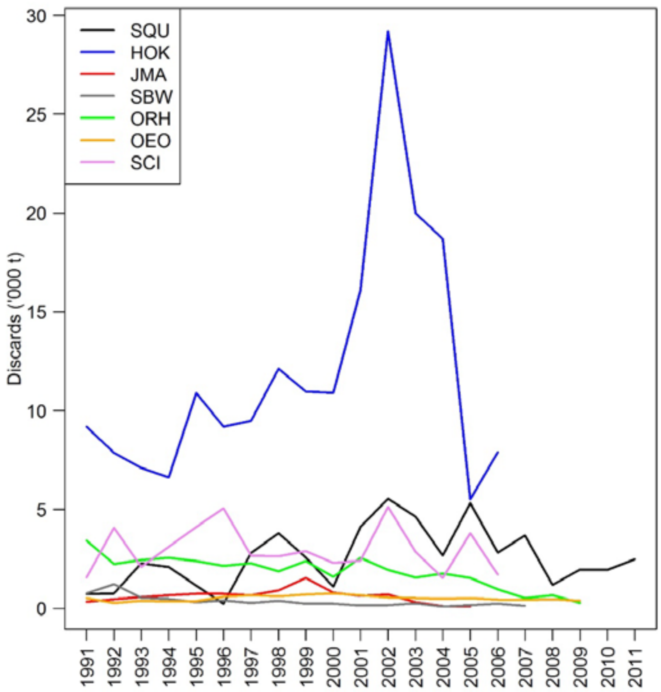


Figure 7.35: Comparison of total estimated discards for all the deepwater trawl fisheries 1990–91 to 2010–11. Data are complete for this period only for arrow squid. SCI, scampi; OEO, oreos; ORH, orange roughy; SBW, southern blue whiting; JMA, jack mackerels; HOK, hoki/hake/ling; SQU, arrow squid.

Table 7.6: Trends in non-protected species bycatch from recent MPI projects where trend determination was an objective.

Fishery	Trends
Arrow squid trawl	Linear regression modelling of observer catch data indicated increased bycatch rates over time (positive slopes) in all species categories and areas except for QMS species in the Stewart-Snares Shelf and Banks Peninsula fisheries. These trends were statistically significant (*p*<0.05) for non-QMS species in the Stewart-Snares Shelf fishery and for invertebrate species in all areas. Bycatch levels for the fishery as a whole also increased over time in each species category, and this increase was significant (*p*<0.05) for invertebrates. Discard rates increased over time in all species categories and areas except for arrow squid in the Banks Peninsula fishery. These trends were statistically significant (*p*<0.05) for QMS species in the Auckland Islands fishery, non-QMS species in the Stewart-Snares Shelf fishery, and for invertebrate species in the Auckland Islands and Banks Peninsula fisheries. Discard levels for the fishery as a whole increased over time in all species categories, and this increase was significant (*p*<0.05) for non-QMS species discards and total discards.
Orange roughy trawl	Increased non-commercial species bycatch between the mid-1990s and mid-2000s was shown to strongly correlate with an overall increase in mean trawl length in the fishery resulting from increased effort away from undersea features.
Scampi trawl	Linear regression modelling of observer catch data indicated significant trends of decreased bycatch over time for QMS species and total species bycatch and a significant trend of increased bycatch for invertebrates. A significant trend of increased discards over time was shown for invertebrates, both rattail categories, and for rattails overall. Recent fleet-wide alterations to the nets that provided escape gaps for larger unwanted fish species (e.g., skates) may be responsible for the above trends. These escape gaps allow for longer tows, as the nets fill up less rapidly, and may lead to greater catches of benthic invertebrates and smaller fish species.

Anderson (2013b) analysed temporal (1990–91 to 2010–11) bycatch trends for individual species or species groups for seven Deepwater trawl and one bottom longline (ling) fisheries. A summary of the bycatch regression slope coefficients for each species and fishery is provided in graphical form in Appendix 7.1. This showed a consistent increase (in six or more of the eight fisheries) for starfish (Asteroidea), deepsea skates (*Notoraja* spp.), Baxters lantern dogfish (*Etmopterus baxteri*), Lucifer dogfish (*E. lucifer*), lanternfish (*Myctophidae*), rough skate (*Zearaja nasuta*), pale ghost shark (*Hydrolagus bemisi*), and javelinfish (*Lepidorhynchus denticulatus*); and consistent decline for bluenose (*Hyperoglyphe antarctica*), shark (unspecified), and skates (*Rajidae* and *Arhynchobatidae*). Some of the trends may be attributable to changes in reporting behaviour, e.g., increased reporting of specific skates and reduced use of the generic skate category. It seems likely that a bycatch decline for well-known species such as bluenose may represent a change in availability, abundance or distribution of that species.

Appendix 7.1: Bycatch trends for seven Deepwater trawl fisheries and one longline fishery (1990–91 to 2010–11). Regression slopes for each species/species group and fishery. Slopes indicating a decline in bycatch over time are highlighted in red, and slopes indicating an increase in bycatch over time are highlighted in green. Species/species groups are ordered alphabetically; blank cells = not estimated; LLL = ling longline fishery; HHL = hoki/hake/ling fishery. NB: These linear regression slopes should be considered only a simple indicator of general changes as relationships may be non-linear; some trends may be strongly influenced by changes in observer recording of species over time. The main purpose of the highlighted cells is to draw attention to species for which closer examination of trends may be warranted.

	Fishery								Scientific name
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
ABR						0.00	0.00		*Alepisaurus brevirostris*
ACA			0.00			0.00	0.00	0.00	*Acanthephyra* spp.
ACN						0.00	0.00		*Acanella* spp.
ACS	0.00	0.02	0.18	0.00		0.11	0.00	0.17	Actinostolidae
ACT		0.00	0.00			0.00	0.00	0.00	*Achiropsetta tricholepis*
ADT			0.00						*Aphrodita* spp.
AER		0.00	0.00			0.00	0.00	0.00	*Aeneator recens*
AFO			0.05			0.00	0.00	0.00	*Aristaeomorpha foliacea*
AGR	0.00	0.00	0.00		0.00	0.00	0.00	-0.21	*Agrostichthys parkeri*
AIR			0.00				0.00		*Argyripnus iridescens*
ALB		0.04	0.00		0.10			0.00	*Thunnus alalunga*
ALL			0.03			0.00		0.00	*Alcithoe larochei*
AMA		0.00	0.00				0.00	0.00	*Acesta maui*
ANC					0.02	0.00			*Engraulis australis*
ANO						0.00	0.00	0.00	*Anoplogaster cornuta*
ANP						0.00	0.00	0.00	*Anotopterus pharao*
ANT	0.00	0.01	-0.02	0.03		0.07	-0.01	0.11	Anthozoa
ANZ		0.03	0.00					0.00	*Ecionemia novaezelandiae*
APD		0.00	0.00						Aphroditidae
API	0.00	-0.04	0.02					0.00	*Alertichthys blacki*
APR		0.03	0.08	-0.01	0.00	0.08	0.04	0.10	*Apristurus* spp.
ARN					0.00				*Argonauta nodosa*
ASR	0.01	0.16	0.18	0.22	0.00	0.03	-0.02	0.23	Asteroidea[46]
AST		0.00	-0.02	0.00		0.00	0.00		Astronesthinae (Subfamily)
ATR			0.00			0.00	0.00	0.00	Actiniaria (Order)
AWA	0.00		0.00			0.00	0.00	0.00	*Astrothorax waitei*
AWI		0.00	0.00					0.00	*Alcithoe wilsonae*
BAC						-0.04		0.00	*Bathygadus cottoides*
BAF						0.00	0.00	0.00	Black anglerfish
BAM			0.00				0.00	0.00	*Bathyplotes* spp.
BAR	0.01	-0.01	0.00		0.06	0.00	0.00	-0.08	*Thyrsites atun*
BAS		0.02	-0.22	0.15	0.00	0.00		0.08	*Polyprion americanus*
BAT		-0.01	0.00			0.01	-0.01	0.00	*Rouleina* spp.
BBA					0.00	0.00		0.00	*Nesiarchus nasutus*
BBE	-0.02	0.07	-0.02		0.00	-0.04	0.05	0.05	*Centriscops humerosus*

[46] Includes the MPI code SFI

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
BCA	0.00	0.00				0.00	0.00	-0.11	*Magnisudis prionosa*
BCD	0.00	0.27	-0.01	0.14		0.00		0.00	*Paranotothenia magellanica*
BCO	-0.04	0.16	0.00	0.03	-0.06	0.00	0.00	-0.02	*Parapercis colias*
BCR		0.00	-0.01			0.00	0.00	-0.02	*Brotulotaenia crassa*
BDA								0.00	*Sphyraena novaehollandiae*
BEE		0.00	0.01		0.00	-0.04	0.16	0.06	*Diastobranchus capensis*
BEL	0.00	0.18	0.04		0.00	0.00	0.00	0.19	*Centriscops* spp.
BEN	0.00		0.00		0.10	0.00	0.00	0.26	*Benthodesmus* spp.
BER		0.00	-0.07		0.00	0.00	0.00	-0.06	*Typhlonarke* spp.
BES		0.00	0.00			0.00	0.00	0.02	*Benthopecten* spp.
BFE						0.00	0.00		*Bathysaurus ferox*
BFI						0.01	0.00	0.01	*Bathophilus filifer*
BFL		0.01						0.00	*Rhombosolea retiaria*
BGZ		0.12						0.00	*Kathetostoma binigrasella*
BHE		0.00	0.00			0.00	0.00	0.00	*Bathypectinura heros*
BIG		0.03			0.00			-0.02	*Thunnus obesus*
BIV		0.00	0.00			0.00	0.00	0.00	Bivalvia
BJA						-0.03		0.00	*Mesobius antipodum*
BKM					0.03			-0.05	*Makaira indica*
BLO						0.00		0.00	*Bathypterois longifilis*
BNE	0.00		0.00		0.02	0.00	0.00	0.03	*Benthodesmus elongatus*
BNO			0.00			0.00	0.00	0.00	*Benthoctopus* spp.
BNS	0.00	-0.06	-0.29	-0.04	-0.07	-0.15	0.01	-0.09	*Hyperoglyphe antarctica*
BNT			0.00		0.00			-0.01	*Benthodesmus tenuis*
BOA	-0.04	0.00	-0.03		0.00	0.00		-0.01	*Paristiopterus labiosus*
BOC		0.02	0.05			0.00		0.00	*Bolocera* spp.
BOE	0.00	0.00	0.00			-0.18	0.01	0.02	*Allocyttus niger*
BOO			0.00			0.02	0.00	0.00	*Keratoisis* spp.
BOT	0.00	0.02	0.00		0.00	0.00	0.00	0.00	Bothidae
BPE		0.00	-0.03		-0.09			-0.01	*Caesioperca lepidoptera*
BPF		0.00						0.00	*Notolabrus fucicola*
BPI		0.00	0.00			0.00	0.00	0.04	*Benthopecten pikei*
BRA		0.00			-0.12		0.00	0.02	*Dasyatis brevicaudata*
BRC	0.00	0.00	-0.12	0.04	0.00	-0.02	0.00	0.01	*Pseudophycis breviuscula*
BRE			0.00		0.00	0.00		0.00	*Bregmaceros macclellandi*
BRG			0.00			0.12	0.00	0.00	Brisingida
BRI	0.00	0.00	0.00					0.00	*Colistium guntheri*
BRN		0.00	0.00			0.00	0.00	0.00	Cirripedia (Class)
BRS	-0.01	0.00						-0.01	*Echinorhinus brucus*
BRZ		0.00	0.02		0.00			0.00	*Xenocephalus armatus*
BSH	-0.01	-0.06	-0.11	0.19	0.00	-0.06	0.02	0.02	*Dalatias licha*
BSK		0.22	0.00		-0.03	-0.01	0.00	-0.14	*Cetorhinus maximus*
BSL						-0.13	0.02	0.10	*Xenodermichthys* spp.
BSP	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	-0.04	*Taractichthys longipinnis*
BSQ	-0.03	0.00	0.00			-0.04	0.00	-0.09	*Sepioteuthis australis*
BTA			0.01		0.00	0.00		0.00	*Brochiraja asperula*
BTD							0.00		*Benthodytes* sp.
BTE						0.00	0.00	0.00	*Benthoctopus tegginmathae*
BTH	-0.05	0.02	0.12	0.02		0.07	0.02	0.11	*Notoraja* spp.
BTP						0.00	0.00		*Bathypathes* spp.
BTS			-0.09			0.00		0.00	*Brochiraja spinifera*
BTU		0.00			0.00	0.00		0.00	*Gasterochisma melampus*
BUT						0.00		0.00	*Odax pullus*
BWH		0.00	0.07		0.06	0.01			*Carcharhinus brachyurus*
BWS		0.04	0.00	-0.02	0.03	0.00	0.00	-0.06	*Prionace glauca*
BYD			0.00		0.00	0.00	0.00	0.04	*Beryx decadactylus*
BYS	0.00	0.01	0.00	0.03	0.00	0.13	0.00	0.26	*Beryx splendens*

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
BYX	0.00	0.02	-0.25	-0.05	-0.01	-0.31	0.00	-0.15	*Beryx splendens & B. decadactylus*[47]
CAL			0.03			0.00	0.00	0.00	*Caenopedina porphyrogigas*
CAM		0.00	0.08			0.00	0.00	0.00	*Camplyonotus rathbunae*
CAN						0.00	0.00		*Cataetyx niki*
CAR	0.00	0.29	0.17	0.34	-0.30	-0.02	0.00	0.14	*Cephaloscyllium isabellum*
CAS	0.00							-0.08	*Coelorinchus aspercephalus*
CAX						0.00	0.00		*Cataetyx* sp.
CAY		0.00	0.00			0.00	0.02	0.00	*Caryophyllia* spp.
CBA						0.00		0.00	*Coryphaenoides dossenus*
CBB		0.03	0.04			0.14	0.00		Coral rubble dead
CBD		0.09			0.00	0.02	0.03	0.00	Coral rubble
CBE		-0.03	-0.03		0.02	0.00		0.03	*Notopogon lilliei*
CBI						0.00	0.00	-0.02	*Coelorinchus biclinozonalis*
CBO	-0.06	-0.03	-0.03			0.01	0.00	-0.14	*Coelorinchus bollonsi*
CBR						0.00	0.00		Dendrophylliidae, Oculinidae, Caryophyllidae
CBX								0.00	*Cubiceps baxteri*
CCA		0.00						0.02	*Cubiceps caeruleus*
CCO			0.03			0.00	0.00	0.04	*Coelorinchus cookianus*
CCR		0.01	0.00			0.00			*Cetonurus crassiceps*
CDL		0.00	0.00		-0.01	-0.17	0.01	0.00	Epigonidae[48]
CDO	0.00	0.13	0.02		0.10	0.00	0.00	0.20	*Capromimus abbreviatus*
CDX		0.00	0.16			0.00		0.00	*Coelorinchus maurofasciatus*
CDY		0.00	0.02			0.00		0.00	*Cosmasterias dyscrita*
CEN				0.00		-0.05		0.00	Squalidae
CEP					0.00	0.00		0.00	*Cepola haastii*
CER						0.00	0.00	0.00	*Ceratias* spp.
CFA						0.00		0.00	*Coelorinchus fasciatus*
CFU		0.00				0.00		0.00	*Corallistes fulvodesmus*
CHA						0.00	0.00	0.02	*Chauliodus sloani*
CHC		0.04				0.00		0.00	*Chaceon bicolor*
CHG				0.12		0.02	0.06	0.02	*Chimaera lignaria*
CHI	0.00	0.00	-0.03	0.08		0.11	0.00	-0.08	*Chimaera* spp.
CHM								0.00	Chiasmodontidae
CHP				0.00		0.04	0.09	0.02	*Chimaera* sp.
CHQ						0.00	0.00	0.03	Cranchiidae
CHR		0.00				0.00	0.05		*Chrysogorgia* spp.
CHX		0.00	-0.05			0.00	0.00	0.02	*Chaunax pictus*
CIC		0.00	0.00			0.00	0.00	0.00	*Crella incrustans*
CIN						0.00			*Coelorinchus innotabilis*
CJA	0.00	0.00	0.03			0.00	0.00	0.10	*Crossaster multispinus*
CJX						0.00		0.00	*Coelorinchus mycterismus*
CKA						0.00	0.00	0.00	*Coelorinchus kaiyomaru*
CKX						0.00	0.00		*Coelorinchus trachycarus & C. acanthiger*
CLL						0.00	0.00		*Corallium* spp.
CMA						0.00			*Coelorinchus matamua*
CMR			0.00					0.00	*Coluzea mariae*
CMT		0.00	0.00			0.00		0.00	Comatulida
CMU						0.00	0.02	-0.02	*Coryphaenoides murrayi*
COB		0.00	0.00		0.00	0.02	0.00	0.00	Antipatharia (Order)
COC		0.00	0.00					0.00	*Austrovenus stutchburyi*
COD		0.00	0.00			0.03	0.00	-0.02	Cod
COE						0.00	0.00	0.00	Coelenterata
COF		0.03	0.00			0.00	0.00	0.03	*Flabellum* spp.

[47] Includes the MPI code BYC

[48] Includes the MPI code EPT

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
COL			0.05			-0.02		0.02	*Coelorinchus oliverianus*
CON	-0.02	0.08	0.02	-0.09	-0.06	-0.04	0.00	0.12	*Conger* spp.
COR		0.00	-0.01	0.00		0.02	0.00	0.00	Stylasteridae (Family)
COT		0.00				0.00	0.00	0.00	*Cottunculus nudus*
COU		-0.01	0.05	0.01		0.06	0.03	-0.01	Corals (all)
COV			0.00					0.00	*Comitas onokeana vivens*
CPA		0.00	0.03	0.04		0.00	0.00	0.10	*Ceramaster patagonicus*
CPD						0.00		-0.03	Centrolophidae
CRA		-0.01	0.00		0.00	0.00	0.00	-0.02	*Jasus edwardsii*
CRB	0.00	-0.07	-0.09	0.02	0.00	-0.01	0.00	0.04	Crab
CRD						0.00		0.00	*Coryphaenoides rudis*
CRE						0.00	0.00	0.00	*Calyptopora reticulata*
CRI		0.00	0.00			0.00	0.00	0.00	Crinoidea
CRM		0.12	0.00		0.00	0.00	0.00	0.00	*Callyspongia cf ramosa*
CRN		0.04				0.00	0.00	0.00	Sea lily, stalked crinoid
CRS		0.00				-0.01		0.00	*Callyspongia ramosa*
CRU		-0.04	-0.05		0.00	0.00	0.00	-0.01	Crustacea
CSE						0.00			*Coryphaenoides serrulatus*
CSH	0.00	0.08	0.05	0.03	-0.08	-0.04	-0.01	0.16	Catshark
CSP		-0.01						0.00	*Coelorinchus spathulatus*
CSQ	-0.03	-0.05	0.01	0.35		0.09	0.03	0.06	*Centrophorus squamosus*
CST						0.00	0.00	-0.01	*Caristius* sp.
CSU						0.04		0.00	*Coryphaenoides subserrulatus*
CTN		0.00	0.00						*Calliostoma turnerarum*
CTU		0.00	0.00					-0.01	*Cookia sulcata*
CUB	0.00	0.00	0.00			0.00	0.00	-0.03	*Cubiceps* spp.
CUC	0.00	-0.02	-0.12		-0.02	0.00	0.00	0.00	*Paraulopus nigripinnis*
CUP						0.00	0.00	0.00	Flabellidae, Fungiacyathidae, Caryophyllidae (Families)
CVI			0.04					0.00	*Pycnoplax victoriensis*
CYL		0.00	0.00			0.10	0.00	0.19	*Centroscymnus coelolepis*
CYO	0.00	0.00		-0.03		0.15	0.00	0.09	*Centroscymnus owstoni*
CYP	0.00	0.00	0.02	0.04		0.23	0.13	0.10	*Centroscymnus crepidater*
DAP		0.00	0.12			0.00		0.00	*Dagnaudus petterdi*
DAS		0.00	0.02		0.00	0.00			*Pteroplatytrygon violacea*
DCO			0.00				0.00	0.00	*Notophycis marginata*
DCS	0.00	0.00	-0.11	0.14	0.00	-0.02		-0.05	*Bythaelurus dawsoni*
DDI			0.00			0.04	0.02	0.00	*Desmophyllum dianthus*
DEA	0.00	0.00	0.00		0.00	0.00	0.00	-0.12	*Trachipterus trachypterus*
DEQ						-0.02		-0.02	*Deania quadrispinosum*
DGT		0.00	0.00		0.00				Callionymidae
DHO		0.00	0.03			0.00	0.00	0.02	*Dermechinus horridus*
DIR		0.00	0.13		0.00	0.00	0.00	0.00	*Diacanthurus rubricatus*
DIS		0.00			0.00	0.00	0.00	0.00	*Diretmus argenteus*
DMG		0.00	0.08	0.00		0.00	0.00	0.08	*Dipsacaster magnificus*
DPO						0.00		-0.02	*Desmodema polystictum*
DPP		0.00	0.00			0.00	0.00	0.00	*Diplopteraster* sp.
DPX						0.00	0.00		*Diplacanthopoma* sp.
DSE		0.00				0.00	0.00	0.00	*Derichthys serpentinus*
DSK	0.00	0.02	-0.18	0.03		0.05	-0.05	0.11	*Amblyraja hyperborea*
DSP	-0.02	0.06	0.00			0.00		0.00	*Congiopodus coriaceus*
DSS					0.00	0.00	0.00	-0.01	*Bathylagus* spp.
DWE	0.00	0.00	-0.07	0.00	0.00	-0.03	0.00	0.20	Deepwater eel
DWO	0.00	0.00	0.01		0.00	0.00	0.00	0.16	*Graneledone* spp.
ECH		0.00	-0.05	-0.01		-0.01	0.00	-0.02	Echinodermata (Phylum)

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
ECN		0.00	0.13	-0.01		0.01	0.00	-0.02	Echinoid[49]
EEL	0.00	0.00	-0.15	-0.01	0.00	0.02	0.00	-0.04	Eel
EEX		0.06				0.00		0.00	*Enypniastes eximia*
EGA		0.00	0.03		0.00	0.00		0.00	*Euciroa galatheae*
EGR					0.11			0.00	*Myliobatis tenuicaudatus*
ELE		0.00	0.00		0.05	0.00	0.00	0.00	*Callorhinchus milii*
ELP		0.00	0.00		0.00	0.00	0.00	0.00	*Elthusa propinqua*
ELT				0.03		0.00	0.00	0.00	*Electrona* spp.
EMA	0.01	0.00	0.00		0.02			-0.20	*Scomber australasicus*
EMO		0.00	-0.02			0.00		0.01	*Etmopterus molleri*
ENE		0.00	0.00			0.00	0.00		*Elthusa neocytta*
EPD			0.00					0.03	*Epigonus denticulatus*
EPL		0.00	0.03		0.00	-0.12	-0.03	0.20	*Epigonus lenimen*
EPO			-0.02			0.00	0.00	0.00	*Melanostigma gelatinosum*
EPR		0.00	0.05			0.07	0.00	0.16	*Epigonus robustus*
EPZ						0.00	0.00	0.00	*Epizoanthus* spp.
ERA	0.00	0.01	0.00		-0.01	0.00	0.00	0.03	*Torpedo fairchildi*
ERE						0.00	0.00	0.00	*Euplectella regalis*
ERO		0.00				0.07	0.00		*Enallopsammia rostrata*
ERR		0.00				0.00	0.00		*Errina* spp.
ESO		0.00	0.00			0.00			*Peltorhamphus novaezeelandiae*
ETB	-0.03	0.06	0.04	0.22	0.00	0.10	0.29	0.21	*Etmopterus baxteri*
ETL	0.00	0.08	0.08	0.06	0.00	-0.13	0.08	0.06	*Etmopterus lucifer*
ETM	0.00	-0.03	-0.03	0.00		0.00	0.11	-0.27	*Etmopterus* sp.
ETP				0.04		-0.04	-0.01	-0.01	*Etmopterus pusillus*
EUC		0.00	0.03			-0.02	0.00	0.13	*Euclichthys polynemus*
EZE		0.03	0.05			0.00	0.00	0.00	*Enteroctopus zealandicus*
FAN						0.00		0.00	*Pterycombus petersii*
FAR		0.00				0.00	0.00	0.00	*Farrea* spp.
FHD	0.00	0.07	0.04	0.00	0.00	0.00	0.00	0.10	*Hoplichthys haswelli*
FLA	0.00	0.20	-0.02		0.00	0.00		0.02	Flatfish
FLO		0.02	0.00			0.00	0.00	-0.01	Flounder
FLY		0.00	0.00			0.00			Exocoetidae
FMA	0.00	0.02	0.13	0.00		0.00	0.00	0.19	*Fusitriton magellanicus*
FOR					0.01		0.00	0.00	*Forsterygion* spp.
FOX		0.00			0.00				*Bodianus flavipinnis*
FRO	0.01	0.13	-0.06		0.04	-0.04	0.00	-0.10	*Lepidopus caudatus*
FRS		0.00				-0.05	0.00	-0.02	*Chlamydoselachus anguineus*
FRX			0.00					-0.01	Trichiuridae
FTU	0.00	0.02			0.00			0.00	*Auxis thazard*
GAO						0.00	0.00	0.00	*Gadomus aoteanus*
GAR		0.00	0.00					0.00	*Hyporhamphus ihi*
GAS		0.00	0.20	0.02	0.00	0.00	0.00	0.06	Gastropoda
GAT			0.03			0.00	0.00	0.00	*Gastroptychus* spp.
GBI		0.00							Gobiidae (Family)
GDU		0.00	0.06			0.20	0.17	0.00	*Goniocorella dumosa*
GFL		0.13	0.00						*Rhombosolea tapirina*
GGL						0.00	0.00		*Guttigadus globosus*
GIZ		0.00	-0.01						*Kathetostoma giganteum*
GLO						0.00			*Glyphocrangon lowryi*
GLS	0.02	0.00	0.00		0.00	0.05	0.00	0.11	Hexactinellida (Class)
GMC	0.00	0.03	0.20					0.00	*Leptomithrax garricki*
GMU		0.00			0.00			0.00	*Mugil cephalus*
GOB		0.00				0.00	-0.01	0.00	*Mitsukurina owstoni*
GOC		0.00			0.00	0.00	0.00	0.00	Gorgonacea (Order)

[49] Includes the MPI code URO

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
GON		0.30	0.00		0.00	0.00		0.05	*Gonorynchus forsteri & G. greyi*
GOR		0.00	0.00			0.00	0.00	0.06	*Gorgonocephalus* spp.
GOU		0.00				0.00		0.00	*Goniocidaris umbraculum*
GPA		0.00	0.00			0.00	0.00	0.00	*Goniocidaris parasol*
GPF		0.00							*Notolabrus cinctus*
GRC		0.00				0.02	0.09	-0.01	*Tripterophycis gilchristi*
GRM		0.00	0.00			0.00	0.03	0.07	*Gracilechinus multidentatus*
GSA			0.00					-0.01	*Hoplostethus gigas*
GSC	0.00	0.41	0.08	0.03		0.00	0.00	0.05	*Jacquinotia edwardsii*
GSH	-0.13	0.13	0.02	0.00	-0.33	-0.18	-0.20	-0.11	*Hydrolagus novaezealandiae*
GSP	0.12	0.19	0.16	0.41	0.00	0.15	0.22	0.19	*Hydrolagus bemisi*
GSQ	-0.02	0.02				0.02	0.00	0.02	*Architeuthis* spp.
GST	0.00	0.00				0.00	0.00	0.00	Gonostomatidae
GUL						0.00	0.00	0.00	*Eurypharynx pelecanoides*
GUR	0.00	0.01	0.00		-0.03	0.00		0.03	*Chelidonichthys kumu*
GVE		0.00					0.00	0.00	*Geodia vestigifera*
GVO		0.00	0.10			0.00	0.00	0.02	*Provocator mirabilis*
GYS						0.00		0.00	*Gyrophyllum sibogae*
HAG	0.00	0.00	-0.03	0.30	0.00	0.00	0.00	0.24	*Eptatretus cirrhatus*
HAK	-0.05	0.03	-0.03	0.16	-0.04	0.01	0.04		*Merluccius australis*
HAL						0.00		0.03	*Halosauropsis macrochir*
HAP	0.00	0.13	-0.08	0.13	0.04	0.00		-0.02	*Polyprion oxygeneios*
HAT		0.00	0.00		-0.02	0.00	0.00	0.00	Sternoptychidae
HCO	-0.03	0.03	0.02	0.48		-0.01	0.00	-0.03	*Bassanago hirsutus*
HDF		0.00			0.00	0.00	0.00	0.00	Leptomeduseae, Anthoathecatae (Orders)
HDR		0.00			0.00	0.00	0.00	0.00	Hydrozoa (Class)
HEC			0.00			0.00	0.00	0.00	*Henricia compacta*
HEP		0.00	-0.02	0.06	-0.03	0.00	0.00	0.01	*Heptranchias perlo*
HEX		0.07	-0.06	0.16	0.00			0.12	*Hexanchus griseus*
HGB						0.02	0.00	0.00	*Hydrolagus* sp. d
HIA	0.00					0.00	0.00	0.00	*Himantolophus appelii*
HIS			0.03			0.00			*Histocidaris* spp.
HJO	0.00	0.00	0.01			0.09	0.10	0.02	*Halargyreus johnsonii*
HMT	0.00	0.00	0.14	0.03	0.00	0.00	0.00	0.08	Hormathiidae
HOK	-0.18	0.04	-0.06	0.17	-0.12	-0.03	0.14		*Macruronus novaezelandiae*
HOL	0.00					0.00	0.00	0.01	*Holtbyrnia* sp.
HOR		0.00						0.01	*Atrina zelandica*
HOW								0.00	*Howella brodiei*
HPB	0.00	-0.12	-0.21	-0.12	-0.22	0.00		-0.22	*Polyprion oxygeneios & P americanus*
HPE						0.00		0.00	*Halosaurus pectoralis*
HSI		0.00	0.24			0.00	0.00	0.00	*Haliporoides sibogae*
HTH	0.00	-0.03	0.09	0.00	0.00	0.14	0.03	0.11	Holothurian unidentified[50]
HTR	0.00	0.00	0.03			0.00	0.00	0.11	*Hippasteria phrygiana*
HYA	0.00	0.06	0.04		0.00	0.04	0.00	0.27	*Hyalascus* sp.
HYB				0.02		0.00		0.00	*Hydrolagus homonycteris*
HYD				0.01	0.00	0.01	0.02	0.04	*Hydrolagus* sp.
HYM			0.07						*Hymenocephalus* spp.
HYP	0.00					0.01	0.00	0.00	*Hydrolagus trolli*
IBR						0.09	0.03	0.00	*Isistius brasiliensis*
ICQ	0.00					0.00			*Idioteuthis cordiformis*
IDI						0.00	0.00		*Idiacanthus* spp.
ISI						0.00	0.02	0.00	Isididae
JAV	0.08	0.25	-0.01	0.06	0.05	0.08	0.16	0.07	*Lepidorhynchus denticulatus*
JDO		0.01			-0.06			-0.02	*Zeus faber*
JFI	0.00	-0.09	-0.06		0.05	0.05	0.02	0.05	Jellyfish

[50] Includes the MPI code SCC

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
JGU		-0.01	-0.07		-0.10			0.01	*Pterygotrigla picta*
JMA	0.00	-0.16	-0.15		-0.01	0.00	0.00	-0.27	*Trachurus declivis, T. murphyi, T. novaezelandiae*
JMD	0.01	-0.09	0.02		0.24	0.01		-0.07	*Trachurus declivis*
JMM	0.00	-0.20	-0.02		-0.05	-0.04		-0.32	*Trachurus murphyi*
JMN		-0.03	0.00		0.55	0.00		-0.06	*Trachurus novaezelandiae*
KAH		0.00			0.02			0.00	*Arripis trutta, A. xylabion*
KIC	0.00	0.00	-0.02	0.00		0.08	-0.02	0.10	*Lithodes murrayi, Neolithodes brodiei*
KIN	0.00	0.00	0.00		0.20	0.00	0.00	0.01	*Seriola lalandi*
KWH		0.00	0.03		0.00	0.00		0.02	*Austrofucus glans*
LAE			0.01			-0.03	-0.01	0.00	*Laemonema* spp.
LAG			0.07			0.00		0.00	*Laetmogone* spp.
LAM		0.00	0.00		0.00			0.00	*Geotria australis*
LAN	0.00	0.20	0.01		0.04	0.02	0.02	0.10	Myctophidae
LAT					0.00	0.00	0.00	0.00	*Alepisaurus ferox*
LCA						0.00		0.00	*Lophotus capellei*
LCH	-0.04	0.00	0.00	0.00	0.00	0.07	0.05	0.03	*Harriotta raleighana*
LCO		0.00				0.00			*Liocarcinus corrugatus*
LDO	-0.01	0.08	-0.03		0.11	-0.06	0.01	0.00	*Cyttus traversi*
LEA		0.00			-0.15				*Meuschenia scaber*
LEG						-0.05	0.00	0.01	*Lepidion schmidti & Lepidion inosimae*
LEP						0.00	0.00		*Lepidocybium flavobrunneum*
LFB					0.00				*Zanclistius elevatus*
LHC		0.00	0.00			0.00		0.00	*Leptomithrax longimanus*
LHE							0.00	-0.03	*Lampanyctodes hectoris*
LHO			0.07			0.00	0.00	0.05	*Lipkius holthuisi*
LIN	-0.06	0.09	-0.12		-0.15	-0.08	-0.06		*Genypterus blacodes*
LIP		0.00	0.00			0.00			*Liponema* spp.
LIZ		0.00	0.00		0.00	0.00			*Synodus* spp.
LLC		0.06	0.00					0.00	*Leptomithrax longipes*
LLE						0.00	0.00	0.00	*Lepidisis* spp.
LMI		0.00	0.00						*Leptomithrax* spp.
LMU		0.00				0.02	0.00	0.06	*Lithodes murrayi*[51]
LNV			0.00			0.00	0.00	0.09	*Lithosoma novaezelandiae*
LPD								0.00	*Lampadena* spp.
LPI						0.01			*Lepidion inosimae*
LPS						0.00	-0.01	0.00	*Lepidion schmidti*
LPT		0.00				0.00	0.00		*Lepidotheca* spp.
LSE						0.00	0.00		*Leiopathes secunda*
LSK	0.00	0.02	0.08		0.00	-0.03	0.00	0.13	*Arhynchobatis asperrimus*
LSO	0.00	-0.02	0.00		0.00			-0.02	*Pelotretis flavilatus*
LUC	0.00	0.00	-0.05			-0.02	0.00	-0.02	*Luciosudus* sp.
LYC						0.00	0.00	0.00	*Lyconus* sp.
MAK	0.02	0.08	0.00	0.07	0.12	-0.06		-0.05	*Isurus oxyrinchus*
MAL						0.00	0.00	0.00	Malacosteidae
MAN	-0.05	-0.02	0.00		0.00	0.03	0.00	-0.11	*Neoachiropsetta milfordi*
MCA						0.20	0.35	-0.01	*Macrourus carinatus*
MCH	0.00		0.00				0.00	0.00	*Notothenia angustata*
MCN						0.00	0.00	0.00	*Malacosteus niger*
MDO	0.00	0.06	0.08		0.00	-0.03	0.00	-0.01	*Zenopsis nebulosa*
MEJ						0.00	0.00	0.00	*Melanocetus johnsonii*
MEN						0.00	0.00	0.00	*Melanostomias* spp.
MGA			0.00						*Munida gracilis*
MIC	-0.03	0.00				0.00		0.00	*Microstoma microstoma*
MIN		0.00				0.00			*Minuisis* spp.

[51] Includes the MPI code LLT

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
MIQ	-0.06	0.00	-0.11			-0.09	0.02	0.03	*Onykia ingens*
MMU		0.00							*Maurolicus australis*
MNI		0.00	0.07			0.00	0.00	0.00	*Munida* spp.
MOC		0.00				0.11	0.04		*Madrepora oculata*
MOD	0.00	0.00	-0.03	0.04	0.00	0.27	0.20	0.20	Moridae
MOK		-0.02	0.00		0.00	-0.02		-0.10	*Latridopsis ciliaris*
MOL		0.00	0.08	0.00		0.00	0.00	0.00	Mollusc
MOO	-0.17	0.02			-0.05	0.00	0.00	-0.15	*Lampris guttatus*
MOR			0.00	0.00		0.00	0.00	-0.01	Muraenidae (Family)
MPH						0.00	0.00		Melamphaidae
MRL							0.00	0.01	Muraenolepididae
MRQ						0.00	0.00	0.00	*Onykia robsoni*
MSL		0.00	0.09	0.00		0.00	0.00	0.00	*Mediaster sladeni*
MST						0.05	0.00	0.03	Melanostomiidae
MUR						-0.02	0.00		*Muraenolepis marmoratus*
MUU		0.00	0.00					0.00	Mullet
MYC								0.00	*Mycale* spp.
NAT	0.00	0.00	0.00		0.00	0.00	0.00	0.00	Natant decapod
NBI			0.00						*Neomyxine biniplicata*
NCA		0.12	0.00		0.00	0.00	0.00	0.00	*Nectocarcinus antarcticus*
NCB		0.52	0.00		0.00			0.02	*Nectocarcinus bennetti*
NEB	0.00	0.00	0.00			0.12	0.00	0.02	*Neolithodes brodiei*
NEC			0.00			0.00	0.00	0.00	*Nematocarcinus* spp.
NET			0.00			0.00		0.00	*Nettastoma parviceps*
NEX					0.01	0.00	0.00	0.01	Nemichthyidae
NMA			0.00						*Notopandalus magnoculus*
NOC			0.00			0.00	0.00	0.03	*Notacanthus chemnitzi*
NOG	0.00	-0.08	-0.04		-0.04	0.00		-0.03	*Nototodarus gouldi*
NOR						0.00	0.02	0.00	*Normichthys yahganorum*
NOS	0.00	0.10	-0.07		-0.04	0.00		0.03	*Nototodarus sloanii*
NOT	0.00	-0.09	-0.03	-0.31		0.01		0.00	Nototheniidae
NSD	0.00	0.02	-0.02	0.16	-0.15	0.00		0.23	*Squalus griffini*
NTO		0.02	0.00			0.00		0.00	*Notomithrax* spp.
NTU					0.00			0.00	*Thunnus thynnus*
NUD		0.00	0.10			0.00		0.00	Nudibranchia (Order)
OAP						0.00			*Ocosia apia*
OAR	0.00	0.00				0.00		-0.12	*Regalecus glesne*
OCP		0.00	0.02		0.00	0.00	0.00	0.00	Octopod
OCT	0.01	0.05	0.00	0.01	-0.02	0.00	0.00	-0.08	*Pinnoctopus cordiformis*
ODO	0.00	0.01	0.03	0.02	-0.04	0.00		-0.01	*Odontaspis ferox*
ODT		0.00	0.00			0.00	0.00	0.00	*Odontaster* spp.
OEO						-0.18		-0.11	*P. maculatus, A. niger, & N. rhomboidalis*
OFH		0.00	-0.05	0.03	0.00	-0.02	0.00	-0.01	*Ruvettus pretiosus*
OMM	0.00	0.00				0.00		0.00	*Ommastrephes* spp.
OMU						0.00			*Odontomacrurus murrayi*
ONG	-0.03	0.22	0.04	0.01	0.00	0.10	0.00	0.12	Porifera (Phylum)
OPA	-0.02	0.13	0.03		0.00			0.00	*Hemerocoetes* spp.
OPE		0.13	-0.08		-0.02	-0.01		-0.02	*Lepidoperca aurantia*
OPH	0.00	0.00	0.00			-0.01	0.00	0.00	Ophiuroid
OPI	0.00	0.00	0.08			0.00	0.00	0.23	*Opisthoteuthis* spp.
OPL		0.02	0.00		0.00				Opheliidae
ORH		0.00	-0.02		0.00		0.03	-0.05	*Hoplostethus atlanticus*
OSE						0.00	0.00	0.00	*Ophisurus serpens*
OSI			0.00			0.00	0.00	0.00	*Ophiocreas sibogae*
OSK	0.00	0.00	0.11		0.00	0.07	0.00	0.16	Rajidae (Family)
OSP	0.00	0.00	0.00			0.00	0.01	0.00	*Crassostrea gigas*
OSQ			0.00					0.00	Octopoteuthiidae

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
OXO						0.00		0.00	*Oreosoma atlanticum*
PAB	0.00					0.06	0.14	0.00	*Paragorgia arborea*
PAD		-0.35	0.00		0.00			0.00	*Ovalipes catharus*
PAG		0.00	0.00			0.00		0.00	Paguroidea
PAH	0.25	0.00			0.00			0.01	*Lampris immaculatus*
PAL	0.00	0.00				0.00	0.00	0.01	Paralepididae
PAM		0.00	0.03			0.00	0.00	0.00	*Pannychia moseleyi*
PAO		0.00				0.00	0.00	0.02	*Pillsburiaster aoteanus*
PBA						0.00	0.00	0.00	*Pasiphaea barnardi*
PCH		0.00	0.03				0.00	0.00	*Penion chathamensis*
PCO			-0.06						*Auchenoceros punctatus*
PDG	0.00	0.06	0.01			-0.06	0.00	0.05	*Oxynotus bruniensis*
PDO			0.00			0.00		0.00	*Paphies donacina*
PDS	0.00		0.00			0.00	0.00	0.07	*Paradiplospinus gracilis*
PED			-0.04			0.00	0.00	0.00	*Aristaeopsis edwardsiana*
PFL			0.00					0.00	*Pseudechinus flemingi*
PHB		0.00				0.00	0.00	0.00	*Phorbas* spp.
PHO	0.00	0.07	0.00		0.00	-0.02	0.00	0.06	*Phosichthys argenteus*
PHW	0.00	0.03	0.00		0.00		0.00	0.00	*Psammocinia cf hawere*
PIG	-0.09	0.26	0.09		0.00	0.00		0.08	*Congiopodus leucopaecilus*
PIL		0.00	0.00		0.23				*Sardinops sagax*
PIN						0.00	0.00	0.02	*Idiolophorhynchus andriashevi*
PIP					0.00			0.00	Syngnathidae
PKI			0.00						*Polyipnus kiwiensis*
PKN				0.04		0.00	0.00	0.07	*Plutonaster knoxi*
PLM			0.00					0.00	*Plesionika martia*
PLS	0.00	0.03	0.01	0.17		0.01	0.02	-0.02	*Proscymnodon plunketi*
PLT			0.02			0.00	0.00	0.05	*Plutonaster* spp.
PLY			0.00			0.00	0.00	0.00	*Polycheles* spp.
PLZ			-0.07			0.00			*Pleuroscopus pseudodorsalis*
PMN						0.00	0.00		*Primnoa* spp.
PMO	0.00	0.00	0.00			0.00	0.00	0.03	*Pseudostichopus mollis*
PMU			0.07			0.00		0.00	*Paramaretia peloria*
PNE	0.00	0.00	0.04	0.03		0.00	0.00	0.00	*Proserpinaster neozelanicus*
PNN			0.03		0.00	0.00	0.00	0.00	*Pennatula* spp.
POL		0.00	0.00		0.00	0.00		0.00	Polychaeta
POM	0.02	0.00			0.00	0.00		0.00	Bramidae
POP		0.00			0.00			0.00	*Allomycterus jaculiferus*
POR	-0.03	-0.03			-0.01	0.00		-0.26	*Nemadactylus douglasii*
POS	0.03	0.06	0.00	0.05	-0.05	0.00	0.00	-0.08	*Lamna nasus*
POT		0.00			0.00				Parrotfish
PPA		0.00				0.00		0.00	*Projasus parkeri*
PRA	0.00	0.00	0.10			0.00	0.00	0.00	Prawn
PRK		0.00	0.18		0.00	0.00		0.00	*Ibacus alticrenatus*
PRO					0.01			0.00	*Protomyctophum* spp.
PRU		0.00	0.04			0.00	0.00	0.02	*Pseudechinaster rubens*
PSE			0.01			0.00	-0.01		*Pseudechinus* spp.
PSI	0.00	0.00	0.18	0.03	0.00	0.00	0.00	0.14	*Psilaster acuminatus*
PSK		0.02	0.06	0.02	0.00	0.13	0.00	0.18	*Bathyraja shuntovi*
PSL						-0.02	0.02		*Paralomis dosleini*
PSO							0.00	-0.03	*Psolus* spp.
PSP		0.00				0.00		0.04	*Psenes pellucidus*
PSQ	0.00	0.00	0.00			0.03	0.00	0.09	*Pholidoteuthis boschmai*
PSY	0.00	0.00	-0.05		0.00	0.04	0.02	-0.03	*Psychrolutes microporos*
PTA						0.00	0.00	0.00	*Pasiphaea* aff. *tarda*
PTM			0.00			0.00		0.00	*Platymaia maoria*
PTO		0.00	0.00	0.07			0.01	0.00	*Dissostichus eleginoides*

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
PTU			0.00		0.00	0.00	0.00	0.00	Pennatulacea (Order)
PUF					0.00	0.00		0.00	*Sphoeroides pachygaster*
PVE		0.00				0.00	0.00	0.00	*Pyramodon ventralis*
PZE	0.00		0.00				0.00	0.02	*Paralomis zealandica*
QSC		0.14		0.00	0.00			0.00	*Zygochlamys delicatula*
RAG	0.00	0.00	0.00		0.00	0.06	0.03	-0.11	*Pseudoicichthys australis*
RAT	-0.08	0.10	-0.02	0.26	-0.10	0.04	0.14	0.03	Macrouridae
RAY		0.00	-0.07		-0.04	0.00	-0.02	0.02	Torpedinidae, Dasyatidae, Myliobatidae, Mobulidae
RBM	0.16	-0.13	0.00	-0.11	0.04	-0.01	0.00	-0.05	*Brama brama*
RBP		0.00			0.00			0.00	*Hypoplectrodes huntii*
RBT	0.01	0.04	0.04		0.06	0.00		0.06	*Emmelichthys nitidus*
RBY		0.03	-0.13		0.03	0.00		-0.19	*Plagiogeneion rubiginosum*
RCH	0.00					0.04	0.00	0.04	*Rhinochimaera pacifica*
RCK			0.02			0.00			Acanthoclinidae
RCO	0.02	0.05	-0.09	0.06	-0.30	0.00	0.00	-0.09	*Pseudophycis bachus*
RDO		0.23	0.00		0.06			0.20	*Cyttopsis roseus*
REM					0.00			0.00	Echeneididae
RGR		0.00	0.00			0.00	0.00	0.00	*Radiaster gracilis*
RHY		0.00	0.21		0.03	0.03	0.00	0.19	*Paratrachichthys trailli*
RIB	0.00	0.08	-0.17	0.05	0.00	-0.06	0.01	0.00	*Mora moro*
RIS		0.00				0.00	0.00	0.08	*Bathyraja richardsoni*
RMU	0.00							-0.02	*Upeneichthys lineatus*
ROC		0.02	-0.02	0.02		0.05	0.04	0.00	*Lotella rhacinus*
RPE		0.00	-0.04		0.00			0.00	Red perch
RPI		0.00			-0.02				*Bodianus vulpinus*
RRC						0.00			*Scorpaena cardinalis & S. papillosus*
RSC		0.00				0.02			*Scorpaena papillosa*
RSK	0.04	0.24	0.15	0.48	-0.10	0.02	0.00	0.12	*Zearaja nasuta*
RSN		0.00	0.00		-0.09			-0.02	*Centroberyx affinis*
RSQ	0.00	0.03	0.00			-0.08	0.00	0.08	*Ommastrephes bartrami*
RUD	0.00	0.00	-0.10		0.00	-0.03	-0.04	-0.02	*Centrolophus niger*
SAB						0.00	0.00	0.00	*Evermannella indica*
SAF		0.00	0.00			0.01		0.00	*Synaphobranchus affinis*
SAI					0.00			0.02	*Istiophorus platypterus*
SAR						0.01			*Squilla armata*
SAU			0.00			0.00		0.00	*Scomberesox saurus*
SAW					0.00	0.00	0.00	-0.01	*Serrivomer* spp.
SBI	0.04		0.00			-0.16	-0.02	-0.03	*Alepocephalus australis*
SBK		0.00	-0.03		0.00	-0.04	0.00	0.06	*Notacanthus sexspinis*
SBN			0.00			0.00	0.00	0.00	Scalpellidae (Family)
SBO	-0.05	0.00	0.01	0.02	0.00	0.02	0.00	0.05	*Pseudopentaceros richardsoni*
SBR	0.00	0.00	-0.05	0.03	0.00	-0.03	0.02	0.02	*Pseudophycis barbata*
SBW		0.08	0.00		0.00	0.00	0.04	0.23	*Micromesistius australis*
SCA		0.03	0.00						*Pecten novaezelandiae*
SCD	0.00	0.10						0.03	*Notothenia microlepidota*
SCG		0.00	-0.09		0.12		0.00	0.02	*Lepidotrigla brachyoptera*
SCH		0.12	-0.04	0.13	-0.16	0.00		0.03	*Galeorhinus galeus*
SCI	0.00	0.00			0.00	0.00	0.00	0.12	*Metanephrops challengeri*
SCM		0.02	0.00	-0.04	0.00	0.11	-0.01	0.19	*Centroscymnus macracanthus*
SCO	0.00	0.00	-0.04	-0.01	0.00	0.02	0.00	0.08	*Bassanago bulbiceps*
SDE		0.00				0.00	0.00	-0.02	*Cryptopsaras couesii*
SDF	0.00		0.00					0.00	*Azygopus pinnifasciatus*
SDL			0.00			0.02			*Scorpaena cardinalis*
SDM		0.00	0.03			0.00	0.00	0.03	*Sympagurus dimorphus*
SDO	0.00	0.47	0.00		0.21	0.00	0.00	0.15	*Cyttus novaezealandiae*
SDR					0.00	-0.01		0.02	*Solegnathus spinosissimus*

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
SEE	0.00	0.00	-0.03	0.18	0.00	0.00	0.00	0.11	*Gnathophis habenatus*
SEN						0.00	0.00		*Actinia* spp.
SEP		0.00						0.00	*Sergia potens*
SEQ		0.00							Sepiolidae
SER		0.00	0.00					0.00	*Sergestes* spp.
SEV		0.05	0.04	0.00	0.03	0.00		0.08	*Notorynchus cepedianus*
SFL		0.12	0.00					0.00	*Rhombosolea plebeia*
SFN						0.00	0.00	0.00	*Diretmichthys parini*
SHA	-0.02	0.10	-0.05	0.22	-0.06	-0.09	-0.10	-0.02	Unspecified sharks and dogfish[52]
SHE	0.00		0.00			0.00		-0.04	*Scymnodalatias sherwoodi*
SHL			-0.02		0.00				*Scyllarus* sp.
SHO					0.00				*Hippocampus abdominalis*
SIA		0.00	0.00			0.19	0.03	0.00	Scleractinia
SID			0.00			0.00	0.00	0.00	Platytroctidae
SKA	-0.07	-0.08	-0.39	-0.35	-0.20	-0.06	-0.02	-0.33	Rajidae Arhynchobatidae (Families)
SKI		-0.13	-0.05	0.03	-0.12	0.00	0.00	-0.03	*Rexea* spp.
SKJ		0.02	0.00		0.00			0.00	*Katsuwonus pelamis*
SLB						0.00	0.00	0.05	*Scymnodalatias albicauda*
SLC						-0.02			*Slosarczykovia circumantarctica*
SLG		0.00	-0.03		0.00	0.00	0.00	0.00	*Scutus breviculus*
SLK			0.00			0.08	0.20	0.21	Alepocephalidae
SLL			0.00		0.00	0.00	0.00	0.00	Scyllaridae
SLO			0.00		0.00			0.00	*Arctides antipodarum*
SLR			-0.04			0.00		0.00	*Optivus elongatus*
SLS		0.00						0.00	*Peltorhamphus tenuis*
SMA		0.02			0.01			0.00	*Stigmatophora macropterygia*
SMC			0.04			-0.08	0.00	-0.05	*Lepidion microcephalus*
SMI	0.00	0.04				0.01	0.00		*Somniosus microcephalus*
SMK		0.00	0.30			0.00		0.00	*Teratomaia richardsoni*
SMO		0.06	0.00		0.00	0.00	0.00	0.00	*Sclerasterias mollis*
SMT			0.04					0.00	*Spatangus mathesoni*
SNA		-0.03	-0.02		0.16	-0.04		-0.06	*Pagrus auratus*
SND	0.00	0.06	-0.03	0.32	-0.01	0.08	0.08	0.00	*Deania calcea*
SNE			0.00			0.00	0.00	0.05	*Simenchelys parasitica*
SNI	0.00	-0.01	0.01		-0.02	0.00		0.00	*Macroramphosus scolopax*
SNO			0.00			0.02		0.03	*Sio nordenskjoldii*
SNR				0.02		0.01	0.05	0.01	*Deania histricosa*
SOC						0.00	0.00	0.00	Alcyonacea (Order)
SOL	0.00	0.00	0.01		0.00	0.00	0.00	0.00	Sole
SOM	0.00					0.03	0.00	0.00	*Somniosus rostratus*
SOP	0.04	0.00				0.05	0.00	-0.01	*Somniosus pacificus*
SOR		0.00	0.00			-0.12	0.04	-0.01	*Neocyttus rhomboidalis*
SOT		0.00	0.00	0.02		0.00	0.00	0.05	*Solaster torulatus*
SPA								0.00	*Sprattus antipodum*
SPD	-0.02	0.05	0.15	0.10	-0.13	-0.21	-0.03	-0.01	*Squalus acanthias*
SPE	0.00	0.06	-0.01	0.06	-0.30	-0.05	0.00	0.01	*Helicolenus* spp.
SPF		0.00			0.00			-0.01	*Pseudolabrus miles*
SPI	0.02	-0.03	-0.12	0.00	0.00	-0.02	0.00	-0.05	Spider crab
SPK			0.00		0.00	0.00		0.00	*Macrorhamphosodes uradoi*
SPL		0.00					0.00	0.00	*Scopelosaurus* sp.
SPN		0.00			0.00	0.00		0.00	Sea pen
SPO		0.00	-0.12	-0.04	-0.27	0.00		-0.03	*Mustelus lenticulatus*
SPP		0.00	0.00		0.02			0.00	*Callanthias* spp.
SPR					0.00	0.00		0.00	*Sprattus antipodum S. muelleri*
SPT		0.00	0.19		-0.01	0.00	0.00	0.02	*Spatangus multispinus*

[52] Includes the MPI codes OSD and DWD

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
SPZ	0.00	0.00	0.02		0.00	0.00		-0.05	*Genyagnus monopterygius*
SQA		0.00	0.00	0.04		0.04	0.06	0.07	*Squalus* spp.
SQI		-0.02			0.00		0.00	0.00	*Pristilepis oligolepis*
SQU	-0.02		0.02		-0.07	-0.10	-0.02	0.00	*Nototodarus sloanii & N. gouldi*
SQX	0.03	0.00	-0.07		0.03	0.04	-0.04	0.15	Squid
SRH			0.01		0.00	-0.01	0.00	0.11	*Hoplostethus mediterraneus*
SRI	0.00					0.02	0.00	0.08	*Scymnodon ringens*
SSC		-0.16	-0.06				0.00	0.02	*Leptomithrax australis*
SSH	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.16	*Gollum attenuatus*
SSI	0.02	0.25	0.03		-0.05	0.02	-0.03	0.06	*Argentina elongata*
SSK	-0.03	0.02	0.02	0.15	-0.21	0.00	0.04	0.03	*Dipturus innominatus*
SSM						-0.06		-0.01	*Alepocephalus antipodianus*
SSO	0.00	0.00				-0.14	0.03	-0.03	*Pseudocyttus maculatus*
SSP		0.00	0.00					0.00	*Pecten novaezelandiae*
STA	-0.03	0.08	-0.09	0.03	-0.26	-0.03	0.00	0.00	*Kathetostoma* spp.
STG		0.00	0.06		-0.01	0.00	0.00	-0.14	Stargazer
STN	0.00	0.09	-0.02		0.01			0.05	*Thunnus maccoyii*
STO						0.00	0.00	0.03	*Stomias* spp.
STP						0.00	0.00	0.00	*Stephanocyathus platypus*
STR		0.03	-0.01		0.03	0.00		0.01	Stingray
STU	-0.03	-0.07			0.03			0.14	*Allothunnus fallai*
SUA		0.00						0.00	*Suberites affinis*
SUH					0.00	0.00		0.01	*Schedophilus huttoni*
SUM	0.00					0.00	0.00	0.00	*Schedophilus maculatus*
SUN	0.00	-0.07	0.03		0.11	0.02		0.05	*Mola mola*
SUR		0.00	-0.08			0.00	0.00	0.02	*Evechinus chloroticus*
SUS						0.00	0.00	0.00	*Schedophilus* sp.
SVA						0.09	0.14	0.00	*Solenosmilia variabilis*
SWA	-0.02	0.08	-0.15		-0.03	-0.04	0.00	0.04	*Seriolella punctata*
SWO		0.00			0.08	-0.05		0.02	*Xiphias gladius*
SWR		0.00				-0.01	0.00	0.00	*Coris sandageri*
SYD			0.00					0.02	*Systellaspis debilis*
SYN			0.02		0.00	-0.02	0.00	0.03	*Synaphobranchidae*
TAL						0.00		0.00	*Talismania longifilis*
TAM		0.00	0.08			0.08	0.15	0.20	*Echinothuriidae & Phormosomatidae*[53]
TAR	0.00	0.16	-0.13	0.02	-0.16	0.00	0.00	0.07	*Nemadactylus macropterus & N.* sp. (king tarakihi)
TAS	0.00					0.00		0.00	*Taractes asper*
TAY		0.00	0.20		0.00	0.00		0.07	*Typhlonarke aysoni*
TET		0.00	0.00			0.00		0.00	*Tetragonurus cuvieri*
TEW		0.00	0.00					0.00	*Tewara cranwellae*
TFA			0.18					0.00	*Trichopeltarion fantasticum*
THO		0.00	0.00			0.00	0.00	0.00	*Thouarella* spp.
THR		-0.08		0.03	-0.02			0.17	*Alopias vulpinus*
TLD		0.00	0.00			0.00	0.00	0.00	*Tetilla leptoderma*
TLO			0.02			0.00	0.00	0.00	*Telesto* spp.
TOA	0.00	0.18	-0.02	0.09	-0.01	0.13	0.01	0.12	*Neophrynichthys* sp.
TOD	0.00	0.11	0.03	0.00	0.00	0.00		0.08	*Neophrynichthys latus*
TOP	-0.04	0.00	-0.02	0.04	0.00	0.02	0.00	0.09	*Ambophthalmos angustus*
TOR		0.08			0.00			0.21	*Thunnus orientalis*
TRA		0.00			-0.01	0.00		-0.01	Trachichthyidae (Family)
TRE		0.00			0.03			0.00	*Pseudocaranx georgianus*
TRS						-0.02		0.00	*Trachyscorpia eschmeyeri*
TRU		0.01	0.00	0.01	0.00			-0.02	*Latris lineata*
TSQ	0.00	0.00	0.00			0.05	0.00	0.05	*Todarodes filippovae*

[53] Includes the MPI codes PHM and ECT

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
TTA		0.00	0.06					0.00	*Typhlonarke tarakea*
TUB			0.00		0.00	0.00	0.00	0.00	*Tubbia tasmanica*
TUR		0.04			0.00			0.00	*Colistium nudipinnis*
TVI						0.00		0.04	*Trachonurus villosus*
UNI				0.12					Unidentified
URP		0.03	0.00			0.00	0.00	0.00	*Uroptychus* spp.
VCO		0.00				0.11	0.14	-0.02	*Antimora rostrata*
VIT						0.00	0.00	0.00	*Vitjazmaia latidactyla*
VKI		0.00						0.00	*Veprichlamys kiwaensis*
VNI			0.00					0.00	*Lucigadus nigromaculatus*
VOL		0.00	0.05	0.00		0.00	0.00	0.02	Volutidae (Family)
VSQ	0.00	0.00	0.00		0.00	0.06	0.00	0.21	*Histioteuthis* spp.
WAR	0.00	-0.01	0.00		-0.09	0.00	0.00	-0.15	*Seriolella brama*
WHE		0.00	-0.04	0.00		0.00	0.00	0.02	Whelk
WHR			0.00			-0.01	0.00	-0.06	*Trachyrincus longirostris*
WHX			0.02			0.06	0.00	0.17	*Trachyrincus aphyodes*
WIN								0.00	*Pteraclis velifera*
WIT	0.00	0.15	0.05	0.00	0.00	0.07	0.00	0.16	*Arnoglossus scapha*
WOE					0.00	0.00	-0.01	0.00	*Allocyttus verrucosus*
WPS		0.11			0.02	0.02		0.02	*Carcharodon carcharias*
WRA		0.00	0.00		0.00		0.00	0.03	*Dasyatis thetidis*
WSE		0.00			-0.01	0.00		0.00	Labridae (Family)
WSH		0.00						0.00	*Rhincodon typus*
WSQ	-0.01	0.12	0.08		0.00	0.12	0.20	0.03	*Onykia* spp.
WWA	-0.03	0.05	0.01	-0.05	0.00	0.01	0.06	0.08	*Seriolella caerulea*
YBF		0.00	0.00		0.00			0.03	*Rhombosolea leporina*
YBO	0.00	0.00	0.15		0.00	0.00		0.10	*Pentaceros decacanthus*
YBP		0.00							*Acanthistius cinctus*
YCO	0.00	0.12	0.00		0.00	0.00		0.00	*Parapercis gilliesi*
YEM		-0.02			0.00				*Aldrichetta forsteri*
YFN		-0.01			0.00			0.00	*Thunnus albacares*
YSG		0.00	0.01		0.00			0.00	*Pterygotrigla pauli*
YSP			0.00			0.00			*Yaldwynopsis spinimana*
ZAS						0.00	0.00	0.00	*Zameus squamulosus*
ZDO			0.00					0.00	*Zenion leptolepis*
ZEL			0.00			0.00		0.00	*Zu elongatus*
ZOR		0.00	0.06			0.00	0.00	0.13	*Zoroaster* spp.

7.5 REFERENCES

Alverson, D L; Freeberg, M H; Murawski, S A; Pope, J G (1994) A global assessment of fisheries bycatch and discards. FAO Technical Paper No. 339. Rome. 233 p.

Anderson, O F (2004a) Fish discards and non-target fish catch in the fisheries for southern blue whiting and oreos. New Zealand Fisheries Assessment Report 2004/9. 40 p.

Anderson, O F (2004b) Fish discards and non-target fish catch in the trawl fisheries for arrow squid, jack mackerel, and scampi in New Zealand waters. New Zealand Fisheries Assessment Report 2004/10. 61 p.

Anderson, O F (2007) Fish discards and non-target fish catch in the New Zealand jack mackerel trawl fishery, 2001–02 to 2004–05. New Zealand Aquatic Environment and Biodiversity Report 8. 36 p.

Anderson, O F (2008) Fish and invertebrate bycatch and discards in ling longline fisheries, 1998–2006. New Zealand Aquatic Environment and Biodiversity Report 23. 43 p.

Anderson, O F (2009a) Fish discards and non-target fish catch in the New Zealand orange roughy trawl fishery, 1999–2000 to 2004–05. New Zealand Aquatic Environment and Biodiversity Report 39. 40 p.

Anderson, O F (2009b) Fish and invertebrate bycatch and discards in southern blue whiting fisheries, 2002–07. New Zealand Aquatic Environment and Biodiversity Report 43. 42 p.

Anderson, O F (2011) Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990–91 until 2008–09. New Zealand Aquatic Environment and Biodiversity Report 67. 60 p.

Anderson, O F (2012) Fish and invertebrate bycatch and discards in New Zealand scampi fisheries from 1990–91 until 2009–10. New Zealand Aquatic Environment and Biodiversity Report 100. 65 p.

Anderson, O F (2013a) Fish and invertebrate bycatch and discards in New Zealand arrow squid fisheries from 1990–91 until 2010–11. New Zealand Aquatic Environment and Biodiversity Report 112. 62 p.

Anderson, O F (2013b) Fish and invertebrate bycatch in New Zealand deepwater fisheries from 1990–91 until 2010–11. New Zealand Aquatic Environment and Biodiversity Report 113. 57 p.

Anderson, O.F. (In Press). Fish and invertebrate bycatch and discards in New Zealand ling longline fisheries from 1992–93 until 2011–12. New Zealand Aquatic Environment and Biodiversity Report No. XX. XX p.

Anderson, O F; Clark, M R (2003) Analysis of bycatch in the fishery for orange roughy, *Hoplostethus atlanticus*, on the South Tasman Rise. Marine and Freshwater Research 54: 643–652.

Anderson, O F; Clark, M R; Gilbert, D J (2000) Bycatch and discards in trawl fisheries for jack mackerel and arrow squid, and in the longline fishery for ling, in New Zealand waters. NIWA Technical Report 74. 44 p.

Anderson, O F; Gilbert, D J; Clark, M R (2001) Fish discards and non-target catch in the trawl fisheries for orange roughy and hoki in New Zealand waters for the fishing years 1990–91 to 1998–99. New Zealand Fisheries Assessment Report 2001/16. 57 p.

Anderson, O F; Smith, M H (2005) Fish discards and non-target fish catch in the New Zealand hoki trawl fishery, 1999–2000 to 2002–03. New Zealand Fisheries Assessment Report 2005/3. 37 p.

Ayers, D; Francis, M P; Griggs, L H; Baird, S J (2004) Fish bycatch in New Zealand tuna longline fisheries, 2000–01 and 2001–02. New Zealand Fisheries Assessment Report 2004/46. 47 p.

Ballara, S L; Anderson, O F (2009) Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report 38. 102 p.

Ballara, S L; Anderson, O F (in prep.) Fish and invertebrate bycatch and discards in New Zealand hoki, hake and ling trawl fisheries from 1992–93 until 2012–13. New Zealand Aquatic Environment and Biodiversity Report XX. XX p.

Ballara, S L; O'Driscoll, R L; Anderson, O F (2010) Fish discards and non-target fish catch in the trawl fishery for hoki, hake, and ling in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report 48. 100 p.

Bellido, J M; Santos, B M; Pennino, G M; Valeiras, X; Pierce, G J (2011) Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management? Hydrobiologia, 670. 317–333.

Borges, L; Zuur, A F; Rogana, E; Officer, R (2005) Choosing the best sampling unit and auxiliary variable for discards estimations. Fisheries Research, 75: 29–39.

Bradford, E (2002) Estimation of the variance of mean catch rates and total catches of non-target species in New Zealand fisheries. New Zealand Fisheries Assessment Report 2002/54. 60 p.

Casini, M; Vitale, F; Cardinale, M (2003) Trends in biomass and changes in spatial distribution of demersal fish species in Kattegatt and Skagerrak between 1981 and 2003. ICES CM 2003/Q:14

Clark, M R; Anderson, O F; Gilbert, D J (2000) Discards in trawl fisheries for southern blue whiting, orange roughy, hoki, and oreos in New Zealand waters. NIWA Technical Report 71. 73 p.

Davies, R W D; Cripps, S J; Nickson, A; Porter, G (2009) Defining and estimating global marine fisheries bycatch. Marine Policy 33: 661–672.

Fernandes, P G; Coull, K; Davis, C; Clark, P; Catarino, R; Bailey, N; Fryer, R; Pout, A (2011) Observations of discards in the Scottish mixed demersal trawl fishery. ICES Journal of Marine Science, 68: 1734–1742.

Francis, M P; Griggs, L H; Baird, S J (2004) Fish bycatch in New Zealand tuna longline fisheries, 1998–99 to 1999–2000. New Zealand Fisheries Assessment Report 2004/22. 62 p.

Francis, M P; Griggs, L H; Baird, S J; Murray, T E; Dean, H A (1999a) Fish bycatch in New Zealand tuna longline fisheries. NIWA Technical Report 55. 70 p.

Francis, M P; Griggs, L H; Baird, S J; Murray, T E; Dean, H A (1999b) Fish bycatch in New Zealand tuna longline fisheries, 1988–89 to 1997–98. NIWA Technical Report 76. 79 p.

Griggs, L H; Baird, S J (2013) Fish bycatch in New Zealand tuna longline fisheries in 2006–07 to 2009–10. New Zealand Fisheries Assessment Report 2013/13. 73 p.

Griggs, L H; Baird, S J; Francis, M P (2007) Fish bycatch in New Zealand tuna longline fisheries, 2002–03 to 2004–05. New Zealand Fisheries Assessment Report 2007/18. 58 p.

Griggs, L H; Baird, S J; Francis, M P (2008) Fish bycatch in New Zealand tuna longline fisheries in 2005–06. New Zealand Fisheries Assessment Report 2008/27. 47 p.

Griggs, L; Doonan, I; McGregor, V; McKenzie, A (2014) Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2012–13 fishing year. New Zealand Fisheries Assessment Report 2014/30. 50 p. http://fs.fish.govt.nz/Page.aspx?pk=113&dk=23652

Kelleher, K (2005) Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper No. 470. FAO, Rome: 131 p.

Ministry for Primary Industries (2013a) Fisheries Assessment Plenary, May 2013: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1357 p.

Ministry for Primary Industries (2013b) Jack Mackerel Chapter, National Fisheries Plan for deepwater and middle depth fisheries. 63 p.

Pope, J G; MacDonald, D S; Daan, N; Reynolds, J D; Jennings, S (2000) Gauging the impact of fishing mortality on non-target species. ICES Journal of Marine Science 57: 689–696.

Ramm, K (2012) Conservation Services Programme Observer Report: 1 July 2010 to 30 June 2011. FINAL REPORT. Conservation Services Programme, Department of Conservation, November 2012.

Saila, S (1983) Importance and assessment of discards in commercial fisheries. FAO Circular No. 765. Rome. 62 p.

Starr, P J; Kendrick, T H (2012) GUR 3 Fishery Characterisation and CPUE Report. SINS-WG-2012-14v2. 72 p. (Unpublished document held by the Ministry for Primary Industries, Wellington.)

Starr, P J; Kendrick, T H (2013) ELE 3 & 5 Fishery Characterisation and CPUE. New Zealand Fisheries Assessment Report 2013/38. 95 p.

Starr, P J; Kendrick, T H; Bentley, N (2010a) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SCH 3. Document 2010/07-v2, 62 p. (Unpublished document held by the Ministry for Primary Industries, Wellington.) (http://cs.fish.govt.nz/forums/thread/3874.aspx)

Starr, P J; Kendrick, T H; Bentley, N (2010b) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SCH 5. Document 2010/08-v2, 65 p. (Unpublished document held by the Ministry for Primary Industries, Wellington.) (http://cs.fish.govt.nz/forums/thread/3875.aspx)

Starr, P J; Kendrick, T H; Bentley, N (2010c) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SCH 7 and SCH 8. Document 2010/09-v2, 149 p. (Unpublished document held by the Ministry for Primary Industries,Wellington.) (http://cs.fish.govt.nz/forums/thread/3876.aspx)

Thompson, S K (1992) Sampling. John Wiley & Sons, Inc., New York. 343 p.

WCPFC (2013) Annual report to the Commission, Part 1: Information on fisheries, research, and statistics, New Zealand. Western and Central Pacific Fisheries Commission Scientific Committee Ninth Regular Session, 6-14 August 2013, Pohnpei, Federated States of Micronesia, WCPFC-SC9-AR/CCM-15. 29 p.http://www.wcpfc.int/meetings/9th-regular-session-scientific-committee.

8 CHONDRICHTHYANS (SHARKS, RAYS AND CHIMAERAS)

Scope of chapter	This chapter outlines the relevant biology of New Zealand chondrichthyans, the nature of any fishing interactions, the management approach, and trends in key indicators of fishing effects. Note that this chapter covers some protected shark species.
Area	All of the New Zealand EEZ and Territorial Sea.
Focal localities	This differs depending upon the species or fishery examined
Key issues	Sustainability of fisheries extractions
Emerging issues	Risk assessment of fisheries extractions
MPI Research (current)	SEA2011-16 and SEA2012-11 Mako shark tagging, SEA2012-10 Development of commercial catch histories 1931–82, SEA2012-17 NPOA sharks extension work, ZBD2011-01 Evaluation of ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in NZ waters, HMS2010-03 Commercial catch sampling programme for highly migratory elasmobranchs.
Other Govt Research (current)	DOC CSP Research: MIT2013-04 Basking shark mitigation: detection and avoidance. MIT2011-01 Protected rays – mitigate captures and assess survival of live-released animals. MBIE project (C01X0905): Conservation of New Zealand's threatened iconic marine megafauna.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
Related issues/chapters	See the Non-protected species (fish and invertebrates) bycatch chapter.

Note: This chapter was new for the AEBAR 2013.

8.1 CONTEXT

Chondrichthyans (cartilaginous fishes) comprise all fish species (except lampreys and hagfish) that lack true bone in their skeletons, specifically sharks, rays, skates and chimaeras. In New Zealand, the impacts of fishing on chondrichthyans are managed under the Fisheries Act (1996), with eleven species subject to the Quota Management System (QMS) and two species prohibited as target species. The management policy framework is contained in Fisheries Plans developed for Deepwater, Highly Migratory, and Inshore fisheries (see Chapter 1 for fuller descriptions and web links). Seven chondrichthyans are also totally protected under the Wildlife Act (1953).

New Zealand has international obligations to collaborate with other countries in the assessment and management of shared and migratory chondrichthyan stocks. New Zealand participates in a number of Regional Fisheries Management Organisations that have some responsibility for chondrichthyans, including Western and Central Pacific Fisheries Commission (which manages tuna fisheries and the associated species), Commission for the Conservation of Southern Bluefin Tuna (southern bluefin tuna), Commission for the Conservation of Antarctic Marine Living Resources (toothfish), and the South Pacific Regional Fisheries Management Organisation (multiple non-Highly Migratory Species). New Zealand is also a signatory to conventions that play a role in the management of some species, including the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the Convention on the Conservation of Migratory Species of Wild Animals.

To address global concerns about the management of chondrichthyans, the Food and Agriculture Organisation of the United Nations (FAO) developed an International Plan of Action for the Conservation and Management of Sharks (IPOA)[54]. The IPOA builds upon the FAO Code of Conduct for Responsible Fisheries and was endorsed by the FAO Council in June 1999 and subsequently adopted by the November 1999 FAO Conference. The overarching goal of the IPOA is: 'to ensure the conservation and management of sharks and their longterm sustainable use.' To achieve this goal the IPOA suggests that each member state of FAO

[54] ftp://ftp.fao.org/docrep/fao/006/x3170e/X3170E00.pdf

that regularly catches sharks, either as target or incidental catch, should develop a National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks).

New Zealand developed an NPOA–Sharks that came into effect in October 2008 (Ministry of Fisheries 2008). It contains a suite of planned actions in the areas of research, compliance and management that aim to fulfil the IPOA's goal. The NPOA–Sharks is essentially a five-year strategic plan that provides an overall framework for the management of all impacts on chondrichthyans[55]. The impacts of fishing are likely to constitute the greatest threats to the sustainability of sharks and consequently they form the primary focus of New Zealand's NPOA 2008. However, it is anticipated that non-fishing related impacts on sharks, such as pollution, coastal development, land use change and climate change will be incorporated into later versions (Ministry of Fisheries 2008).

The NPOA-Sharks applies to all chondrichthyans that are found within New Zealand's Exclusive Economic Zone (EEZ) and Territorial Sea (New Zealand fisheries waters), migratory species that frequent New Zealand fisheries waters, and species taken by New Zealand-flagged vessels fishing on the High Seas (including the Ross Sea, Antarctica). Appendix 8.1 provides a list of all 117 known New Zealand chondrichthyans, along with their management class and IUCN and Department of Conservation threat classes.

8.2 BIOLOGY

The population dynamics of chondrichthyans differ markedly from those of bony fishes. Chondrichthyans have a mammal-like reproductive strategy of producing a small number of well-developed young, rather than spawning large numbers of undeveloped eggs as do most bony fishes. Chondrichthyans either lay large yolky eggs on the seabed or give birth to live young, but in both reproductive modes the number of young produced annually is usually in single digits or in the low tens. A few species may produce more than 100 young per litter (e.g. blue shark has up to 135 young (Last & Stevens 2009)) but even in these more fecund species, large litter sizes are exceptional and the average number of young per female is much lower (30–40 in the blue shark (Last & Stevens 2009)). Gestation periods and reproductive cycles last 10 months to two years in many species, and may be as high as three years (e.g. school shark, mako shark (Mollet et al 2000, Walker 2005)). Fecundity may increase with the size of females (e.g. rig and school shark (Francis & Mace 1980, Walker 2005)) so if human activities reduce the average size of females in a population (as often happens in fisheries) the reproductive output may decline faster than the rate of population decline. These characteristics mean that chondrichthyans have a much closer, potentially almost linear, relationship between population size and recruitment. They also have limited potential for density-dependent compensatory mechanisms that might boost reproductive output at low population sizes.

Many cartilaginous fishes are also long-lived and slow growing, further reducing their capacity for recovering from population declines. Many species have ages at maturity greater than 10 years and longevities in excess of 20 years, although some are faster growing and are therefore more productive (e.g. rig (Francis & Ó Maolagáin 2000)). The combination of low reproductive rate and low growth rate makes chondrichthyans particularly vulnerable to overfishing (Camhi et al 1998, Smith et al 1998, Dulvy et al 2003, Pikitch et al 2008, Simpfendorfer & Kyne 2009).

Six feeding studies have been carried out in the last few years on a suite of middle depth to deepwater chondrichthyans, mainly using stomach content data collected during Chatham Rise trawl surveys (Jones 2008, 2009, Dunn et al 2010a, 2010b, Forman & Dunn 2012, Dunn et al 2013). The diets of blue, porbeagle and mako sharks have been analysed using samples collected by observers on tuna longline vessels (Horn et al 2013). Fish and squid were the primary prey of shark species, with chimaeras having a diet dominated by benthic invertebrates, and skates also feeding on benthic and natant invertebrates. There was evidence of both depth- and diet-related niche separation. In one study, DNA testing was used to identify stomach contents. The importance of discards in the diet of some sharks and rays was highlighted. In a seventh study, juvenile rig were found to feed mainly on benthic crustaceans such as mud

[55] In the IPOA and in the NPOA–Sharks, 'sharks' are defined to include all chondrichthyans, viz. sharks, rays and chimaeras. However, in this chapter, we use the terms chondrichthyans, sharks, rays, chimaeras in their strict sense to avoid confusion. Skates are a type of ray and are grouped with rays.

crabs and snapping shrimps in estuaries around New Zealand (Getzlaff 2012).

8.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

There are numerous examples worldwide of chondrichthyan stocks collapsing under fishing pressure, and little attention has been focussed on their management. This situation reflects the generally low importance of chondrichthyans in terms of quantity and value in commercial catches, and the consequent low research and management priority accorded to them. However the rapid increase in demand for, and value of, shark fins over the last two decades has resulted in a rapid increase in chondrichthyan fishing mortality throughout the world, and many chondrichthyan populations are now believed to be severely depleted. There is also widespread public opposition to shark 'finning', in which only the fins are kept and the rest of the shark is discarded at sea, because of concerns about sustainability, wastage, and finning of live sharks. (Live shark finning is an offence under the Animal Welfare Act 1999.)

Chondrichthyans are caught by most fishing methods, although trawling, netting and lining are the most important. Chondrichthyans are caught in nearly all parts of the world, ranging from tropical to arctic/antarctic waters, and from estuaries and shallow coastal waters to the deepest areas fished. Historically, most chondrichthyan catches worldwide have been taken as bycatch in fisheries for other target species. However, the increased value of shark fins has driven a move towards target fishing for some shark species elsewhere in the world, and increased utilisation of incidentally caught sharks. Consequently reported global landings of chondrichthyans increased steadily up to almost 900 000 t in the early 2000s but have been declining since then (Worm et al 2013). However unreported catches are undoubtedly substantial so the true extent of chondrichthyan catches remains unclear (Bonfil 1994, Camhi et al 1998, Clarke et al 2006, Worm et al 2013). Furthermore, the fate of discarded chondrichthyans has rarely been quantified: measures of mortality rates of chondrichthyans at the time they are hauled to a fishing vessel are available for some species (Francis et al 1999a, Campana et al 2009, Griggs & Baird 2013), but estimates of subsequent survival of live releases are rare (Moyes et al 2006, Campana et al 2009, Musyl et al 2011, Hutinchision et al 2013).

Despite these uncertainties, there is ample evidence that many chondrichthyan populations are now over-fished and that fishing effort is still expanding in habitats containing some of the most vulnerable species, especially deepwater chondrichthyans (Kyne & Simpfendorfer 2007, Simpfendorfer & Kyne 2009, Rice & Harley 2012a, 2012b). Management measures have been implemented by many countries, particularly for targeted species, and Regional Fisheries Management Organisations are paying greater attention to the need to manage species that occur in international waters or straddle the national waters of multiple countries. Efforts are also focusing on reducing shark finning, particularly in fisheries catching pelagic sharks, by requiring fins to be attached to sharks at the point of landing, or to comprise no more than 5% of the landing by weight. However it is not clear that this requirement has been effective in reducing catches (Clarke et al 2012, Worm et al 2013).

8.4 STATE OF KNOWLEDGE IN NEW ZEALAND

A total of 117 chondrichthyans are known from New Zealand waters (including the Ross Sea), however that number is expected to grow slightly as taxonomic studies continue on deepwater species. Of these species, 12 are chimaeras, 30 are skates and rays, and 75 are sharks. Many New Zealand species also occur elsewhere in the world (some have worldwide distributions) but a high percentage (30%) are endemic to New Zealand. New Zealand's chondrichthyan fauna is small compared with that in Australia, which has more than 322 species (Last & Stevens 2009), but that partly reflects New Zealand's lack of tropical environments. The high percentage of endemic species makes New Zealand's fauna unique and highly distinctive.

No complete risk assessment has been conducted for New Zealand chondrichthyans, but some species have been included in risk assessments for other species (e.g. Marine Stewardship Council certification of hoki fisheries). The largest threat to chondrichthyan populations is probably from fishing activities, although other potential impacts include underwater noise, dredging, sonar surveys, electromagnetic fields generated by power stations and undersea cables, loss of habitat, eutrophication and sedimentation, entrapment by aquaculture facilities, and shark ecotourism (Francis & Lyon 2013). More than 70 of New Zealand's chondrichthyan species are caught by fishers (Ministry of Fisheries 2008). Eleven chondrichthyans are managed under the QMS (Ministry for Primary Industries 2012a, 2013), seven are fully protected (Francis & Lyon 2012), two cannot be targeted, and the remainder are Non-QMS species (Appendix 8.1). Due to reporting requirements commercial landings of chondrichthyans are relatively well known, but less is known about recreational and customary catches.

A nationwide survey from 1 October 2011 to 30 September 2012 provides the most reliable estimates of recreational chondrichthyan catches (Table 8.1) (Wynne-Jones et al in press). The majority of the recreational catch is from inshore QMS species; mako is the only shark listed that is not normally considered an inshore species. 'Stingray' is likely to include more than one species and 'sand shark' is likely to refer mainly to rig or school shark. Mako sharks are also targeted/bycatch in the gamefish charter boat fishery, so estimates for mako are potentially underestimates as the survey was not designed to sample gamefishers on charter boats. Estimates in tonnes are only available for rig and spiny dogfish and these constitute 4.0% and 0.4% percent respectively of the reported commercial landings in the same year for those species. All subsequent data reported in this chapter are from the commercial fishery.

Commercial catches of chondrichthyan species during the eight-year period 2004−05 to 2011−12 are shown in Table 8.2 and Figure 8.1. Spiny dogfish produced by far the greatest catches, followed by school shark. Dark ghost shark, rough skate, rig and elephantfish formed a second tier of species, and blue shark, pale ghost shark, smooth skate and seal shark formed a third tier; the remaining species had relatively low catches (less than 270 t per year on average). Unspecified sharks and unspecified deepwater sharks were both important categories, indicating that fishers were not accurately recording all catches to species level. Reported discards were significant for spiny dogfish, seal shark, carpet shark, shovelnose dogfish and other deepwater and unspecified sharks (Figure 8.1). Live releases of seven specified chondrichthyans are permitted under Schedule 6 of the Fisheries Act, and from 2006−07 such releases were not counted against quota (Table 8.3). Spiny dogfish may also be discarded dead. Live releases were negligible compared with landings and discards, being greatest for smooth skate, rough skate and blue shark (100−108 t per species between 2006−07 and 2011−12). However, live releases may have been under-reported by fishers. The survival rate of discarded and released sharks is unknown, and probably varies enormously with species, fishing method, handling by fishers, and other factors.

Table 8.1: Recreational harvest estimates for New Zealand chondrichthyan species for the 2011–2012 fishing year. Mean fish weights are only available for some species, otherwise only the counts are shown. Mgmt class = Management class, QMS is shown, all others are Non-QMS and non-protected species; CV = Coefficient of variation of the estimate to the left. Reproduced in part from Wynne-Jones et al (in press).

Species	Mgmt class	Fishers (n)	Events (n)	Harvest (n)	CV	Mean Weight (kg)	Harvest (tonnes)	CV
Rig	QMS	159	241	47 718	0.14	1.09	52.05	0.14
School Shark	QMS	95	160	30 555	0.17	-	-	-
Spiny Dogfish Shark	QMS	97	119	22 200	0.19	1.02	22.60	0.19
Stingray		46	59	11 053	0.40	-	-	-
Elephant Fish	QMS	24	47	6 198	0.34	-	-	-
Sand Shark		10	18	3 719	0.54	-	-	-
Hammerhead Shark		10	12	1 429	0.34	-	-	-
Bronze Whaler Shark		5	5	570	0.52	-	-	-
Mako Shark	QMS	5	6	529	0.51	-	-	-
Carpet Shark		3	5	452	0.67	-	-	-

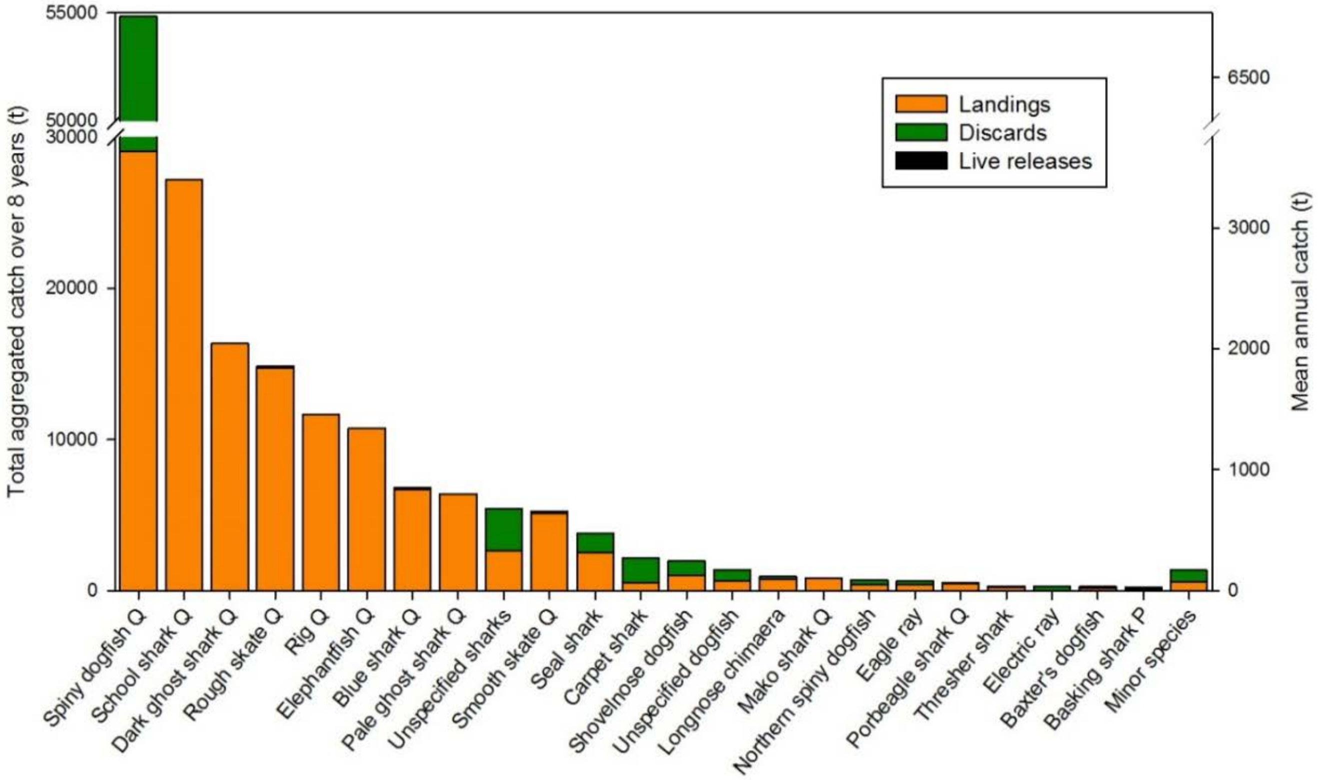


Figure 8.1: Reported total landings, discards and live releases for chondrichthyan species aggregated across 2004–05 to 2011–12. The average annual catches are shown on the right axis. 'Q' indicates QMS species, 'P' indicates protected species. Basking shark was protected in 2010. Source: Ministry for Primary Industries catch-effort database.

Table 8.2: Reported total catches (tonnes, including discards and live releases) for chondrichthyan species from 2004–05 to 2011–12, arranged in descending order of total catch. Only species with more than 10 t of aggregated catch are included. The management class is also shown for Non-QMS species. Source: Ministry for Primary Industries catch-effort database. (NB: Catches of QMS species differ from landings in Table 8.3 because they include discards and releases, and came from a different source.)

Species	Mgmt class	Code	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	Total
Spiny dogfish	QMS	SPD	7588	8272	7577	6443	6364	6626	6250	5704	54825
School shark	QMS	SCH	3508	3138	3269	3340	3608	3389	3618	3315	27185
Dark ghost shark	QMS	GSH	2145	1734	1992	1936	2041	2070	2326	2095	16339
Rough skate	QMS	RSK	2163	1762	1820	1629	2005	1961	1937	1553	14829
Rig	QMS	SPO	1527	1390	1547	1530	1330	1439	1457	1445	11663
Elephantfish	QMS	ELE	1186	1266	1260	1443	1398	1386	1412	1382	10732
Blue shark	QMS	BWS	829	856	954	774	825	746	804	1054	6843
Pale ghost shark	QMS	GSP	978	743	807	905	859	799	632	695	6418
Unspecified sharks		OSD	558	727	810	772	650	609	597	697	5419
Smooth skate	QMS	SSK	677	730	714	705	600	581	649	580	5235
Seal shark		BSH	690	631	504	550	428	386	325	277	3791
Carpet shark		CAR	130	187	259	288	291	296	349	336	2137
Shovelnose dogfish		SND	262	321	242	304	307	192	186	145	1958
Unspecified dogfish		DWD	245	203	128	167	220	234	98	78	1373
Longnose spookfish		LCH	151	124	116	109	108	131	97	101	937
Mako shark	QMS	MAK	175	94	91	82	82	76	95	160	854
Northern spiny dogfish		NSD	46	80	90	98	88	88	123	102	714
Eagle ray		EGR	55	52	79	92	95	81	105	108	666
Porbeagle shark	QMS	POS	65	62	64	46	65	68	77	60	508
Thresher shark		THR	46	38	45	46	37	30	38	38	317
Electric ray		ERA	23	27	32	48	40	30	37	38	274
Baxter's dogfish		ETB	12	22	46	27	35	46	47	30	264
Basking shark	Protected	BSK	93	26	29	37	11	22	7	0	226
Bronze whaler shark		BWH	17	17	22	21	17	18	14	16	142
Long-tailed stingray		WRA	17	15	25	19	13	10	9	12	119
Short-tailed stingray		BRA	18	11	13	15	12	11	16	13	109
Broadnose sevengill shark		SEV	4	4	10	16	19	17	18	19	106
Leafscale gulper shark		CSQ	0	3	2	33	22	20	14	9	103
Lucifer's dogfish		ETL	3	3	10	0	18	26	17	25	103
Unspecified stingray		STR	5	12	18	13	9	8	20	9	94
Hammerhead shark	Non-target	HHS	8	9	7	13	17	8	15	13	89
Deepwater spiny skate		DSK	7	3	6	14	17	11	13	0	69
Slender smoothhound		SSH	0	11	5	1	6	5	27	10	65
Giant chimaera		CHG	3	1	6	6	14	1	6	19	56
Prickly dogfish		PDG	2	0	12	11	9	6	7	4	51
Longnose deepsea skate		PSK	0	1	10	15	7	7	2	1	41
Unspecified rays		RAY	4	1	1	4	5	4	1	3	22
Unspecified chimaeras		CHI	0	0	0	1	2	2	11	1	17
Owston's dogfish		CYO	1	2	3	2	2	1	3	3	16
Spinetail devilray	Protected	MJA	1	0	5	2	6	1	0	0	15
Unspecified skates		OSK	1	3	3	2	2	2	1	2	14
Numbfish		BER	2	0	0	0	5	1	3	2	13
Softnose skate		LSK	0	5	3	0	0	2	1	1	12
Largespine velvet dogfish		SCM	0	1	2	3	1	2	2	0	11
Unspecified catshark		APR	0	0	0	0	8	2	0	1	11

Table 8.3: TACCs and 2011–12 landings (tonnes) of the eleven chondrichthyans managed under the QMS. Also shown are the date of entry of each species into the QMS, and date of addition to Schedule 6 of the Fisheries Act that allows release of fish into the sea. Source: Monthly Harvest Returns (Ministry for Primary Industries 2012a, 2013). (NB: Landings differ from the catches in Table 8.2 because the latter include discards and releases, and came from a different source.)

Species	Code	TACC (tonnes)	2011-12 landings	Entry into QMS	Addition to Schedule 6
Spiny dogfish	SPD	12660	5864	2004	2004
School shark	SCH	3436	3276	1986	2013
Dark ghost shark	GSH	3012	2241	1998	
Rough skate	RSK	1986	1563	2003	2003
Elephantfish	ELE	1283	1377	1986	
Rig	SPO	1941	1305	1986	2012
Blue shark	BWS	1860	1006	2004	2004
Pale ghost shark	GSP	1780	659	1999	
Smooth skate	SSK	849	544	2003	2003
Mako shark	MAK	200	101	2004	2004
Porbeagle shark	POS	110	55	2004	2004

8.4.1 QMS SPECIES

The eleven chondrichthyans managed under the QMS are shown in Table 8.3 with their Total Allowable Commercial Catches (TACCs) and 2011–12 landings. Landings of all but one species (elephantfish) were below the TACCs.

QMS chondrichthyans are treated in detail in MPI's annual Fisheries Assessment Plenary reports (Ministry for Primary Industries 2012a, 2013) and that material is not repeated here. Quantitative stock assessments have been attempted for only three chondrichthyan stocks (rig in SPO 3 and SPO 7, and elephantfish in ELE 3) but only the assessment for SPO 7 was accepted and adopted by the MPI Southern Inshore Working Group. The status of other stocks has been estimated from trends in standardised CPUE and trawl surveys.

A summary of the status of the stocks of QMS chondrichthyans is given in Appendix 8.2. Stock status has been estimated for seven of the 11 QMS chondrichthyans, and 26 of the 45 stocks. None of the stocks was considered to be below the 'hard limit' reference point, two stocks (SPO 7, POS 1) were considered about as likely as not (40–60%) to be below the 'soft limit' or other target reference point, and three stocks (POS 1, SCH 5 and 7) were considered to be in an 'overfishing' state; the remainder of the stocks were considered to be in a favourable state.

8.4.2 PROTECTED SPECIES

Seven chondrichthyans are currently protected in New Zealand fisheries waters: white shark (also known as white pointer shark) was protected in 2007; spinetail devilray, manta ray, whale shark, deepwater nurse shark and basking shark in 2010; and oceanic whitetip shark in 2013.

Under-reporting of protected species by commercial fishers introduces a major bias into estimates of fishery interactions (Francis & Lyon 2012), but good observer coverage can go a long way to overcoming these biases. Observer coverage has been reasonably good over the last decade or more in some large valuable fisheries (e.g. trawl fisheries for hoki and orange roughy), and on chartered foreign fishing vessels (e.g. in the tuna longline fishery). Trawl fisheries around southern New Zealand and tuna purse seine fisheries in northern New Zealand receive reasonable coverage, providing good information on captures of basking sharks, white sharks and spinetail devilrays. However, observer coverage has not always been representative of the spatial and temporal distribution of these fisheries. Inshore fisheries, notably set net, bottom longline, and trawl fisheries, have received only sparse observer coverage. These fisheries may have unobserved and unrecorded mortality of some protected species, especially basking shark, white shark and deepwater nurse shark.

BASKING SHARK

Basking sharks are frequently taken as bycatch around southern New Zealand (Francis & Lyon 2012). The main capture locations are the east coast South Island off Banks Peninsula, the west coast South Island between Westport and Hokitika, Puysegur, the shelf edge south and east of Stewart Island and the Snares Islands, and around the Auckland Islands. Basking sharks were mainly caught in FMAs 3, 5, 6 and 7. Captures (and sightings) of basking sharks also occurred around North Island but were relatively uncommon (Francis & Duffy 2002, Francis & Sutton 2012).

Most basking shark records came from trawl fisheries. The sharks were caught mainly by vessels targeting barracouta and hoki off east coast South Island, hoki off west coast South Island, and arrow squid off Southland-Auckland Island. Basking sharks are also caught in set nets but were rarely reported by fishers, and the observer coverage of this fleet has been low, so the set net bycatch cannot be quantified. Basking sharks are rarely entangled in surface longlines (Francis & Duffy 2002).

Most additional commercial records came from the early 2000s, but reporting rates appeared to be very low before 2000 (Francis & Lyon 2012). Francis & Sutton (2012) found a highly significant association between the numbers of basking sharks caught and vessel nationality in each of the three main fishery areas. This was due to relatively large numbers of sharks being caught by Japanese vessels in the late 1980s and early 1990s. Other operational fleet variables and environmental variables examined were not correlated with shark catch rates. Reasons for the high catch rates by Japanese trawlers are unknown, but may relate to targeting of the sharks for their liver oil, or a high abundance of sharks in the late 1980s and early 1990s (Francis & Sutton 2012).

Annual catch weights reported by commercial fishers ranged from 3 t to 150 t per year. Catch weights before 1999–2000 were undoubtedly under-reported. Few sharks were returned to the sea alive, and even fewer were likely to have survived their release.

WHITE SHARK

White shark captures were reported from throughout mainland New Zealand and as far south as the Auckland Islands, but not from around the other outlying islands (Francis & Lyon 2012). Regions with multiple captures included the west coast South Island off Hokitika, the southern edge of the Stewart–Snares Shelf, and the Auckland Islands Shelf. White sharks were mainly caught in FMAs 1, 5, 6 and 7.

Most white shark records came from trawl and set net fisheries with few captures reported from surface and bottom longlines. Observer coverage of the set net and bottom longline fleet has been low, so the bycatch in these fisheries is likely to have been under-estimated.

Three white sharks observed on surface longlines were recorded as struck off the line or lost. One white shark observed caught in a set net in 2009 was retained, whereas another shark was released alive. The life status of sharks observed caught on bottom longlines and in trawls was never recorded.

A maximum of 6.3 t was reported landed in 1990, but catches reported in other years have been low (and often zero). Catches of white sharks are undoubtedly under-reported.

WHALE SHARK

No captures of whale sharks have been reported by fishers or observers in New Zealand waters (Francis & Lyon 2012). However, a single individual was caught by a coastal trawler off South Canterbury in the late 1970s (as communicated to Duffy in Duffy 2005). This is exceptional, as whale sharks are typically only seen in northeastern North Island waters during summer (Duffy 2002).

DEEPWATER NURSE SHARK (SMALLTOOTH SANDTIGER SHARK)

Deepwater nurse sharks have been reported frequently by fishers and observers from along the edge of the continental shelf between Otago Peninsula and south of the Snares Islands (Francis & Lyon 2012). Clusters of records are also available from the Chatham Islands, and off Banks Peninsula and Farewell Spit. However, the southern limit of the known distribution of deepwater nurse sharks in New Zealand is a line from Cape Kidnappers in Hawke Bay to Cape Egmont. Given that most of the records are from south of that range, and that many ODO weights were implausibly small, most records of this species are erroneous, probably owing to use of an incorrect species code. The only plausible commercial and observer database records of deepwater nurse shark captures are three from FMA 2 and one from the Louisville Seamount Chain (Francis & Lyon 2012).

There are other published records of deepwater nurse sharks being caught in set nets off New Plymouth (Stewart 1997, Fergusson et al 2008), trawl in Hawke Bay, and by the NIWA research trawl vessel Tangaroa on the Norfolk Ridge (Garrick 1974, Stewart 1997, Fergusson et al 2008), confirming that the species is occasionally caught in northern waters. Duffy (2005) cited anecdotal information that deepwater nurse sharks were "not uncommon" bycatch in a set net fishery operating around White Island and Volkner Rocks in the eastern Bay of Plenty, but noted that this fishery had ceased. Duffy (2005) and Fergusson et al (2008) also reported the capture of deepwater nurse sharks from the same location for display at Kelly Tarlton's Sealife Aquarium from the mid 1980s to the early 2000s, but all of the sharks died and the practice was discontinued.

SPINETAIL DEVILRAY AND MANTA RAY

Spinetail devilrays and manta rays occur mainly in north-eastern North Island waters during summer (Duffy & Abbott 2003). Most if not all mobulid rays reported caught in commercial fisheries were likely to have been spinetail devilrays (Paulin et al 1982); no manta rays have been confirmed caught in New Zealand waters (Duffy 2005, Jones & Francis 2012). However, it is possible that manta rays are occasionally caught in purse seines along the north-east coast of North Island.

All commercial and observer records of mobulid rays were from the northern North Island in FMAs 1 and 9, and most records came from purse seine vessels (Francis & Lyon 2012, Jones & Francis 2012). Most observer records were from the edge of the continental shelf between the Bay of Islands and Great Barrier Island. Commercial purse seine records are available from the eastern Bay of Plenty, and there are a few commercial and observer records from the North Taranaki Bight. Three devilrays have been reported on surface longlines, mainly near the 1000 m depth contour. Observer and commercial records were not available before 2001–02, although devilray bycatch in purse seine catches was documented between 1975 and 1981 by Paulin et al (1982). All observed devilrays were discarded by fishers. The three rays caught on surface longlines were alive when retrieved, but the life status of rays caught in purse seines was not recorded. Annual catch weights have only been reported by commercial fishers since 2003–04, and were less than 5 t per year.

OCEANIC WHITETIP SHARK

No analysis has been conducted of New Zealand fishery interactions with the oceanic whitetip shark, but only 19 individuals have been observed caught in New Zealand fisheries (Ministry for Primary Industries 2012b). Commercial catches of oceanic whitetip sharks have been observed aboard surface longline vessels (Francis et al 1999b), and this is likely to be the main or only method that catches them. Most catches are likely to be in FMAs 1, 2, 9 and 10. The oceanic whitetip shark is a tropical species that enters northern New Zealand waters only in summer, and possibly only in summers that are warmer than normal (Francis et al 1999b).

8.4.3 NON-QMS SPECIES

More than 50 species of Non-QMS chondrichthyans are known to be caught by fishers in New Zealand waters. However, most of them are rarely caught (or rarely reported). The main species known to be caught by commercial fishers (Table 8.2) can be grouped into five categories: inshore rays, inshore sharks, deepwater chimaeras, deepwater sharks and deepwater skates (Table 8.4). No analysis has been done of the interactions of most of these species with fisheries, but the presumed important fishing methods that catch these species are indicated in Table 8.4.

Inshore rays and sharks are caught by a variety of fishing methods. Recent closures of strips of inshore waters to set netting and trawling to protect Hector's and Maui's dolphin on the north-west coast of North Island and around much of South Island may have benefitted shark and ray species that occur there, and their habitats and nursery areas. However most of these species are highly vulnerable to trawl, set net and bottom longline, and have nurseries in shallow coastal waters and harbours that are still fished by set nets and longline, and to a lesser extent trawls. Little is known about the fishery interactions of these species (but for an analysis of hammerhead shark captures see Francis (2010)). Similarly, there is little information on the biological productivity of most of the species, but many (all of the rays and thresher shark) have very low reproductive output (a few young per year) and are therefore highly susceptible to overfishing.

Deepwater chondrichthyans are caught incidentally in deepwater trawl tows, some species in considerable quantities (Table 8.2) (Blackwell 2010). Seven species of squaloid deepwater sharks, shovelnose dogfish, Baxter's dogfish, lucifer dogfish, Owston's dogfish, longnose velvet dogfish, leafscale gulper shark, and seal shark commonly occur over the middle and lower continental slope in depths greater than 600 m. Shovelnose dogfish has a wider distribution, as it also occurs on the upper and middle slope (400–600 m in depth). These seven shark species are commonly taken as bycatch in the middle depths and deepwater fisheries for hoki, orange roughy, and oreos. They are either discarded at sea, or processed for their fins and livers (Blackwell 2010). Catches of seal shark and shovelnose dogfish increased through the early 1990s, peaked in the early 2000s, and then declined, but these increases may have been affected by improved identification and reporting of deepwater shark catches (Blackwell 2010; Table 8.2). Data are available from the MPI Observer Programme (Figure 8.2), but coverage of the distribution of deepwater sharks has been unrepresentative.

Some species that are not caught or reported in quantities sufficient to be included in Table 8.4 may also be vulnerable to overfishing. These include endemic species with limited geographic and/or depth ranges that overlap in space with the operations of deepwater trawlers, for example Dawson's catshark (Francis 2006), and some of the rarer deepwater skates and chimaeras. Their low catch weights probably reflect their rarity.

Table 8.4: Main Non-QMS species of chondrichthyans caught by commercial fishers, classified by species group and depth range. Only species with more than 10 t of aggregated catch between 2004–05 and 2011–12 are included. The main fishing methods thought to catch these species are also indicated (Source: M. Francis, pers. comm.).

			Method		
Species group	Species	Code	Trawl	Bottom longline	Set net
Inshore rays	Eagle ray	EGR	+	+	+
	Electric ray	ERA	+	+	+
	Longtailed stingray	WRA	+	+	+
	Shorttailed stingray	BRA	+	+	+
	Unspecified stingray	STR	+	+	+
	Unspecified rays	RAY	+	+	+
Inshore sharks	Bronze whaler shark	BWH		+	+
	Carpet shark	CAR	+	+	+
	Hammerhead shark	HHS		+	+
	Sevengill shark	SEV		+	+
	Thresher shark	THR	+		+
Deepwater chimaeras	Giant chimaera	CHG	+		
	Longnose chimaera	LCH	+		
	Unspecified chimaeras	CHI	+		
Deepwater dogfish	Baxter's dogfish	ETB	+		
	Largespine velvet dogfish	SCM	+		
	Leafscale gulper shark	CSQ	+		
	Lucifer's dogfish	ETL	+		
	Northern spiny dogfish	NSD	+		
	Owston's dogfish	CYO	+		
	Prickly dogfish	PDG	+		
	Seal shark	BSH	+		
	Shovelnose dogfish	SND	+		
	Slender smoothhound	SSH	+		
	Unspecified catshark	APR	+		
	Unspecified dogfish	DWD	+		
Deepwater skates	Deepwater spiny skate	DSK	+		
	Longnose deepsea skate	PSK	+		
	Numbfish	BER	+		
	Softnose skate	LSK	+		
	Unspecified skates	OSK	+		

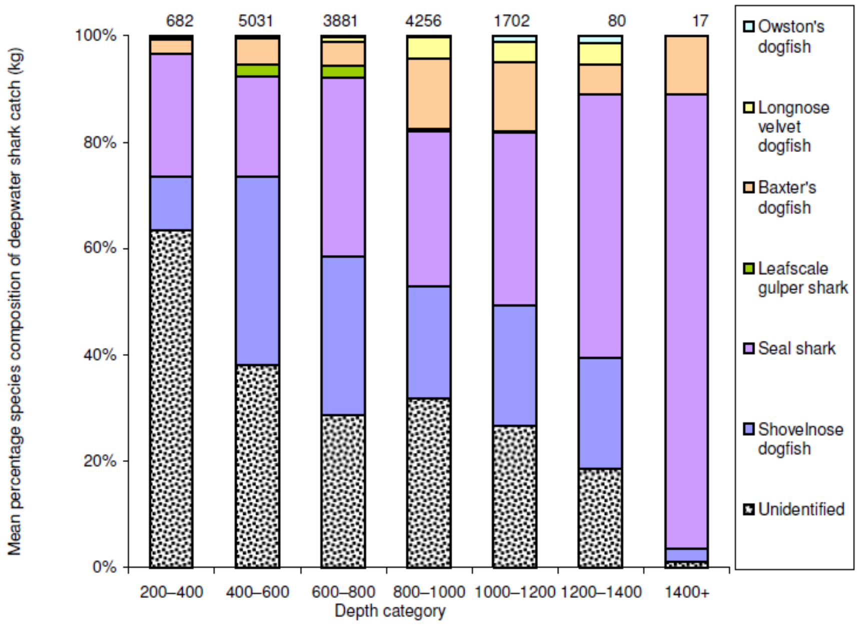


Figure 8.2: Mean catch composition of deepwater chondrichthyans reported from the Observer Programme database, all years 2001–02 to 2005–06, by major depth category (number of observations shown above bars). Source: Blackwell (2010).

8.5 INDICATORS AND TRENDS

QMS SPECIES

Standardised CPUE analyses have been carried out to monitor trends in the relative abundance of some stocks of 4 of the 11 QMS chondrichthyans species (rig, school sharks, elephantfish, and pale ghost shark) (Table 8.5). For 13 out of 15 stocks that are monitored, stock size is stable or increasing in recent years; stock size is declining for school shark in QMAs 5 and 7.

Many shark species cannot be monitored by trawl survey because large sharks are able to outswim the net, and so are not sampled representatively. However, trawl survey relative abundance indices are used to monitor the populations of rig, school shark, spiny dogfish, elephantfish, rough and smooth skates, and pale and dark ghost sharks (Table 8.5). For 18 out of 21 species/FMA combinations, abundance is stable or increasing in recent years; however smooth skate in FMAs 4 and 7, and pale ghost shark in FMA 4, have a downwards trend.

PROTECTED SPECIES

Of the seven protected chondrichthyan species, only the basking shark has any form of population monitoring and that is limited to assessing trends in relative abundance from incidental captures. Observer-based unstandardised CPUE analyses of trawl catches in three trawl fisheries (East Coast South Island EC, West Coast South Island WC, and Southland–Auckland Island SA) are shown in

Figure 8.1Figure 8.3 (Francis & Sutton 2012). Inter-annual variation was large, with peak observer records occurring in 1987–92, 1997–2000 and 2003–05 depending on the region. Some years had very low or zero CPUE. Francis & Smith (2010) used Bayesian predictive hierarchical models to estimate catches and catch rates in the three trawl fisheries from observer data between 1994–95 and 2007–08. The predicted strike rates showed no overall trend since 1994–95 in any of the three areas. A total of 95 sharks were observed in 49 165 tows in the 14-year period, an overall unstandardised capture rate of 1.9 per 1000 tows. The overall predicted capture rate was 2.5 sharks per 1000 tows, with area-specific rates of 3.9 (EC), 2.0 (WC), and 1.9 (SA) per 1000 tows. The total predicted number of captures was 922 with a CV of 19%. Predicted captures peaked in 1997–98 and then declined steadily to low numbers. Much of the recent decline in basking shark bycatch was probably attributable to a decline in fishing effort of about 50% between 2002–03 and 2006–08 in the three areas (Francis & Smith 2010). However, unstandardised catch rates from observer data were much higher in 1988–92 than at any time since. Those high rates may be attributable to targeting by Japanese vessels

(Francis & Sutton 2012). However, the very low (often zero) CPUE since then, and lack of large numbers and aggregations of basking sharks observed in Department of Conservation aerial surveys for dolphins around Banks Peninsula during the last decade, are cause for concern. There may not have been large aggregations of basking sharks in New Zealand waters since 1992. Whether such a long period without large aggregations is part of a long-term, natural cycle, or evidence of a decline in population abundance, cannot yet be determined (Francis & Smith 2010).

Table 8.5: Trends in abundance of QMS species monitored by standardised CPUE analysis and trawl surveys. Changes in trends through time are indicated by forward slashes, and multiple substocks or multiple indices within QMAs are separated by commas. Blanks, none or unreliable. Source: Ministry for Primary Industries (2013) unless otherwise indicated.

CPUE indices		QMA 1	QMA 2	QMA 3	QMA 4	QMA 5	QMA 6	QMA 7	QMA 8	Source
Rig	SPO	Nil, Down/ Nil, Nil	Up/Nil	Nil				Down/Up, Nil	Down/Up, Nil	
School shark	SCH	Nil, Up/Nil	Up	Down/Up		Nil/Down		Nil/Down	Nil	
Elephantfish	ELE			Up		Up				
Pale ghost shark	GSP	Nil				Up				MacGibbon & Fu (2013)
Trawl survey indices				FMA 3	FMA 4	FMA 5	FMA 6	FMA 7		
Rig	SPO			Up				Down/Up		
School shark	SCH			Up	Up					FMA 4: O'Driscoll et al. (2011)
Spiny dogfish	SPD			Up/Nil	Up/Nil	Nil	Nil	Nil		FMAs 5&6: Bagley et al. (2013)
Elephantfish	ELE			Up						
Rough skate	RSK			Up	Nil			Nil		
Smooth skate	SSK			Up	Up/Down			Down		
Dark ghost shark	GSH			Up	Up/Nil			Nil		
Pale ghost shark	GSP				Nil/Down	Up				

Legend:
- (green) Trend up in recent years
- (grey) Stable in recent years
- (red) Trend down in recent years

NON-QMS SPECIES

Some Non-QMS deepwater chondrichthyans have been monitored by trawl surveys on the Chatham Rise and Sub-Antarctic (Campbell Plateau) over a period of almost two decades. Trends in relative abundance indices and mean length were provided by O'Driscoll et al (2011) and Bagley et al (2013) and are summarised in Table 8.6. These survey series covered only a small part of the known distributions of these species, and it is not known how representative the results are. Most species showed no trends in biomass or mean length. However, on the Chatham Rise dark ghost shark, school shark, spiny dogfish and smooth skates showed increasing trends in biomass, while prickly dogfish increased and then declined. In the Sub-Antarctic, leafscale gulper shark, Baxter's dogfish and shovelnose dogfish all increased.

Anderson (2013) analysed trends in bycatch quantities caught in eight deepwater trawl fisheries from 1990–91 to 2010–11. Some species showed consistent declines or increases across six or more of the eight fisheries. Deepsea skates, Baxter's dogfish, lucifer dogfish, rough skate and pale ghost shark all increased while shark unspecified and skates unspecified decreased. These trends appear to be a direct result of better reporting of deepwater sharks and skates by species code rather than by an unspecified generic code, and should not be interpreted as trends in abundance of the species (see Appendix 8.1 – from the non-protected bycatch chapter).

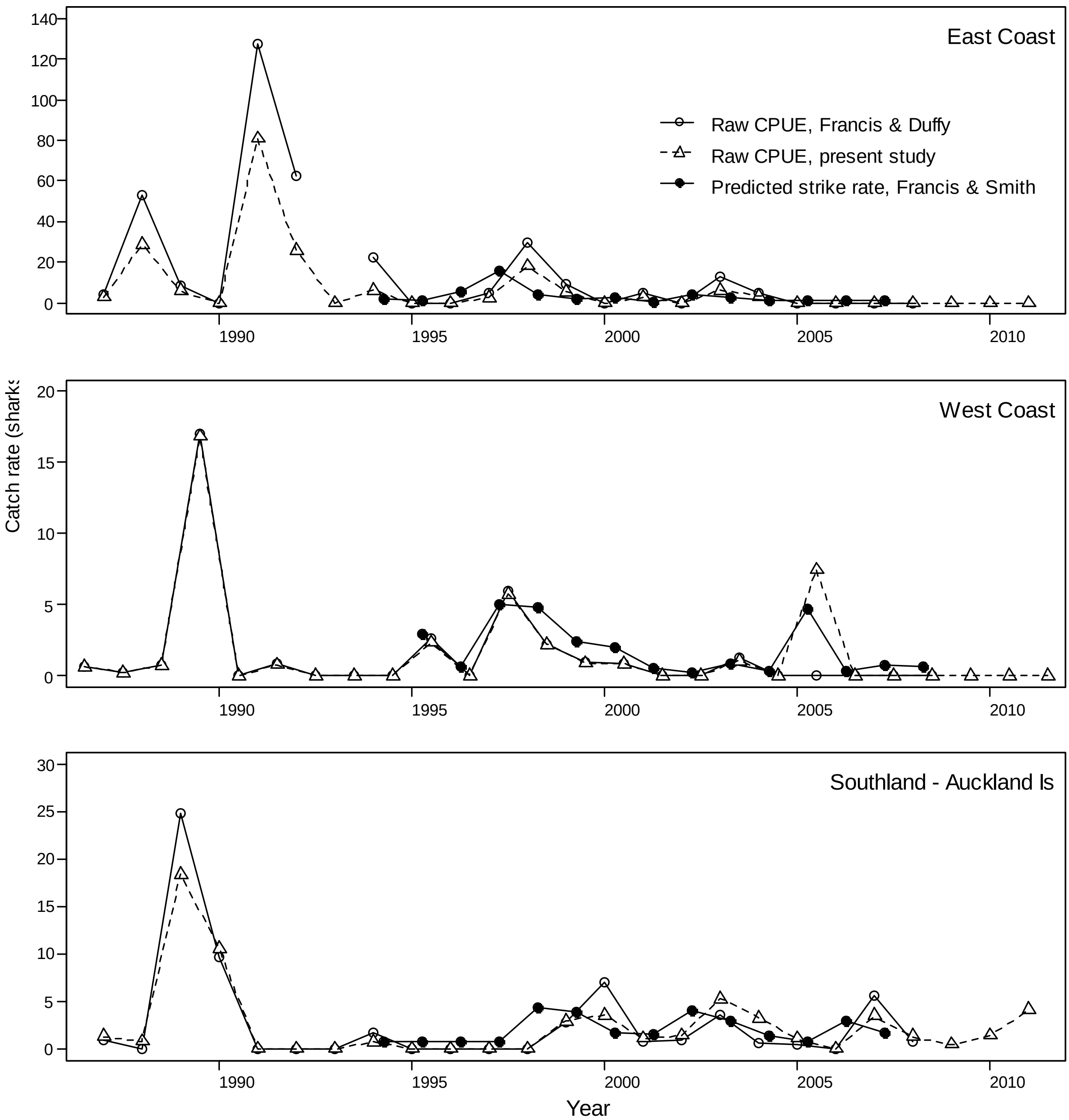


Figure 8.3: Basking shark catch rate indices for three fishery areas. For raw CPUE indices, years are calendar years for West Coast and July–June years (labelled as the greater of the two years) for East Coast and Southland-Auckland Is. For predicted strike rate, years are fishing years (labelled as the greater of the two years). Source: Francis & Sutton (2012).

Table 8.6: Trends in relative biomass and mean length determined from time series of research bottom trawl surveys of the Chatham Rise and the Sub-Antarctic (Campbell Plateau). Sources: O'Driscoll et al (2011), Bagley et al (2013).

Code	Species	Quality of biomass estimate	Biomass trend	Mean length trend
Chatham Rise, 1992-2010				
BSH	Seal shark	moderate	no change	
CYP	Longnose velvet dogfish	poor		no change
ETB	Baxter's dogfish	moderate	no change	no change
ETL	Lucifer's dogfish	very good	no change	no change
GSH	Dark ghost shark	very good	increase	decrease
GSP	Pale ghost shark	very good	no change	decrease
LCH	Longnose spookfish	very good	no change	no change
PDG	Prickly dogfish	moderate	increase then decrease	
SCH	School shark	moderate	increase	
SKA	Unspecified skates	good	no change	
SND	Shovelnose dogfish	good	no change	no change
SPD	Spiny dogfish	very good	increase	increase then decrease
SSK	Smooth skate	good	increase	no change
Subantarctic, 1991-1993 and 2000-2009				
BTH	Bluntnose deepwater skates	moderate	no change	
CSQ	Leafscale gulper shark	moderate	increase	increase
CYP	Longnose velvet dogfish	moderate	no change	no change
ETB	Baxter's dogfish	good	increase	no change
ETL	Lucifer's dogfish	good	no change	decrease
GSH	Dark ghost shark	poor		no change
GSP	Pale ghost shark	very good	no change	no change
LCH	Longnose spookfish	good	no change	no change
SND	Shovelnose dogfish	good	increase	no change
SPD	Spiny dogfish	good	no change	decrease

8.6 REFERENCES

Anderson, O F (2013) Fish and invertebrate bycatch in New Zealand deepwater fisheries from 1990–91 until 2010–11. New Zealand Aquatic Environment and Biodiversity Report 113. 57 p.

Bagley, N W; Ballara, S L; O'Driscoll, R L; Fu, D; Lyon, W (2013) A review of hoki and middle depth summer trawl surveys of the Sub-Antarctic, November December 1991–1993 and 2000–2009. New Zealand Fisheries Assessment Report 2013/41. 63 p.

Blackwell, R G (2010) Distribution and abundance of deepwater sharks in New Zealand waters, 2000–01 to 2005–06. New Zealand Aquatic Environment and Biodiversity Report 57. 51 p.

Bonfil, R (1994) Overview of world elasmobranch fisheries. FAO Fisheries Technical Paper 341. 119 p.

Camhi, M; Fowler, S; Musick, J; Bräutigam, A; Fordham, S (1998) Sharks and their relatives. Ecology and conservation. Occasional paper of the IUCN Species Survival Commission 20. 39 p.

Campana, S E; Joyce, W; Manning, M J (2009) Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. Marine Ecology Progress Series 387: 241–253.

Clarke, S C; Harley, S J; Hoyle, S D; Rice, J S (2012) Population trends in Pacific oceanic sharks and the utility of regulations on shark finning. Conservation Biology 27: 197–209.

Clarke, S C; McAllister, M K; Milner-Gulland, E J; Kirkwood, G P; Michielsens, C G J; Agnew, D J; Pikitch, E K; Nakano, H; Shivji, M S (2006) Global estimates of shark catches using trade records from commercial markets. Ecology Letters 9: 1115–1126.

Duffy, C (2005) Rationale and background information justifying protection of additional marine fishes under the Wildlife Act. Department of Conservation. (Unpublished report held by the Department of Conservation.) 14 p.

Duffy, C A J (2002) Distribution, seasonality, lengths, and feeding behaviour of whale sharks (*Rhincodon typus*) observed in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 36: 565–570.

Duffy, C A J; Abbott, D (2003) Sightings of mobulid rays from northern New Zealand, with confirmation of the occurrence of Manta birostris in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 37: 715–721.

Dulvy, N K; Sadovy, Y; Reynolds, J D (2003) Extinction vulnerability in marine populations. Fish and Fisheries 4: 25–64.

Dunn, M R; Griggs, L; Forman, J; Horn, P (2010a) Feeding habits and niche separation among the deep-sea chimaeroid fishes *Harriotta raleighana*, *Hydrolagus bemisi* and *Hydrolagus novaezealandiae*. Marine Ecology -Progress Series 407: 209–225. <http://dx.doi.org/10.3354/meps08580>

Dunn, M R; Stevens, D W; Forman, J S; Connell, A (2013) Trophic interactions and distribution of some squaliforme sharks, including new diet descriptions for *Deania calcea* and *Squalus acanthias*. PLoS ONE 8 e59938: 1–14.

Dunn, M R; Szabo, A; McVeigh, M S; Smith, P J (2010b) The diet of deep sea sharks and the benefits of using DNA identification of prey. Deep Sea Research I 57: 923–930.

Fergusson, I K; Graham, K J; Compagno, L J V (2008) Distribution, abundance and biology of the smalltooth sandtiger shark *Odontaspis ferox* (Risso, 1810) (Lamniformes: Odontaspididae). Environmental Biology of Fishes 81: 207–228.

Forman, J S; Dunn, M R (2012) Diet and scavenging habits of the smooth skate *Dipturus innominatus*. Journal of Fish Biology 80: 1546–1562.

Francis, M P (2006) Distribution and biology of the New Zealand endemic catshark, *Halaelurus dawsoni*. Environmental Biology of Fishes 75: 295–306.

Francis, M P (2010) Review of research and observer data on hammerhead sharks (*Sphyrna zygaena*). Final Research Report for Ministry of Fisheries. 8 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Francis, M P; Duffy, C (2002) Distribution, seasonal abundance and bycatch of basking sharks (*Cetorhinus maximus*) in New Zealand, with observations on their winter habitat. Marine Biology 140: 831–842.

Francis, M P; Griggs, L H; Baird, S J; Murray, T E; Dean, H A (1999a) Fish bycatch in New Zealand tuna longline fisheries. NIWA Technical Report 55. 70 p.

Francis, M P; Lyon, W S (2012) Review of commercial fishery interactions and population information for eight New Zealand protected fish species. NIWA client report WLG2012-64. 67 p.

Francis, M P; Lyon, W S (2013) Review of anthropogenic impacts other than fishing on cartilaginous fishes. New Zealand Aquatic Environment and Biodiversity Report 107. 17 p.

Francis, M P; Mace, J T (1980) Reproductive biology of *Mustelus lenticulatus* from Kaikoura and Nelson. New Zealand Journal of Marine and Freshwater Research 14: 303–311.

Francis, M P; Ó Maolagáin, C (2000) Age, growth and maturity of a New Zealand endemic shark (*Mustelus lenticulatus*) estimated from vertebral bands. Marine and Freshwater Research 51: 35–42.

Francis, M P; Smith, M H (2010) Basking shark (*Cetorhinus maximus*) bycatch in New Zealand fisheries, 1994–95 to 2007–08. New Zealand Aquatic Environment and Biodiversity Report 49. 57 p.

Francis, M P; Sutton, P (2012) Possible factors affecting bycatch of basking sharks (*Cetorhinus maximus*) in New Zealand trawl fisheries. NIWA client report WLG2012-48. 38 p.

Francis, M P; Worthington, C J; Saul, P; Clements, K D (1999b) New and rare tropical and subtropical fishes from northern New Zealand. New Zealand Journal of Marine and Freshwater Research 33: 571–586.

Garrick, J A F (1974) First record of an odontaspidid shark in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 8: 621–630.

Getzlaff, C (2012) Diet and foraging behaviour of juvenile rig (*Mustelus lenticulatus*) from New Zealand harbours and estuaries. M.Sc. thesis. Massey University, Palmerston North. 102 p.

Griggs, L H; Baird, S J (2013) Fish bycatch in New Zealand tuna longline fisheries 2006–07 to 2009–10. New Zealand Fisheries Assessment Report 2013/13. 73 p.

Hitchmough, R; Bull, L; Cromarty, P (2007) New Zealand threat classification system lists 2005. Department of Conservation, Wellington. 194 p.

Horn, P L; Ballara, S L; Sutton, P J H; Griggs, L H (2013) Evaluation of the diets of highly migratory species in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 116.

Hutchinson, M; Itano, D; Muir J; Leroy, B; Holland, K (2013) Fishery interactions and post-release survival rates of silky sharks caught in purse seine fishing gear. Western Cetnral Pacific Fisheries Commission, Scientific Committee Paper, WCPFC-SC9-2013/ EB-WP-12.

Jones, E; Francis, M P (2012) Protected rays – occurrence and development of mitigation methods in the New Zealand tuna purse seine fishery. NIWA client report prepared for the Department of Conservation WLG2012-49. 35 p.

Jones, M R L (2008) Biology and diet of *Coryphaenoides subserrulatus* and *Etmopterus baxteri* from the Puysegur region, southern New Zealand. New Zealand Journal of Marine and Freshwater Research 42: 333–337.

Jones, M R L (2009) Diets of eight fish species from the upper slope off the Wairarapa coast, North Island, New Zealand, with notes on the diets of others. New Zealand Journal of Marine and Freshwater Research 43: 929–939.

Kyne, P M; Simpfendorfer, C A (2007) A collation and summarization of available data on deepwater chondrichthyans: biodiversity, life history and fisheries. A report prepared by the IUCN Shark Specialist Group for the Marine Conservation Biology Institute. 137 p.

Last, P R; Stevens, J D (2009) Sharks and rays of Australia. Second edition. CSIRO, Hobart. 644 p.

MacGibbon, D J; Fu, D (2013) Fishery characterisation and standardised CPUE analyses for pale ghost shark, *Hydrolagus bemisi* (Didier, 2002) (Chimaeridae), 1989–90 to 2009–10. New Zealand Fisheries Assessment Report 2013/33. 120 p.

Ministry for Primary Industries (2012a) Fisheries Assessment Plenary, November 2012: stock assessment and yield estimates. Ministry for Primary Industries, Wellington, New Zealand, Wellington. 531 p.

Ministry for Primary Industries (2012b) Protection of oceanic whitetip shark. Regulatory impact statement. Ministry for Primary Industries, Wellington. (Unpublished report held by Ministry for Primary Industries, Wellington.) 5 p.

Ministry for Primary Industries (2013) Fisheries Assessment Plenary, May 2013: stock assessments and yield estimates. Ministry for Primary Industries, Wellington, New Zealand, Wellington. 1357 p.

Ministry of Fisheries (2008) New Zealand National Plan of Action for the conservation and management of sharks. Ministry of Fisheries, Wellington. (Unpublished report held by the Ministry for Primary Industries, Wellington.) 90 p.

Mollet, H F; Cliff, G; Pratt, H L; Stevens, J D (2000) Reproductive biology of the female shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, with comments on the embryonic development of lamnoids. Fishery Bulletin 98: 299–318.

Moyes, C D; Fragoso, N; Brill, R W; Musyl, M K (2006) Predicting postrelease survival in large pelagic fish. Transactions of the American Fisheries Society 135: 1389–1397.

Musyl, M K; Brill, R W; Curran, D S; Fragoso, N M; McNaughton, L M; Nielsen, A; Kikkawa, B S; Moyes, C D (2011) Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the central Pacific Ocean. Fishery Bulletin 109: 341–368.

O'Driscoll, R L; MacGibbon, D; Fu, D; Lyon, W; Stevens, D W (2011) A review of hoki and middle-depth trawl surveys of the Chatham Rise, January 1992–2010. New Zealand Fisheries Assessment Report 2011/47. 72 p.

Paulin, C D; Habib, G; Carey, C L; Swanson, P M; Voss, G J (1982) New records of *Mobula japanica* and *Masturus lanceolatus*, and further records of *Luvaris imperialis* (Pisces: Mobulidae, Molidae, Louvaridae) from New Zealand. New Zealand Journal of Marine and Freshwater Research 16: 11–17.

Pikitch, E K; Camhi, M D; Babcock, E A (2008) Introduction. In: Camhi, M D; Pikitch, E K; Babcock, E A (Eds.). Sharks of the open ocean: biology, fisheries and conservation, pp. 3–13. Blackwell Publishing, Oxford, United Kingdom.

Rice, J; Harley, S (2012a) Stock assessment of oceanic whitetip sharks in the western and central Pacific Ocean. Western Central Pacific Fisheries Commission Scientific Committee eighth regular session No. WCPFC-SC8-2012/SA-WP-06 Rev 1. 53 p.

Rice, J; Harley, S (2012b) Stock assessment of silky sharks in the western and central Pacific Ocean. Western Central Pacific Fisheries Commission Scientific Committee eighth regular session No. WCPFC-SC8-2012/SA-WP-07 Rev 1. 53 p.

Simpfendorfer, C A; Kyne, P M (2009) Limited potential to recover from overfishing raises concerns for deep-sea sharks, rays and chimaeras. Environmental Conservation 36: 97–103.

Smith, S E; Au, D W; Show, C (1998) Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research 49: 663–678.

Stewart, A (1997) Toothy sand tiger. Seafood New Zealand October 1997: 91–92.

Walker, T I (2005) Reproduction in fisheries science. In: Hamlett, W.C. (ed.). Reproductive biology and phylogeny of Chondrichthyes, pp. 81-127. Science Publishers, Enfield, USA.

Worm, A; Davis, B; Kettemer, L; Ward-Paige, C A; Chapman, D; Heithaus, M R; Kessel, S T; Gruber, S H (2013) Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy 40: 194–204.

Wynne-Jones, J; Heinemann, A; Gray, A; Hill, L (in press) New Zealand recreational marine fishing survey 2011–2012. New Zealand Fisheries Assessment Report 2013/xx. 70 p.

8.7 APPENDICES

Appendix 8.1: List of New Zealand chondrichthyans, with details of their fisheries management classification, and IUCN and Department of Conservation threat classes. IUCN threat classes: EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient. The regional red list class is given for Squalus acanthias (LC) because it differs from the global class of VU. DOC threat classes: GD, Gradual Decline; RR, Range restricted; SP, Sparse; NOT, Not Threatened; MI, Migrant; VA, Vagrant. DOC qualifiers: CD, Conservation Dependent; DP, Data Poor; RC, Recovering; SO, Secure Overseas; TO, Threatened Overseas. Sources: IUCN Redlist classes as at July 2013 (L. Harrison, Shark Specialist Group IUCN, pers. comm.); DOC threat classes 2005 (Hitchmough et al 2007).

List of New Zealand chondrichthyans (including four skate species occurring in the Ross Sea, Anatarctica)								
Compiled and maintained by Malcolm Francis (NIWA) with input from Andrew Stewart (Te Papa), Clinton Duffy (DOC) and Peter McMillan (NIWA)								
Group	Family	Species	Common name	Code	Management class	IUCN redlist class	DoC threat class	DoC qualifier
Chimaera	Callorhinchidae	*Callorhinchus milii* Bory de St Vincent, 1823	Elephantfish	ELE	QMS	LC	NOT	CD,RC
Chimaera	Rhinochimaeridae	*Harriotta haeckeli* Karrer, 1972	Smallspine spookfish	HHA	Non-QMS	DD	NOT	DP,SO
Chimaera	Rhinochimaeridae	*Harriotta raleighana* Goode & Bean, 1895	Longnose spookfish	LCH	Non-QMS	LC	NOT	SO
Chimaera	Rhinochimaeridae	*Rhinochimaera pacifica* (Mitsukuri, 1895)	Pacific spookfish	RCH	Non-QMS	LC	NOT	SO
Chimaera	Chimaeridae	*Chimaera lignaria* Didier, 2002	Purple chimaera, giant chimaera	CHG	Non-QMS	DD	NOT	SO
Chimaera	Chimaeridae	*Chimaera panthera* Didier, 1998	Leopard chimaera	CPN	Non-QMS	DD	NOT	
Chimaera	Chimaeridae	*Chimaera* sp.	Brown chimaera, longspine chimaera	CHP	Non-QMS		NOT	
Chimaera	Chimaeridae	*Hydrolagus bemisi* Didier, 2002	Pale ghost shark	GSP	QMS	LC	NOT	
Chimaera	Chimaeridae	*Hydrolagus homonycteris* Didier 2008	Black ghost shark	HYB	Non-QMS	DD	NOT	SO
Chimaera	Chimaeridae	*Hydrolagus novaezealandiae* (Fowler, 1910)	Dark ghost shark	GSH	QMS	LC	NOT	
Chimaera	Chimaeridae	*Hydrolagus trolli* Didier and Seret, 2002	Pointynose blue ghost shark	HYP	Non-QMS	DD	NOT	SO
Chimaera	Chimaeridae	*Hydrolagus* sp. D [Didier]	Giant black ghost shark	HGB	Non-QMS		DD	
Shark	Chlamydoselachidae	*Chlamydoselachus anguineus* Garman, 1884	Frill shark	FRS	Non-QMS	NT	SP	DP,SO
Shark	Hexanchidae	*Heptranchias perlo* (Bonnaterre, 1788)	Sharpnose sevengill shark	HEP	Non-target	NT	SP	DP,SO
Shark	Hexanchidae	*Hexanchus griseus* (Bonnaterre, 1788)	Sixgill shark	HEX	Non-QMS	NT	SP	DP,SO
Shark	Hexanchidae	*Notorynchus cepedianus* (Peron, 1807)	Broadnose sevengill shark	SEV	Non-QMS	DD	NOT	DP,SO
Shark	Echinorhinidae	*Echinorhinus brucus* (Bonnaterre, 1788)	Bramble shark	BRS	Non-QMS	DD	SP	DP,SO
Shark	Echinorhinidae	*Echinorhinus cookei* Pietschmann, 1928	Prickly shark	ECO	Non-QMS	NT	SP	DP,SO
Shark	Squalidae	*Cirrhigaleus australis* White, Last & Stevens, 2007	Southern mandarin dogfish	MSH	Non-QMS	DD	SP	DP,TO
Shark	Squalidae	*Squalus acanthias* Linnaeus, 1758	Spiny dogfish	SPD	QMS	LC	NOT	SO
Shark	Squalidae	*Squalus griffini* Phillipps, 1931	Northern spiny dogfish	NSD	Non-QMS	LC	NOT	SO
Shark	Squalidae	*Squalus raoulensis* Duffy & Last, 2007	Kermadec spiny dogfish	SQA	Non-QMS	LC	DD	
Shark	Squalidae	*Squalus* sp. 5	Green-eye dogfish	SQA	Non-QMS		DD	
Shark	Centrophoridae	*Centrophorus harrissoni* McCulloch, 1915	Harrisson's dogfish		Non-QMS	EN	DD	TO
Shark	Centrophoridae	*Centrophorus squamosus* (Bonnaterre, 1788)	Leafscale gulper shark	CSQ	Non-QMS	VU	NOT	
Shark	Centrophoridae	*Deania calcea* (Lowe, 1839)	Shovelnose dogfish	SND	Non-QMS	LC	NOT	SO
Shark	Centrophoridae	*Deania histricosum* (Garman, 1906)	Rough longnose dogfish	SNR	Non-QMS	DD		
Shark	Centrophoridae	*Deania quadrispinosum* (McCulloch, 1915)	Longsnout dogfish	DEQ	Non-QMS	NT	DD	SO
Shark	Etmopteridae	*Centroscyllium* sp. cf. *kamoharai*	Fragile dogfish		Non-QMS		DD	
Shark	Etmopteridae	*Etmopterus granulosus* (Günther, 1880)	Baxter's dogfish	ETB	Non-QMS	LC	NOT	SO
Shark	Etmopteridae	*Etmopterus lucifer* Jordan & Snyder, 1902	Lucifer's dogfish	ETL	Non-QMS	LC	NOT	SO
Shark	Etmopteridae	*Etmopterus molleri* (Whitley, 1939)	Moller's lantern shark	EMO	Non-QMS	LC	NOT	SO
Shark	Etmopteridae	*Etmopterus pusillus* (Lowe, 1839)	Smooth lantern shark	ETP	Non-QMS	LC	SP	DP,SO

Appendix 8.1 (continued)

Shark	Etmopteridae	*Etmopterus* cf. *unicolor*	Bristled lantern shark		Non-QMS		NOT	SO
Shark	Etmopteridae	*Etmopterus viator* Straube 2012	Blue-eye lantern shark	EVI	Non-QMS			
Shark	Somniosidae	*Centroscymnus coelolepis* Bocage & Capello, 1864	Portuguese dogfish	CYL	Non-QMS	NT	NOT	
Shark	Somniosidae	*Centroscymnus owstonii* Garman, 1906	Owston's dogfish	CYO	Non-QMS	LC	NOT	
Shark	Somniosidae	*Centroselachus crepidater* (Bocage & Capello, 1864)	Longnose velvet dogfish	CYP	Non-QMS	LC	NOT	
Shark	Somniosidae	*Proscymnodon plunketi* (Waite, 1909)	Plunket's shark	PLS	Non-QMS	NT	NOT	
Shark	Somniosidae	*Scymnodalatias albicauda* Taniuchi & Garrick, 1986	Whitetail dogfish	SLB	Non-QMS	DD	SP	DP,SO
Shark	Somniosidae	*Scymnodalatias sherwoodi* (Archey, 1921)	Sherwood's dogfish	SHE	Non-QMS	DD	SP	
Shark	Somniosidae	*Scymnodon* cf. *ringens* Bocage & Capello, 1864	Knifetooth dogfish	SRI	Non-QMS		DD	SO
Shark	Somniosidae	*Somniosus antarcticus* Whitley, 1939	Southern sleeper shark	SOP	Non-QMS	DD	SP	DP,SO
Shark	Somniosidae	*Somniosus longus* (Tanaka, 1912)	Little sleeper shark	SOM	Non-QMS	DD	DD	SO
Shark	Somniosidae	*Zameus squamulosus* (Günther, 1877)	Velvet dogfish	ZAS	Non-QMS	DD	SP	DP,SO
Shark	Oxynotidae	*Oxynotus bruniensis* (Ogilby, 1893)	Prickly dogfish	PDG	Non-QMS	DD	NOT	DP,SO
Shark	Dalatiidae	*Dalatias licha* (Bonnaterre, 1788)	Seal shark, black shark	BSH	Non-QMS	NT	NOT	SO
Shark	Dalatiidae	*Euprotomicrus bispinatus* (Quoy & Gaimard, 1824)	Pygmy shark	EBI	Non-QMS	LC	NOT	SO
Shark	Dalatiidae	*Isistius brasiliensis* (Quoy & Gaimard, 1824)	Cookie cutter shark	IBR	Non-QMS	LC	NOT	SO
Shark	Heterodontidae	*Heterodontus portusjacksoni* (Meyer, 1793)	Port Jackson shark	PJS	Non-QMS	LC	VA	SO
Shark	Rhincodontidae	*Rhincodon typus* (Smith, 1828)	Whale shark	WSH	Protected	VU	MI	SO
Shark	Odontaspidae	*Odontaspis ferox* (Risso, 1810)	Deepwater (smalltooth) sand tiger shark	ODO	Protected	VU	SP	TO
Shark	Pseudocarchariidae	*Pseudocarcharias kamoharai* (Matsubara, 1936)	Crocodile shark.	CRC	Non-QMS	NT	DD	SO
Shark	Mitsukurinidae	*Mitsukurina owstoni* Jordan, 1898	Goblin shark	GOB	Non-QMS	LC	SP	DP,SO
Shark	Alopiidae	*Alopias superciliosus* (Lowe, 1839)	Bigeye thresher	BET	Non-QMS	VU	NOT	TO
Shark	Alopiidae	*Alopias vulpinus* (Bonnaterre, 1788)	Thresher shark	THR	Non-QMS	VU	NOT	TO
Shark	Cetorhinidae	*Cetorhinus maximus* (Gunnerus, 1765)	Basking shark	BSK	Protected	VU	GD	TO
Shark	Lamnidae	*Carcharodon carcharias* (Linnaeus, 1758)	White shark, white pointer	WPS	Protected	VU	GD	TO
Shark	Lamnidae	*Isurus oxyrinchus* Rafinesque, 1810	Mako shark, shortfin mako	MAK	QMS	VU	NOT	SO
Shark	Lamnidae	*Lamna nasus* (Bonnaterre, 1788)	Porbeagle shark	POS	QMS	VU	NOT	TO
Shark	Scyliorhinidae	*Apristurus ampliceps* Sasahara, Sato & Nakaya 2008	Roughskin cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus* cf. *australis Sato, Nakaya & Yorozu 2008*	Pinocchio cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus exsanguis* Sato, Nakaya and Stewart 1999	Pale catshark	APR	Non-QMS	LC	NOT	
Shark	Scyliorhinidae	*Apristurus melanoasper* Iglésias, Nakaya & Stehmann 2004	Fleshynose cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus pinguis* Deng, Xiong & Zhan 1983	Cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus sinensis* Chu & Hu 1981	Freckled cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus* sp.	Cat shark	APR	Non-QMS		NOT	
Shark	Scyliorhinidae	*Bythaelurus dawsoni* (Springer, 1971)	Dawson's cat shark	DCS	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Cephaloscyllium isabellum* (Bonnaterre, 1788)	Carpet shark	CAR	Non-QMS	LC	NOT	
Shark	Scyliorhinidae	*Cephaloscyllium* sp.	Swellshark		Non-QMS		DD	
Shark	Scyliorhinidae	*Parmaturus bigus* Seret & Last, 2007	Shorttail cat shark		Non-QMS	DD		
Shark	Scyliorhinidae	*Parmaturus macmillani* Hardy, 1985	McMillan's cat shark	PCS	Non-QMS	DD	DD	SO
Shark	Scyliorhinidae	*Parmaturus* sp.	Rough-backed cat shark		Non-QMS		DD	
Shark	Scyliorhinidae	*Parmaturus* sp.			Non-QMS			
Shark	Pseudotriakidae	*Gollum attenuatus* (Garrick, 1954)	Slender smooth hound	SSH	Non-QMS	LC	NOT	SO
Shark	Pseudotriakidae	*Pseudotriakis microdon* Capello, 1868	False cat shark	PMI	Non-QMS	DD	DD	SO

Appendix 8.1(continued)

Shark	Triakidae	*Galeorhinus galeus* (Linnaeus, 1758)	School shark, tope	SCH	QMS	VU	NOT	CD,TO
Shark	Triakidae	*Mustelus lenticulatus* Phillipps, 1932	Rig	SPO	QMS	LC	NOT	CD
Shark	Triakidae	*Mustelus* sp.	Kermadec Rig		Non-QMS		RR	SO
Shark	Carcharhinidae	*Carcharhinus brachyurus* (Günther, 1870)	Bronze whaler	BWH	Non-QMS	NT	NOT	SO
Shark	Carcharhinidae	*Carcharhinus falciformis* (Bibron in Muller & Henle, 1839)	Silky shark	CAF	Non-QMS	NT	MI	SO
Shark	Carcharhinidae	*Carcharhinus galapagensis* (Snodgrass & Heller, 1905)	Galapagos shark	CGA	Non-QMS	NT	RR	SO
Shark	Carcharhinidae	*Carcharhinus longimanus* (Poey, 1861)	Oceanic whitetip shark	OWS	Protected	VU	MI	SO
Shark	Carcharhinidae	*Carcharhinus obscurus* (Le Sueur, 1818)	Dusky shark	DSH	Non-QMS	VU	MI	SO
Shark	Carcharhinidae	*Galeocerdo cuvier* (Peron & Le Sueur, 1822)	Tiger shark	TIS	Non-QMS	NT	MI	SO
Shark	Carcharhinidae	*Prionace glauca* (Linnaeus, 1758)	Blue shark	BWS	QMS	NT	NOT	SO
Shark	Sphyrnidae	*Sphyrna zygaena* (Linnaeus, 1758)	Hammerhead shark, smooth hammerhead	HHS	Non-target	VU	NOT	SO
Batoid	Narkidae	*Typhlonarke aysoni* (Hamilton, 1902)	Blind electric ray	TAY	Non-QMS	DD	NOT	DP
Batoid	Narkidae	*Typhlonarke tarakea* Phillipps, 1929	Oval electric ray	TTA	Non-QMS	DD	NOT	DP
Batoid	Torpedinidae	*Torpedo fairchildi* Hutton, 1872	Electric ray	ERA	Non-QMS	DD	NOT	
Batoid	Arhynchobatidae	*Arhynchobatis asperrimus* Waite, 1909	Longtail skate	LSK	Non-QMS	DD	NOT	
Batoid	Arhynchobatidae	*Bathyraja* cf. *eatonii*	Antarctic allometric skate	BEA	Non-QMS			
Batoid	Arhynchobatidae	*Bathyraja maccaini* Springer 1971	MacCain's skate	MCS	Non-QMS	NT		
Batoid	Arhynchobatidae	*Bathyraja richardsoni* (Garrick, 1961)	Richardson's skate	RIS	Non-QMS	LC	DD	SO
Batoid	Arhynchobatidae	*Bathyraja shuntovi* Dolganov, 1985	Longnose deepsea skate	PSK	Non-QMS	DD	NOT	
Batoid	Arhynchobatidae	*Bathyraja* sp.	Antarctic dwarf skate	BHY	Non-QMS			
Batoid	Arhynchobatidae	*Bathyraja* sp.	Blonde skate		Non-QMS			
Batoid	Arhynchobatidae	*Brochiraja albilabiata* Last & McEachran, 2006			Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja asperula* (Garrick & Paul, 1974)	Smooth deepsea skate	BTA	Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja leviveneta* Last & McEachran, 2006			Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja microspinifera* Last & McEachran, 2006			Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja spinifera* (Garrick & Paul, 1974)	Prickly deepsea skate	BTS	Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Notoraja sapphira* Seret & Last 2009	Sapphire skate	BTH	Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus C] sp. A [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus C] sp. B [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus C] sp. C [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus D] sp. A [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Rajidae	*Amblyraja georgiana* (Norman 1938)	Antarctic starry skate	SRR	Non-QMS	DD		
Batoid	Rajidae	*Amblyraja* cf. *hyperborea* (Collette, 1879)	Arctic skate	DSK	Non-QMS		NOT	
Batoid	Rajidae	*Dipturus innominatus* (Garrick & Paul, 1974)	Smooth skate	SSK	QMS	NT	NOT	CD
Batoid	Rajidae	*Zearaja nasuta* (Banks in Müller & Henle, 1841)	Rough skate	RSK	QMS	LC	NOT	
Batoid	Dasyatidae	*Dasyatis brevicaudata* (Hutton, 1875)	Shorttail stingray	BRA	Non-QMS	LC	NOT	SO
Batoid	Dasyatidae	*Dasyatis thetidis* Ogilby in Waite, 1899	Longtail stingray	WRA	Non-QMS	DD	NOT	SO
Batoid	Dasyatidae	*Pteroplatytrygon violacea* (Bonaparte, 1832)	Pelagic stingray	PES	Non-QMS	LC	NOT	SO
Batoid	Myliobatidae	*Myliobatis tenuicaudatus* Hector, 1877	Eagle ray	EGR	Non-QMS	LC	NOT	SO
Batoid	Mobulidae	*Manta birostris* (Donndorff, 1798)	Manta ray	RMB	Protected	VU	MI	SO
Batoid	Mobulidae	*Mobula japanica* (Müller & Henle, 1841)	Spinetail devilray	MJA	Protected	NT	NOT	SO

Appendix 8.2: Indicative information on status of stocks for the eleven shark species subject to the QMS.

Based on the Status of the Stocks 2012 data published by the Ministry for Primary Industries on its website (http://fs.fish.govt.nz/Page.aspx?pk=16&tk=478)

Species name	Plenary stock	Date of last assessment	At or above target levels?	Below the soft limit?	Below the hard limit?	Over-fishing?	Corrective management action	Assessment approach and notes
Blue shark*	BWS1	2008					-	WCPFC scheduled an assessment for 2013 but data inadequacies prevented this assessment being completed. An assessment is now planned for 2015.
Elephant fish	ELE2 ELE7	-					-	
Elephant fish	ELE3	2012	●	●●	●●●	●●	-	Standardised catch per unit effort (CPUE) analysis and trawl survey
Elephant fish	ELE5	2012	●	●●	●●	●●	-	Standardised CPUE analysis
Ghost shark - dark	GSH1 GSH2 GSH7 GSH8 GSH9	-					-	GSH7 – Trawl survey
Ghost shark - dark	GSH3	-				●●	-	Trawl survey
Ghost shark - dark	GSH4 GSH5 GSH6	-					-	
Ghost shark - pale	GSP1 GSP5	2011		●●	●●●		-	Trawl survey
Ghost shark - pale	GSP7	-					-	
Mako shark*	MAK1	2008					TAC reduced from Oct 2012	Unstandardised CPUE analysis

* denotes highly migratory species, for which stock status cannot be determined for the portion of the stock found within New Zealand waters.

Species name	Plenary stock	Date of last assessment	At or above target levels?	Below the soft limit?	Below the hard limit?	Over-fishing?	Corrective management action	Assessment approach and notes
Porbeagle shark*	POS1	2008	▬			▬	TAC reduced from Oct 2012	Indicator analysis. An assessment is planned under the CCSBT for 2014.
Rig	SPO1	-					-	Standardised CPUE analysis undertaken since publication of 2012 Plenary
Rig	SPO2 SPO3 SPO8	2011			●●		-	Standardised CPUE analysis SPO3 – trawl survey
Rig	SPO7	2010	▬	■	●●		TACC reduced in 2006	Standardised CPUE analysis SPO7 – trawl survey
School shark	SCH1 SCH2 SCH3 SCH8	2010			●●	●●	-	Standardised CPUE analysis SCH3 – trawl survey
School shark	SCH4	-					-	
School shark	SCH5 SCH7	2011			●●	■	-	Standardised CPUE analysis SCH7 – trawl survey
Skate – rough	RSK1 RSK3 RSK7 RSK8	2007					-	RSK3, 4 7 – trawl survey
Skate – smooth	SSK1 SSK3 SSK7 SSK8	2007					-	SSK3, 4, 7 – trawl survey
Spiny dogfish	SPD1 SPD8	-					-	
Spiny dogfish	SPD3 SDP7	2009			●●		-	Trawl survey
Spiny dogfish	SPD4	2009			●●		-	Trawl survey
Spiny dogfish	SPD5	-					-	

* denotes highly migratory species, for which stock status cannot be determined for the portion of the stock found within New Zealand waters.

NOTES

At or above target levels? The "at or above target levels" indicator describes the present status of the stock relative to its target (usually BMSY, the average biomass associated with a maximum sustainable yield (MSY) strategy, or FMSY, the associated fishing mortality, or appropriate surrogates or proxies for these metrics, or alternative reference points that will result in higher average biomass.

If a stock is below the target, then under the Fisheries Act 1996, the Minister must take corrective action to rebuild the stock to or above BMSY (or a related target level).

Depleted? Collapsed? Overfishing? These indicators of stock and fishery status are defined in paragraph 28 of the Harvest Strategy Standard for New Zealand Fisheries approved by the Minister of Fisheries on 24 October 2008: "The status of fisheries and stocks will be characterised in the following way:

- If the MSY-compatible fishing mortality rate, FMSY, or an appropriate proxy is exceeded on average, overfishing will be deemed to have been occurring, because stocks fished at rates exceeding FMSY will ultimately be depleted below BMSY.
- A stock that is determined to be below the soft limit [default: 1/2 BMSY or 20% of the unfished level, whichever is higher] will be designated as depleted [or overfished] and in need of rebuilding.
- A stock that is determined to be below the hard limit [default: 1/4 BMSY or 10% of the unfished level, whichever is higher] will be designated as collapsed."

In April 2009, the Ministry's Stock Assessment Methods Working Group adopted a probabilistic scale for categorising the "At or above target levels", depleted, collapsed and overfishing indicators (based on the scale developed by the Intergovernmental Panel on Climate Change (IPCC) in 2007). While these probability categories are best applied in situations where models give appropriate quantitative outputs, they can also be used subjectively, based on expert opinion, when such model outputs are not available, or are highly uncertain. The stock status table uses the IPCC criteria, coded according to the following key:

At or above target levels?	Probability	Description	Deleted? Collapsed? Overfishing?
●●●●	> 99 %	Virtually Certain	■■■■
●●●	> 90 %	Very Likely	■■■
●●	> 60 %	Likely	■■
●	40 - 60 %	About as Likely as Not	■
■■	< 40 %	Unlikely	●●
■■■	< 10 %	Very Unlikely	●●●
■■■■	< 1 %	Exceptionally Unlikely	●●●●

Note that green circles indicate a favourable status, while orange squares indicate an unfavourable status, with the number of circles or squares indicating the degree to which the status is favourable or unfavourable.

Whether or not a stock is likely to be at or above the target level, or to be depleted or overfished, or collapsed, or subject to overfishing, is based on the most recent stock assessment summarised in the Ministry's Fishery Assessment Plenary Report. The current (2013) stock status may be better or worse than that indicated by the most recent stock assessment. Where several alternative assessment runs are reported (as is frequently the case), or if the assessment results are contentious, the result reported represents the best judgement on the part of the Chair of the appropriate Fisheries Assessment Working Group, and the Ministry's Principal Advisor Fisheries Science.

Corrective management action: This column describes corrective management action underway for those stocks believed to be below the target level, or subject to overfishing.

Grey shading indicates that stock status is unknown, because an appropriate quantitative analysis to ascertain stock status relative to a target or limit has not been undertaken, or because such an analysis was not definitive, generally because of insufficient or inadequate data.

Source: based on the Status of the Stocks 2012 data published by the Ministry for Primary Industries on its website (http://fs.fish.govt.nz/Page.aspx?pk=16&tk=47

THEME 3: BENTHIC IMPACTS

9 BENTHIC (SEABED) IMPACTS

Scope of chapter	This chapter outlines the main effects of mobile bottom (or demersal) fishing gear on seabed habitats and communities All trawl gears contacting the seabed and shellfish dredges are included. Danish seines and more or less static methods like bottom longline and potting are excluded in this version, as are fisheries outside the EEZ.
Area	All of the New Zealand Territorial Sea (TS) and Exclusive Economic Zone (EEZ). There will be some relevance for out-of-zone bottom trawl fisheries.
Focal localities	Areas that are fished more frequently and habitats that are more sensitive to disturbance are likely to be most affected; areas that are closed to bottom impacting methods will not be directly affected. Bottom trawling offshore is most intense on the western flanks and to the southwest of the Chatham Rise, the edge of the Stewart-Snares shelf, south of the Auckland Islands, and off the northwest coast of the South Island. In coastal waters shallower than 250 m, trawling is most intense along the east coast of North Island, south of East Cape, and in Tasman and Golden Bays. Shellfish dredges probably have the greatest effect but their footprint is much smaller than that of bottom trawl fisheries and in generally shallow waters.
Key issues	Habitat modification, potential loss of biodiversity, potential loss of benthic productivity, potential modification of important breeding or juvenile fish habitat leading to reduced fish recruitment.
Emerging issues	Potential for effects on habitats of particular significance to fisheries management (HPSFM). The need for (and opportunities presented by) better spatial information on inshore fisheries from finer scale reporting of fishing locations (including logbooks). Cumulative effects and interactions with other stressors (including existing effects, especially in the coastal zone, and climate change.
MPI Research (current)	BEN2007/01, *Assessing the effects of fishing on soft sediment habitat, fauna, and processes;* DAE2010/04, *Monitoring the trawl footprint for deepwater fisheries;* DAE2010/01, *Taxonomic identification of benthic samples*; ZBD201203, *Chatham Rise Benthos – Ocean Survey 20/20*.
NZ Government Research (current)	MBIE programmes: C01X0907, *Coastal Conservation Management;* C01X0906, *Impacts of resource use on vulnerable deep-sea communities*. Previous OBI programmes *Coasts & Oceans* C01X0501 and *Marine Biodiversity & Biosecurity* C01X0502, and MBIE programme C01X0808, *Deepsea mining of the Kermadec Ridge* are now part of NIWA core funding. DOC14302, Overlap of trawl footprint with protected coral distributions
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture
Related chapters/issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring, marine mining/sand extraction, land-based effects.

Note: This chapter has been updated for the AEBAR 2014.

9.1 CONTEXT

For the purpose of this document, the term “mobile bottom fishing methods” includes all types of trawl gear that are used in contact with the seabed as well as shellfish dredges of various designs and Danish seines. Relative to the information about trawls and dredges there is little information available about the distribution and effects of Danish seining, so Danish seining is not considered in detail. The benthic effects of other methods of catching fish on or near the seabed that do not involve deliberately towing or dragging fishing gear across the seabed are thought to be considerably less than those of the mobile methods (although they are not always negligible) and these methods are not considered in this document.

Trawls and dredges are used to catch a relatively high proportion of commercial landings in New Zealand and such methods can represent the only effective and economic way of catching some species. However, the resulting disturbance to seabed habitats and communities may have consequences for biodiversity and ecosystem services, including fisheries and other secondary production. The guiding sections of the Fisheries Act 1996 for managing the effects of fishing, including benthic effects, are s.8(2)(b) which specifies that "ensuring sustainability" (s.8(1)) includes "avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment" and s.9 which specifies a principle that "biological diversity of the aquatic environment should be maintained". Also potentially relevant is the principle in s.9 that "habitat of particular significance for fisheries management should be protected" (see the chapter on Habitats of Particular Significance for Fisheries Management for more details).

One approach to managing the effects of mobile bottom fishing methods is through the use of spatial controls. A wide variety of such controls apply in New Zealand waters (Figure 9.1). Some of these controls were introduced specifically to manage the effects of trawling, shellfish dredging, and Danish seining in areas or habitats considered sensitive to such disturbance (e.g., the bryozoans beds off Separation Point, between Golden and Tasman Bays, and the sponge-dominated fauna to the north of Spirits and Tom Bowling Bays in the far north). Other closures exist for other reasons but have the effect of protecting certain areas of seabed from disturbance by mobile bottom fishing methods. These include no-take marine reserves, pipeline and power cable exclusion zones, and areas set aside to protect marine mammals (e.g., see Figure 9.2 for areas where trawling is prohibited, Figure 9.3 for areas where gear and seasonal restrictions apply, and Figure 9.4 for areas related to marine reserves and marine farms). Marine reserves provide marine protection in a range of habitats within the Territorial Sea. Although marine reserves provide a higher level of protection by prohibiting all extractive activities, most tend to be small. New Zealand's 34 marine reserves protect about 7.6% of New Zealand's Territorial Sea; however, 99% of this is in two marine reserves in the territorial seas around offshore island groups in the far north and far south of New Zealand's EEZ (Helson et al 2010). Until 2000, most closures that had the effect of protecting areas of seabed from disturbance by trawling and dredging were in the Territorial Sea.

In the Exclusive Economic Zone, 18 seamount closures were established in 2000 to protect representative underwater topographic features from bottom trawling and dredging (Brodie & Clark 2003, see Figure 9.1). These areas include 25 features, including 12 large seamounts more than 1000 m high, covering 2% (81 000 km2) of the EEZ. The seamount areas are closed to all types of trawling and dredging. In 2006, members of the fishing industry proposed the closure of about 31% of the EEZ to bottom trawling and dredging in Benthic Protection Areas (BPAs), including the existing seamount closures. The design criteria for the BPAs were they should be large, relatively unfished, have simple boundaries, and be broadly representative of the marine environment. After a consultation process, a substantially revised package of BPAs (including three additional areas totalling 13 887 km2, 10 additional active hydrothermal vents, and 35 topographic features) that complemented the existing seamount closures was implemented by regulation in 2007 (Helson et al 2010, Figure 9.1). BPAs cover about 1.1 million km2 (30%) of New Zealand's EEZ and are closed to trawling on or close to the bottom. Midwater trawling well off the bottom is permitted in the BPAs if two observers are on board and an approved net monitoring system is used. Much of the seabed within BPAs is below trawlable depth (maximum trawlable depth is about 1600 m) and all are outside the Territorial Sea. In combination, the seamount closures and the BPAs include: 28% of underwater topographic features (a term that includes underwater hills, knolls, and seamounts); 52% of seamounts over 1000 m high; and 88% of known active hydrothermal vents.

9.2 GLOBAL UNDERSTANDING

Concerns about the use of towed fishing gear on benthic habitats were first raised by fishermen in the fourteenth century in the UK (Lokkeborg 2005). They were worried about the capture of juvenile fish and the detrimental effects on food sources for harvestable fish. Despite this long history of concern, it is really only in the last 20 years that research efforts have focused strongly on the effects of mobile bottom fishing methods on benthic (seabed) communities, biodiversity, and production. This activity, combined with controversy around fishing effects, has spawned numerous reviews in the past 10 years that seek to summarise or synthesise the information (Jones 1992, Dayton et al 1995; Jennings & Kaiser 1998; Watling & Norse 1998; Lindeboom & deGroot 1998, Auster & Langton 1999; Hall 1999; ICES 2000a and b, Kaiser & de Groot 2000; NMFS 2002, NRC 2002, Dayton et al 2002; Thrush & Dayton 2002; Lokkeborg 2005, Barnes & Thomas 2005, Clark & Koslow 2007).

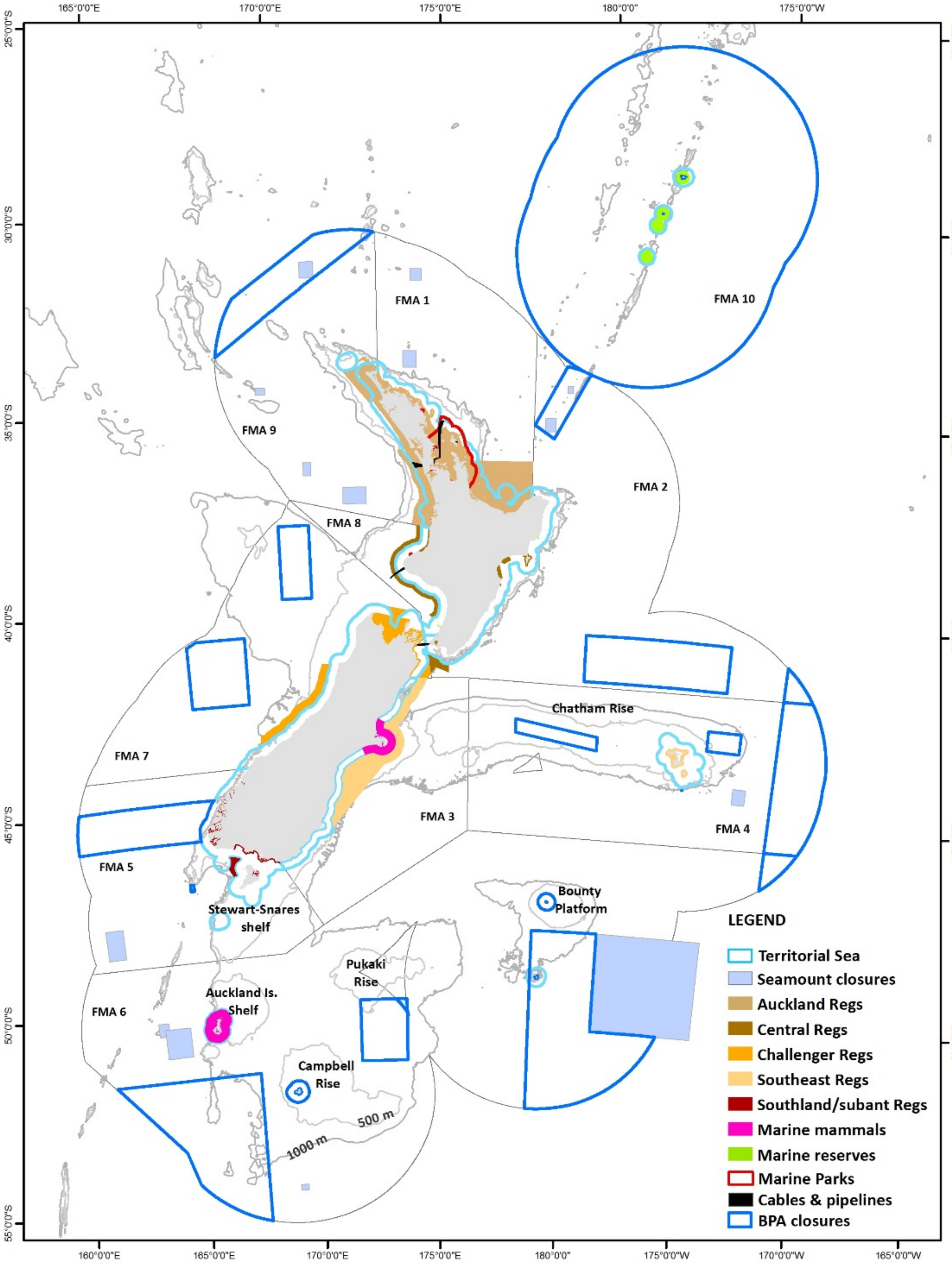


Figure 9.1: Map, adapted from Baird & Wood 2010, of the major spatial restrictions to trawling and the Ministry for Primary Industries Fishery Management Areas (FMAs) within the outer boundary of the New Zealand EEZ. Vessels longer than 28 m may not trawl within the TS and additional restrictions are specified in the Fisheries (Auckland Kermadecs Commercial Fishing) Regulations 1986, the Fisheries (Central Area Commercial Fishing) Regulations 1986, the Fisheries (Challenger Area Commercial Fishing) Regulations 1986 the Fisheries (South East Area Commercial Fishing) Regulations 1986, and the Fisheries (Southland and Sub-Antarctic Areas Commercial Fishing) Regulations 1991. For more details of BPAs see Helson et al 2010.

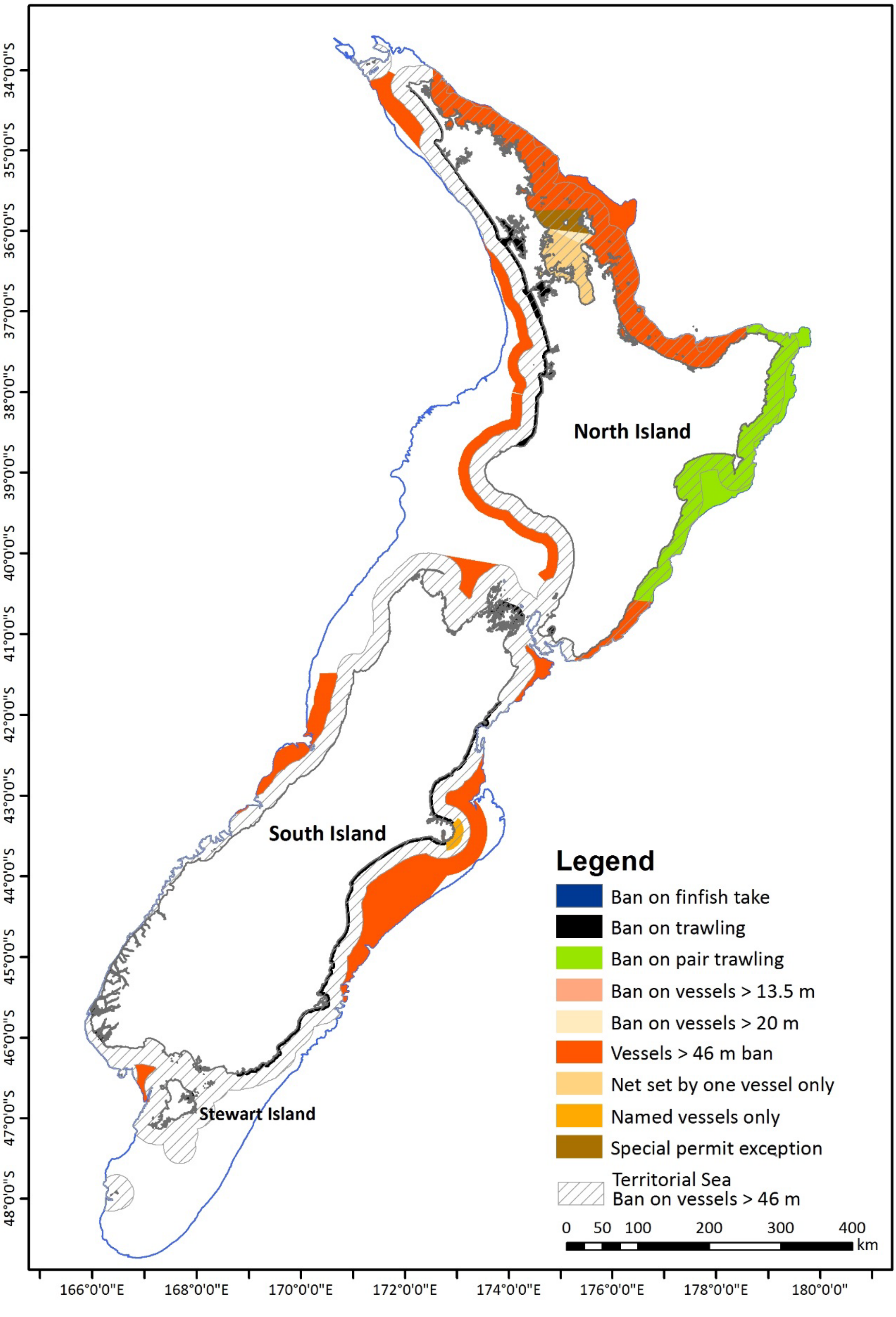


Figure 9.2: Areas showing where trawling is prohibited and other relevant restrictions apply in waters shallower than 250 m depth. Note the area shown as "Ban on pair trawling" also is closed to vessels over 46 m (Baird et al 2014).

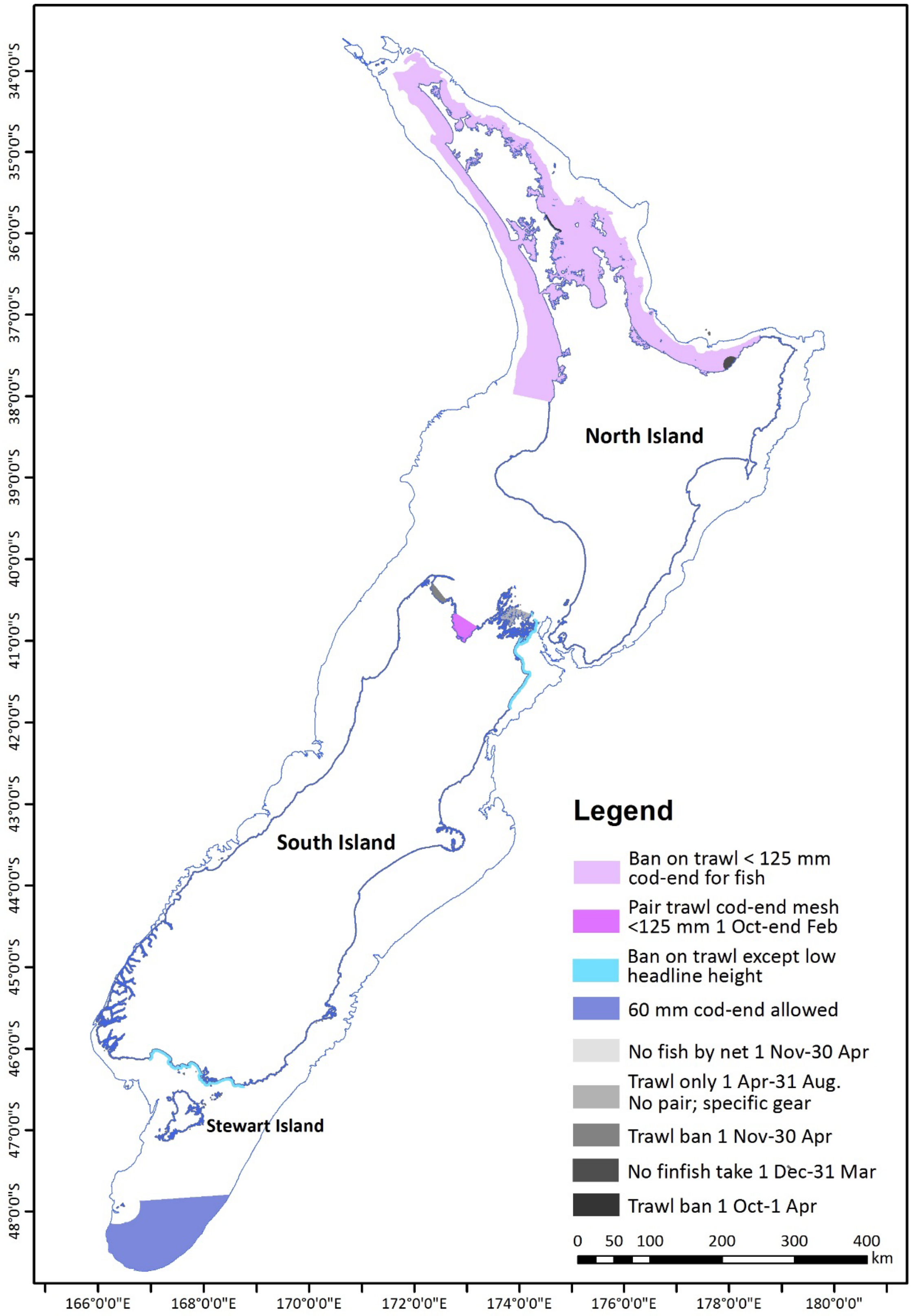


Figure 9.3: Areas where gear and seasonal restrictions apply to the use of trawl gear, in waters shallower than 250 m depth (Baird et al 2014).

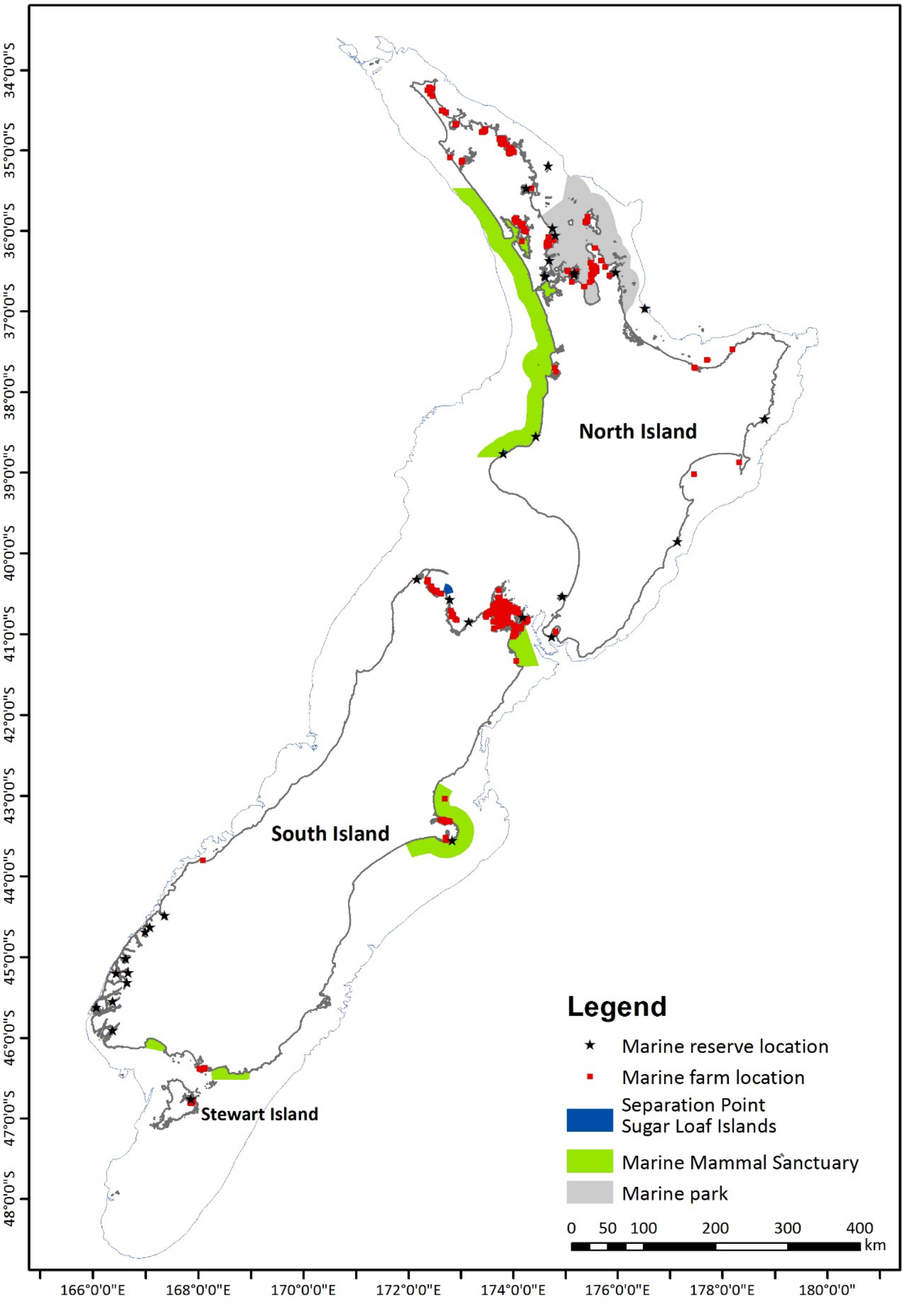


Figure 9.4: Points indicative of locations of marine reserves and marine farms, Separation Point and Sugar Loaf Islands closed areas, marine mammal sanctuaries, and marine parks, in waters shallower than 250 m depth (Baird et al 2014).

Benthic habitats provide shelter and refuge for juvenile fish and the associated fauna can be the prey of demersal fish species. Towed fishing gears (particularly trawl doors), affect benthic habitats and organisms but the level of effect will depend on the type of trawl doors and ground gear used, and the physical and biological characteristics of the seabed habitats in the fishing grounds. The effects are difficult to assess because of the complexity of benthic communities and their temporal and spatial variability, and interpretation can also be complicated by environmental gradients or change. For reasons of accessibility, cost, and tractability, most research on seabed disturbance caused by human activities worldwide has been carried out in coastal systems, and our understanding of the effects of physical disturbance in the sparse but highly diverse communities of the deep sea has developed only recently. The reviews above broadly indicate that numerical abundance of many invertebrates declines (sometimes substantially) after mining, trawling, or other major disturbance. Trawling and dredging can re-suspend sediment and can, depending on sediment and local currents, alter sediment characteristics. Physical effects include furrows and berms from trawl doors, furrows from the bobbins and rock hoppers, and sediment resorting, but the magnitude of these effects depends on sediment type, currents, and wave action (if any). Bottom trawling can also alter natural sediment fluxes and reduce organic carbon turnover (Pusceddu et al 2014), the depth of the oxic layer in sediments (Churchill 1989, Warnken et al 2003, Bradshaw et al 2012), and the shape of the upper continental slope (Puig et al 2012), reducing morphological complexity and benthic habitat heterogeneity. The mixing of sediments and overlying water can alter the chemical makeup of the sediment and have considerable effects in deep, stable waters (Rumohr 1998). Chemical release from the sediment can also be changed, as shown for phosphate in the North Sea (ICES 1992, noting lower fluxes were observed after trawling events). Trawling can alter benthic communities, reduce total biomass of benthic species, and increase predation by scavengers. Sites subject to greater natural disturbance are generally thought to be less susceptible to change from bottom contact fishing (but see Schratzberger et al 2009 who concluded that common anthropogenic disturbances differ fundamentally from natural disturbance). There has been less work on the effects of other methods of catching demersal fish or crustaceans that do not involve deliberately towing or dragging fishing gear across the seabed, but some of these methods can have non-negligible effects (e.g., Sharp et al 2009, Williams et al 2011).

Studies of recovery dynamics are rarer still, but a return to pre-disturbance levels after bottom-contact fishing can take up to several years, even in some sites subject to considerable natural disturbance (see Kaiser et al 2006 for a summary). In shallow regions with mobile sediments, the effects are generally difficult to detect and recovery can be rapid (e.g., Jennings et al 2005). Examining epifauna, Lambert et al (2014) estimated recovery from scallop dredging to take from less than 1 year to over 10 years, depending on functional group, with faster recovery in areas with faster tidal currents, and large bodied species recovering faster when conspecifics were abundant locally. Hard-bottom fauna is predicted to recover most slowly and Williams et al (2010) concluded that hard-bottom fauna on Australasian seamounts did not show signs of recovery within 5–10 years. Recovery rate is typically correlated with the spatial extent of a disturbance event (e.g., Hall 1994, Kaiser et al 2003, see also Figure 9.5) and the effects of some "catastrophic" natural disturbance events, such as large-scale marine mudslides, can be detected for hundreds of years, even for taxa thought to be robust to physical disturbance such as nematodes (Hinz et al 2008).

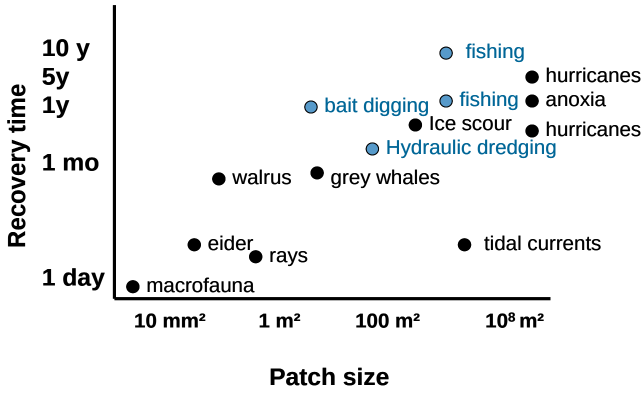


Figure 9.5: General relation between the spatial extent of disturbance events and the time taken to recover from such events in marine systems (after Kaiser et al 2003). Blue dots signal human impacts, including fishing in habitats of different abilities to recover, and black dots signal natural disturbance.

Rice (2006) summarised the findings of five major reviews of the effects of mobile bottom-contacting fishing gears on benthic species, communities, and habitats (available at: http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf). In this "review of reviews" Rice (2006) summarised the findings of the multiple working groups that contributed to the reviews as follows:

Rice's (2006) conclusions about the effects on habitats of mobile bottom fishing gears were that they:

- can damage or reduce structural biota (All reviews, strong evidence or support).
- can damage or reduce habitat complexity (All reviews, variable evidence or support).
- can reduce or remove major habitat features such as boulders (Some reviews, strong evidence or support).
- can alter seafloor structure (Some reviews, conflicting evidence for benefits or harm).

Other emergent conclusions on habitat effects included:

- There is a gradient of effects, with greatest effects on hard, complex bottoms and least effect on sandy bottoms (All reviews, strong support, with qualifications).
- There is a gradient of effects, with greatest effects on low energy environments and least (often negligible) effect on high-energy environments (All reviews, strong support).
- Trawls and mobile dredges are the most damaging of the gears considered (Three of the reviews considered other gears; all drew this conclusion, often with qualifications).

Mobile bottom gears affect benthic species and communities in that they:

- can change the relative abundance of species (All reviews, strong evidence or support).
- can decrease the abundance of long-lived species with low turnover rates (All reviews, moderate to strong evidence or support).
- can increase the abundance of short-lived species with high turnover rates (All reviews, moderate to occasionally strong evidence or support).
- affect populations of surface-living species more often and to greater extents than populations of burrowing species (All reviews, weak to occasionally strong evidence or support).
- have lesser effects in high-energy or frequent natural disturbance environments than in low energy environments where natural disturbances are uncommon (Four reviews (the other did not address the factor), strong evidence or support).
- affect populations of structurally fragile species more often and to greater extents than populations of "robust" species (All reviews, variable evidence and support).
- Abundance of scavengers increases temporarily in areas where bottom trawls have been used (Three reviews, variable support or evidence, all argue for the effects being transient).
- Rates of nutrient cycling or sedimentation are increased in areas where bottom trawls have been used (Two reviews, mixed views on magnitude of effects and conditions under which they occur).

Considerations in the application or adoption of mitigation measures:

- The effect of mobile fishing gears on benthic habitats and communities is not uniform. It depends on:
  - The features of the seafloor habitats, including the natural disturbance regime (All reviews, strong evidence or support);
  - the species present (All reviews, strong evidence or support, though not mentioned by NMFS panel);
  - the type of gear used and methods of deployment (All reviews, moderate to strong evidence support);
  - the history of human activities, particularly past fishing, in the area of concern (All reviews, strong evidence or support).
- Recovery time from trawl-induced disturbance can take from days to centuries, and depends on the same factors as listed above. (All reviews, strong evidence or support).
- Given the above considerations, the effect of mobile bottom gears has a monotonic relationship with fishing effort, and the greatest effects are caused by the first few fishing events (All reviews, moderate to strong evidence or support).
- Application of mitigation measures requires case specific analyses and planning; there are no universally appropriate fixes (Three reviews, moderate to strong evidence or support. The issue of implementing mitigation was not addressed in the FAO review. It was also stressed in the US National Academy of Sciences review and discussed in the ICES review that extensive local data are not necessary for such case-specific planning. The effects of mobile bottom gears on seafloor habitats and communities are consistent enough with well-established ecological theory,

and across studies, that cautious extrapolation of information across sites is legitimate).

Rice (2006) concluded *"These overall conclusions on impacts and mitigation measures, and recommendations for management action form a coherent and consistent whole. They are relevant to the general circumstances likely to be encountered in temperate, sub-boreal, and boreal seas on coastal shelves and slopes, and probably areas … beyond the continental shelves. They allow use of all relevant information that can be made available on a case by case basis, but also guide approaches to management in areas where there is little site-specific information."*

Since Rice's (2006) paper, Kaiser et al (2006) published a meta-analysis of 101 separate manipulative experiments that confirms many of Rice's findings. Shellfish dredges have the greatest effect of the various mobile bottom fishing gears, biogenic habitats are the most sensitive to such disturbance (especially for attached fauna on hard substrates) and unconsolidated, coarse sediments (e.g., sands) are the least sensitive. Kaiser et al (2006) concluded that recovery from disturbance events can take months to years, depending on the combination of fishing method and benthic habitat type. This meta-analysis of manipulative experiments was an important development, reinforcing the inferences drawn from multiple mensurative observations at much larger scale ("fisheries scale") in New Zealand (e.g., Thrush et al 1998, Cryer et al 2002) and overseas (e.g., Craeymeersch et al 2000, McConnaughey et al 2000, Bradshaw et al 2002, Blyth et al 2004, Tillin et al 2006, Hiddink et al 2006). This is a powerful combination that implies substantial generality of the findings.

The international literature is, therefore, clear that bottom (demersal) trawling and shellfish dredging are likely to have largely predictable and sometimes substantial effects on benthic community structure and function. However, the positive or negative consequences for ecosystem processes such as production had not been addressed until more recently (e.g., Jennings et al 2001, Reiss et al 2009, Hiddink et al 2011). It has been mooted that frequent disturbance should lead to the dominance of smaller species with faster life histories and that, because smaller species are more productive than larger ones, system productivity and production should increase under trawling disturbance. However, when this proposition has been tested, it has not been supported by data in real fishing situations (e.g., Hermsen et al 2003, Reiss et al 2009) and where overall productivity has been assessed, it decreases with increasing trawling disturbance.

For example, Veale et al (2000) examined spatial patterns in the scallop fishing grounds in the Irish Sea and found that total abundance, biomass, and secondary production (including that of most individual taxa examined) decreased significantly with increasing fishing effort. Echinoids, cnidarians, prosobranch molluscs, and crustaceans contributed most to the differences. Jennings et al (2001) showed that, in the North Sea, trawling led to significant decreases in infaunal biomass and production in some areas even though production per unit biomass rose with increased trawling disturbance. The expected increase in relative production did not compensate for the loss of total production that resulted from the depletion of large-bodied species and individuals. Hermsen et al (2003) found that mobile fishing gear disturbance had a conspicuous effect on benthic megafaunal production on Georges Bank, and cessation of such fishing led to a marked increase in benthic megafaunal production, dominated by scallops and urchins. Hiddink et al (2006) estimated that more than half of the southern North Sea was trawled sufficiently frequently to depress benthic biomass by 10% or more, and that 27% was in a state where benthic production was depressed by 10% or more. They estimated that recovery from this situation would take 2.5–6 years or more once fishing effort had been eliminated. They further estimated that fishing reduced benthic biomass and production by 56% and 21%, respectively, compared with an unfished situation. Reiss et al (2009) found that, although sediment composition was the most important driver of benthic community structure in their North Sea study area, the intensity of fishing effort was also important and reductions in the secondary production of the infaunal community could be detected even within this heavily fished region.

The types of models developed by Hiddink et al 2006, 2011 (but see also Ellis & Pantus 2001 and Dichmont et al 2008) can be used to assess the likely performance of different management approaches or levels of fishing intensity. Such management-strategy-evaluation (MSE) methods involve specifying management objectives, performance measures, a suite of alternative management strategies, and evaluating these alternatives using simulation (Sainsbury et al 2000). For instance, the early study by Ellis & Pantus (2001) assessed the effect of trawling on marine benthic communities by combining an implementation of the spatial and temporal behaviour of the local fishing fleet with realistic ranges for the removal and recovery of benthic organisms. The model was used to compare the outcomes of two radically different management approaches, spatial closures and reductions in fishing effort. From a New Zealand perspective, Mormede & Dunn (2013) developed a simple spatially explicit population model as a tool to assist Ecological Risk Assessments, and Lundquist et al (2010, 2013) used a more sophisticated spatially explicit landscape mosaic model with variable connectivity between patches to assess the implications of different spatial and temporal patterns of disturbance in the model landscape. They found that the scale of the disturbance regime (which could be trawling or any other physical disturbance) and the dispersal processes interact, and that the scales of these processes greatly influenced changes in the structure and diversity of the model community, and that recovery across the mosaic depended strongly on dispersal. System stability also decreased as dispersal distance decreased. Patterns of abundance of different species groups observed across gradients of fishing pressure were in general agreement with model predictions.

9.3 STATE OF KNOWLEDGE IN NEW ZEALAND

To understand the effects of mobile bottom fishing methods on benthic habitats, it is necessary to have knowledge of:

- the distribution of such habitats,
- the extent to which mobile bottom fishing methods are used in each habitat (the overlap),
- the consequences of any such disturbance (potentially in conjunction with other disturbances or stressors), and
- the nature and speed of recovery from the disturbance.

These components will be dealt with in turn.

9.3.1 DISTRIBUTION OF HABITATS

Mapping of benthic habitats at the large scales inherent in fisheries management is expensive and time-consuming so the New Zealand government commissioned an environmental classification to provide a spatial framework that subdivided the TS and EEZ into areas having similar environmental and biological character. This Marine Environment Classification (MEC) was launched in 2005 (Snelder et al 2004, 2005, 2006) using available physical and chemical predictors, because environmental pattern was thought a reasonable surrogate for biological pattern. The authors suggested that the MEC provided managers with a useful spatial framework for broad scale management, but cautioned that the full utility and limitations would become clear only as the MEC was applied to real issues. They described the MEC as a tool to organise data, analyses and ideas, and as only one component of the information that would be employed in any analysis. The 20-class version (Figure 9.6, Table 9.1) has been the most widely cited, although additional classification levels provide more detail that is significantly correlated with biological layers. The 2005 MEC was not optimised for any specific ecosystem component but was "tuned" against data for demersal fish, phytoplankton, and benthic invertebrates. It performed least well as a classification of benthic invertebrates and, at the 20-class level, grouped most of the Chatham Rise and Challenger Plateau into a single class. Although separation of these two areas was evident as the MEC was driven to larger numbers of classes, their inclusion within a single class in the 20-class classification was considered counter-intuitive because their productivity and fisheries are known to be very different.

This disquiet with the predictions of the original MEC for benthic habitat classes led to the development of alternatives that might perform better for benthic systems. First of these was a classification optimised for demersal fish (Leathwick et al 2006). Several variants of this classification out-performed the original MEC for demersal fish, particularly at lower levels of classification detail and it was adopted by the Ministry for the Environment for their indicators related to bottom trawling and their 2010 Environmental Snapshot where the trawl footprint is compared with putative habitats (Ministry for the Environment 2010, see also: https://www.mfe.govt.nz/environmental-reporting/marine/fishing-activity-indicator/fishing-activity-seabed-trawling.html).

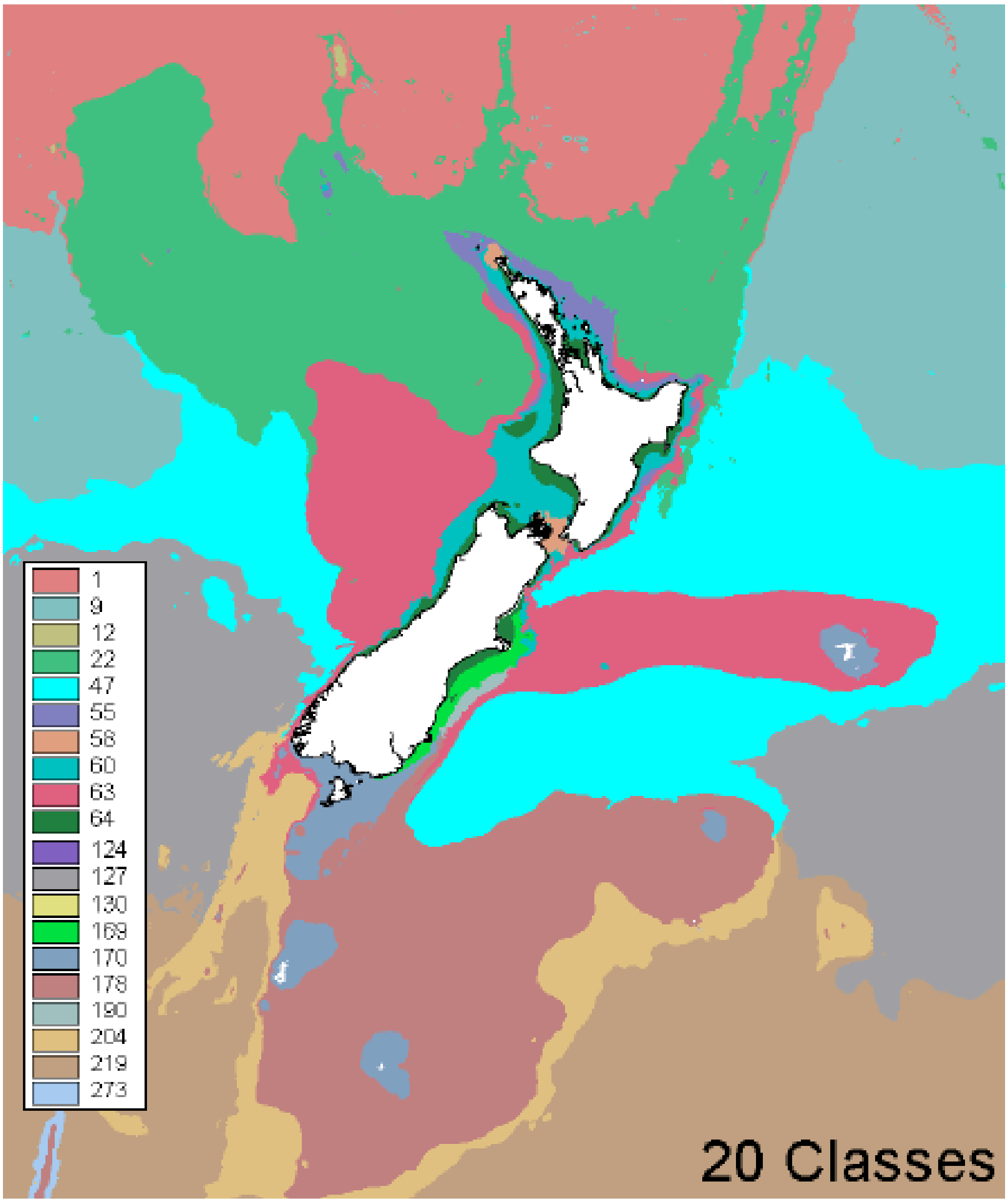


Figure 9.6: The 20-class version of the 2005 general purpose Marine Environment Classification (MEC, from Snelder et al 2005). The class numbers are nominal; for attributes of each class at this level, see Table 9.1.

Based partly on this experience, the Ministry of Fisheries commissioned a Benthic-Optimised Marine Environment Classification, BOMEC. Many more physical, chemical, and biological data layers were available for the development and tuning of this classification than for the 2005 MEC. Especially relevant for benthic invertebrates was the inclusion of a layer for sediment grain size (notably absent from the MEC). Generalised Dissimilarity Modelling (GDM, Ferrier et al 2002, 2007, Leathwick et al 2011) was used to define the classification because this approach is well suited to the sparse and unevenly distributed biological data available. The BOMEC classes (15-class level version shown in Figure 9.7) were strongly driven by depth, temperature, and salinity into five major groups: inshore and shelf; upper slope; northern mid-depths; southern mid-depths; and deeper waters (generally beyond the fishing footprint, down to 3000 m, the limit of the analysis). Waters deeper than 3000 m could be considered an additional class. The 15-class BOMEC levels were used in conjunction with a broad sediment type classification and broad depth bands to identify 112 benthic habitats shallower than 250 m (Figure 9.8)(Baird et al 2014).

Recent testing (Bowden et al 2011) has indicated that the BOMEC out-performs the original MEC at predicting benthic habitat classes on and around the Chatham Rise, but that none of the available classifications is very good at predicting the abundance and composition of benthic invertebrates at the fine scale of the sampling undertaken (tens of metres to kilometres). This, in conjunction with the findings of Leathwick et al (2006), reinforces the role of environmental classifications as broad-scale predictors of general patterns at broad scale (tens to hundreds of kilometres) when more specific biological information is not available.

Where broad scale classification methods are not applicable, other approaches have been taken. The trawl fisheries for orange roughy, oreos, and cardinalfish take place to a large extent on seamounts or other features (Clark & O'Driscoll 2003, O'Driscoll & Clark 2005). These features are often geographically small and, in common with other, localised habitats like vents, seeps, and sponge beds, do not appear on broad-scale habitat maps (e.g., at EEZ scale) and cannot realistically be predicted by broad-scale environmental classifications. Many features have been extensively mapped in recent years (e.g., Rowden et al 2008), and seamount classifications based on biologically-referenced physical and environmental "proxies" have also been developed, in New Zealand waters by Rowden et al (2005), and globally by Clark et al (2010a&b). Davies & Guinotte (2011) developed a method of predicting the framework-forming (i.e, physically structuring) coldwater corals that are a focus for benthic biodiversity in deepwater systems. Work continues worldwide, including in New Zealand, on the development of sampling, analytical, and modelling techniques to provide cost-effective assessments of the distribution of marine habitats at a range of scales. Bowden et al (2014) provide a desk top assessment of future options for monitoring deepwater benthic communities, and conclude that photographic approaches sampling mega-epifauna are likely to be the most cost effective and relevant for detecting ecological effects at the scale of deep sea fisheries. Such sampling could be added to existing surveys, but would require dedicated time. Opportunistic sampling from trawl surveys or observer data cannot be relied upon to provide representative samples of the benthic community. NIWA has a MBIE-funded project "Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region" in collaboration with Victoria University of Wellington and the Marine Conservation Institute (USA). The research will develop a model to predict the locations of VMEs to inform New Zealand and South Pacific Regional Fisheries Management Organisation (SPRFMO) initiatives on spatial management in the South Pacific region. There may be applications within the New Zealand EEZ.

Table 9.1: Average values for each of the eight defining environmental variables in each class of the 20-class level of the MEC classification. After Snelder et al 2005.

Class	Area (km^2)	Depth	Slope	Orbital velocity	Radiation mean	SST amplitude	SST gradient	SST winter	Tidal current	2-class level	4-class level	9-class level
1	88,503	-3001	1.4	0	17.5	2.3	0.01	19.5	0.06	Oceanic	Subtropical	Deep
22	53,368	-1879	1.5	0	15.4	2.4	0.01	16.3	0.11			
9	64,306	-5345	1.4	0	14.8	2.6	0.01	16.1	0.03			Abyssal
47	60,053	-2998	1.0	0	12.1	2.4	0.01	11.6	0.07		Shelf and subtropical front	Central
55	2,213	-334	1.6	0	15.5	2.4	0.02	15.1	0.20			
63	26,626	-754	0.9	0	12.8	2.4	0.02	12.1	0.18			
178	39,360	-750	0.4	0	9.5	1.3	0.01	7.6	0.15			Southern
127	60,884	-4830	0.5	0	10.7	1.7	0.01	10.0	0.05		Sub-Antarctic	
204	18,277	-2044	3.0	0	9.2	0.9	0.01	8.0	0.08			
273	805	-2550	9.1	0	8.4	1.4	0.03	4.4	0.05			
219	93,982	-4779	0.6	0	8.9	1.0	0.01	6.7	0.04			
12	149	-94	0.9	113	17.8	2.3	0.01	19.3	0.30	Coastal		Northern
58	394	-117	0.7	57	14.7	2.2	0.03	13.0	1.09			Central
60	4,084	-112	0.3	21	14.4	2.5	0.02	13.2	0.26			
64	2,689	-38	0.3	272	14.2	2.9	0.02	12.6	0.19			
124	68	-8	0.4	836	13.4	2.3	0.02	12.7	0.00			
130	14	-10	0.4	353	14.1	2.4	0.09	11.9	0.21			
169	932	-66	0.2	113	12.4	2.7	0.04	9.9	0.21			
190	339	-321	1.9	3	12.3	2.3	0.06	9.4	0.10			
170	5,208	-129	0.3	99	10.2	1.3	0.02	9.3	0.55			Southern

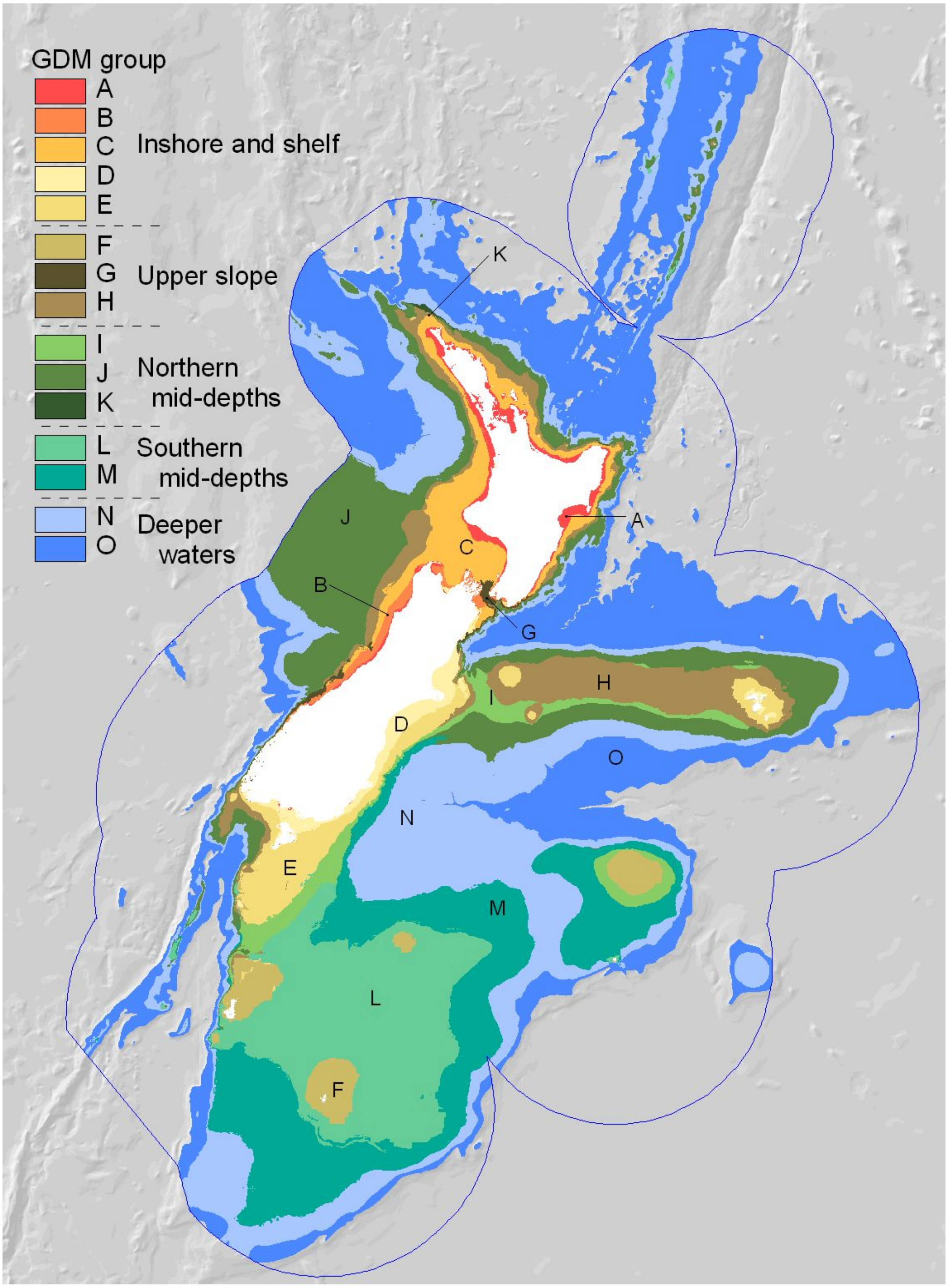


Figure 9.7: Map of the distribution of Benthic Optimised Marine Environment Classification (BOMEC) classes defined by multivariate classification of environmental data transformed using results from GDM analyses of relationships between environment and species turnover averaged across eight taxonomic groups of benthic species. From Leathwick et al 2010.

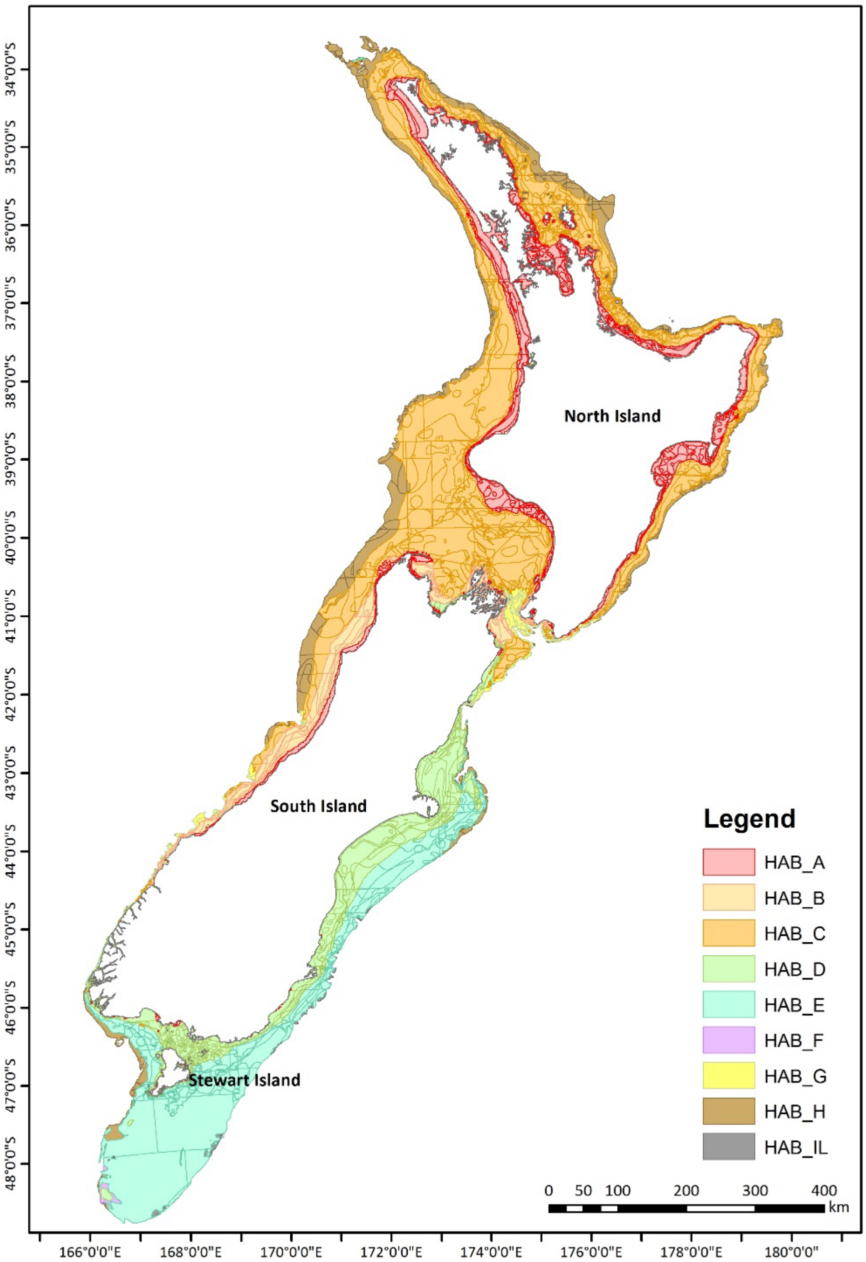


Figure 9.8: The broad habitat definitions based on the BOMEC classes, with divisions indicating areas of different sediment, depth zone, and statistical area in waters shallower than 250 m depth. From Baird et al (2014).

9.3.2 DISTRIBUTION OF FISHING

Since 1989–90, mobile bottom fishing has been reported on one of three standardised reporting forms (Table 9.2). Trawl Catch Effort and Processing Returns (TCEPRs) contain detailed spatial and other information for each trawl tow, whereas Catch Effort and Landing Returns (CELRs) include only summarised information for each day's fishing, with very limited spatial resolution. Since 2007–08, Trawl Catch and Effort Returns (TCERs) have been available for smaller, predominantly inshore trawlers. These include spatial and other information for each trawl tow but in less detail than on TCEPRs. Between 1989–90 and 2004–05, only about 25% of all mobile bottom fishing events were reported on TCEPRs. Another 25% were bottom trawls reported on CELRs, and the remaining 50% were dredge tows for shellfish reported on CELRs. The distribution of trawling reported on CELRs is not the same as that reported on TCEPRs; the smaller trawlers using CELRs are much more likely than the larger boats to fish close to the coast and target inshore species such as flatfish, red cod, tarakihi, and red gurnard (collectively 73% of all trawl tows reported on CELRs).

Table 9.2: Attributes, usage, and resolution of spatial reporting required on Trawl Catch Effort and Processing Returns (TCEPRs) Trawl Catch and Effort Returns (TCERs) and Catch Effort and Landing Returns (CELRs).

	Trawl catch and effort reporting forms		
	TCEPR	TCER	CELR
Year of introduction	1988–89	2007–08	1988–89
Vessels using	All trawlers >28 m Other vessels as directed Other vessels optional	All trawlers 6–28 m unless exempted	Trawlers not using TCER or TCEPR Shellfish dredgers
Trawl tow reporting	Tow by tow, start and finish locations, speed, depth, gear	Tow by tow, start location, speed, depth, gear	Daily summary, number of tows, effort, gear
Spatial resolution	1 minute (lat/long)	1 minute (lat/long)	Statistical reporting area (optionally lat/long)

Baird et al (2002) and Baird et al (2011) described the distribution and frequency of reported fishing by mobile bottom fishing gear (dredge, Danish seine, bottom trawl, bottom pair trawl, and mid-water trawl in contact with the bottom) in New Zealand's TS and EEZ during the 1990s and up to 2004–05, respectively, and this work has recently been updated to 2009–10 by Black et al (2013) for data reported on TCEPR. They showed that fishing was highly heterogeneous (spatially), but had considerable consistency among years; sites that were fished heavily in one year were likely to be fished heavily in other years and vice versa. A similar but more detailed analysis was conducted for the Chatham Rise and Sub-Antarctic areas by Baird et al (2006). Tows reported on TCEPRs were included in the main spatial analysis but some additional analysis was possible using tows reported on CELRs. Until 2006–07, many inshore vessels used CELRs and these comprised a substantial proportion of reported trawling, even for some "deepwater" species. For instance, Cryer & Hartill (2002) estimated that, in the Bay of Plenty in the 1990s, 78%, 75%, and 39% of trawl tows targetting tarakihi, gemfish, and hoki, respectively, were reported on CELR forms. Since 2007–08, almost all trawling effort has been reported on TCEPR or TCER forms.

Black et al (2013) updated the three annual measures of fishing effort: the number of tows, the aggregate swept area (using assumed door spreads, see Figure 9.9), and the coverage ("footprint") of the total trawl contact. Trawls were represented spatially as tracklines between the reported start and finish positions buffered by the assumed door spread to generate trawl polygons. The aggregate swept area for a year is the sum of the areas of the polygons and the "footprint" is the estimated area of the seabed that is covered by the polygons overlaid. The estimated swept areas and footprint do not account for any modification that might occur alongside the trawl path as represented by the swept area polygon (e.g., by suspended sediments transported by currents away from the trawl track). Black et al (2013) produced maps of the aggregate swept area by year for each of the 11 main target species or species groups, and various tables and figures describing trends. The annual number of trawls peaked in 1997–98 at 74 504 tows (swept area about 201 575 km^2). In 2009–10, 34 060 tows were reported on TCEPRs (about 79 600 km^2)

Baird et al (2011) used reported tows on small topographic features that are a focus for orange roughy and cardinalfish fisheries by defining polygons for these tows as radii around the reported start position with the area swept estimated from the reported duration and speed of the tow. These short tows do not appear to contribute substantially to broad-scale plots like Figure 9.9, yet can represent intense fishing effort on particular, small seamount features (e.g. Rowden et al 2005, O'Driscoll & Clark 2005).

Previous trawl footprint analyses (Baird et al 2011; Black et al 2013) have recognised that they underestimated trawl effort in inshore areas through exclusion of data recorded on CELR forms. Baird et al (2014) analysed a combined data set of TCEPR and TCER data for the area shallower than 250 m for 2007–08 to 2011–12 (Figure 9.9, Figure 9.10).

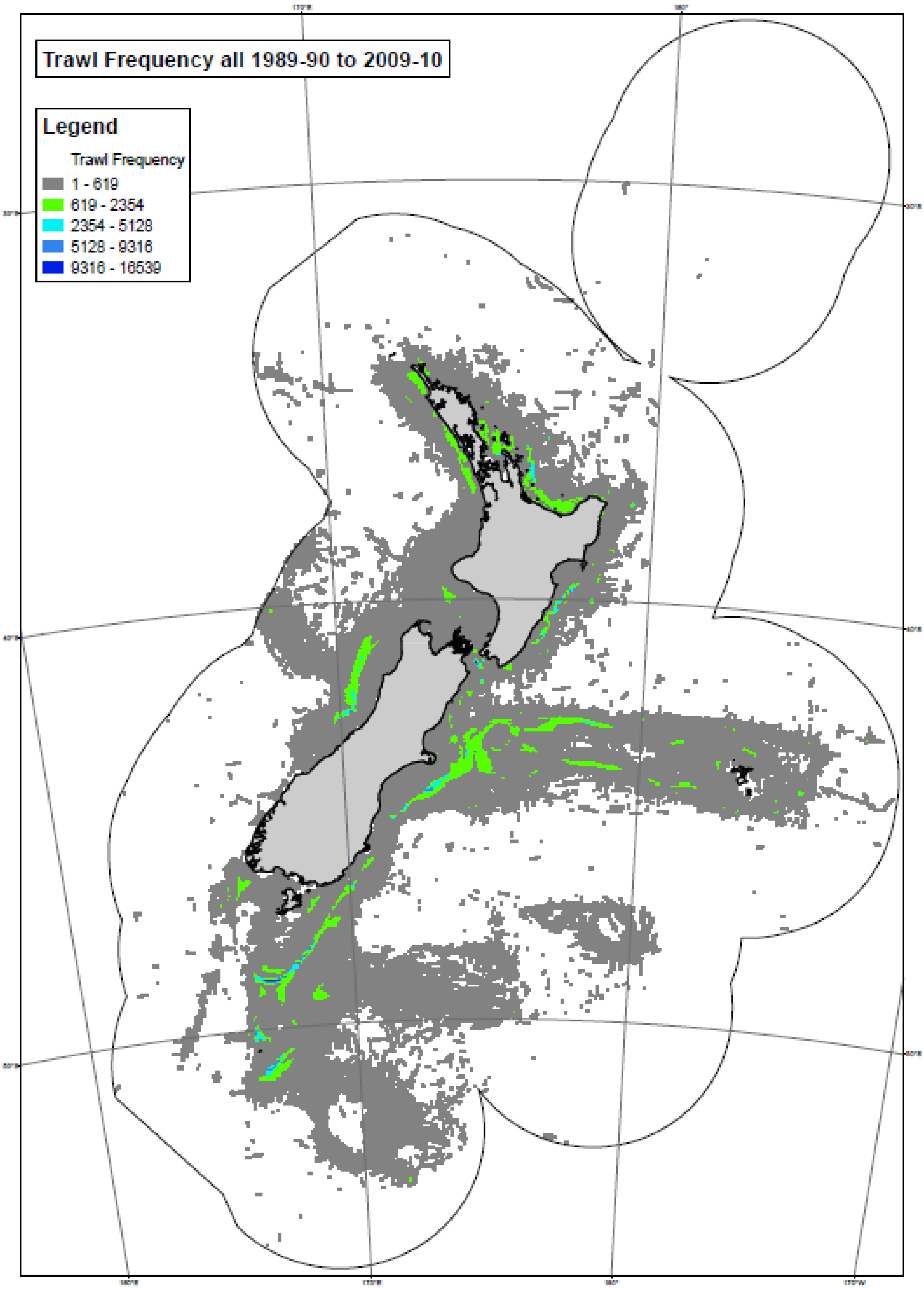


Figure 9.9: Map from Black et al 2013 showing the frequency of bottom-contacting trawling effort reported on TCEPR forms 1989–90 to 2009–10. The colour scale indicates the frequency of bottom trawling estimated by Black et al for each 5 × 5 km cell, all target species combined (e.g., the most frequently fished 25 km2 cells had over 16 000 tows recorded over 21 years).

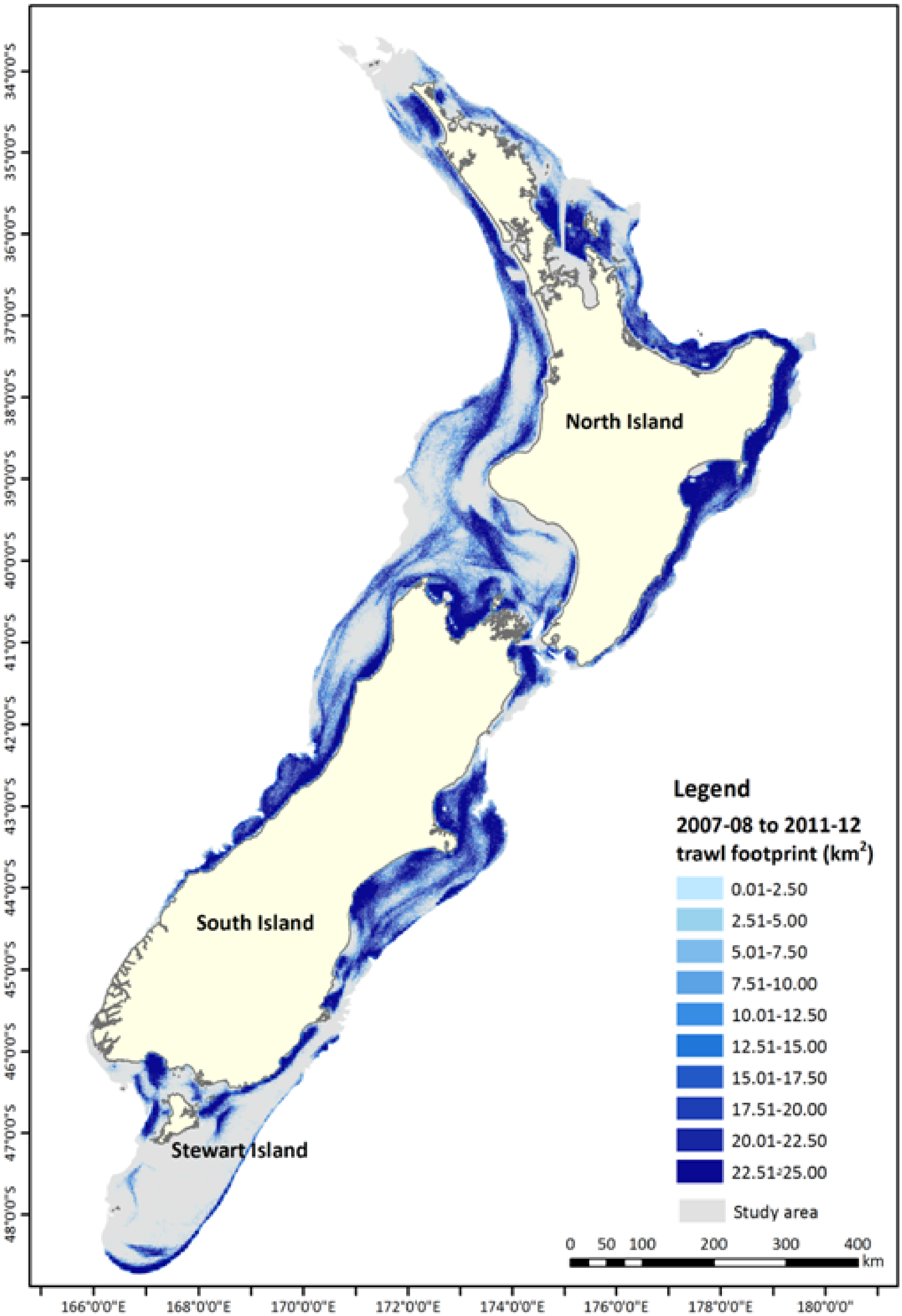


Figure 9.10: Total trawl cell based for footprint for the area shallower than 250 m for 2007–08 to 2011–12 combined (Baird et al 2014).

After the peak of over 140 000 reported trawl tows in 1996–97 and 1997–98 (Figure 9.11) when slightly over half of all tows were reported on TCEPRs, overall trawling effort declined to less than 80 000 tows per year by 2013–14, only about 40% of which is reported on TCEPRs (virtually all other tows are reported on TCERs).

Dredging for shellfish (oysters and scallops) is conducted in a number of specific areas that have separate, smaller statistical reporting areas (Figure 9.12). Over the 16-year dataset, there were almost 1.5 million scallop dredge tows in the four main scallop fisheries and over 0.6 million oyster dredge tows in the two dredge oyster fisheries. These data are collected on CELRs, usually at the spatial scale of a scallop or oyster fishery area and the data have been summarised as the number of dredge tows. No estimates of the area swept by these dredges have been made, but the number of reported tows has declined markedly since the early 1990s (Figure 9.13).

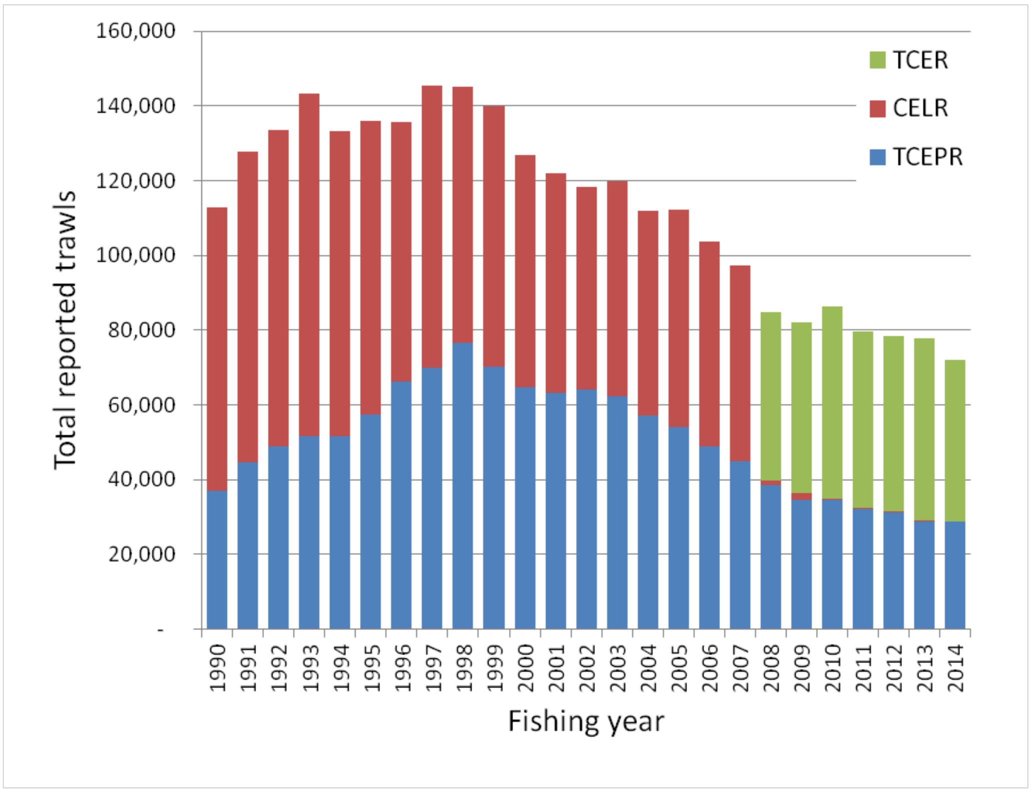


Figure 9.11: The number of trawl tows reported on Trawl Catch Effort and Processing Returns (TCEPR), Catch Effort and Landing Returns (CELR) and Trawl Catch and Effort Return (TCER) between the 1989–90 (1990) and 2013–14 (2014) fishing years. Data for the 2013–14 year may be incomplete.

Our knowledge of the distribution of mobile bottom fishing effort within our TS and EEZ is, by international standards, very good; since 2007–08 we have had tow-by-tow reporting of almost all trawling with a spatial precision of about 1 nautical mile. The distribution of dredge tows for shellfish is not reported with such high precision, but records kept by fishers in industry logbooks are often much more detailed than the Ministry for Primary Industries standard returns, and have sometimes been used to support spatial analyses that would not have been possible using the standard returns (e.g., Tuck et al 2006 for project ZBD2005/15 on the Coromandel scallop fishery and Michael et al 2006 for project ZBD2005/04 on the Foveaux Strait oyster fishery). These studies indicate the value of records with higher spatial precision.

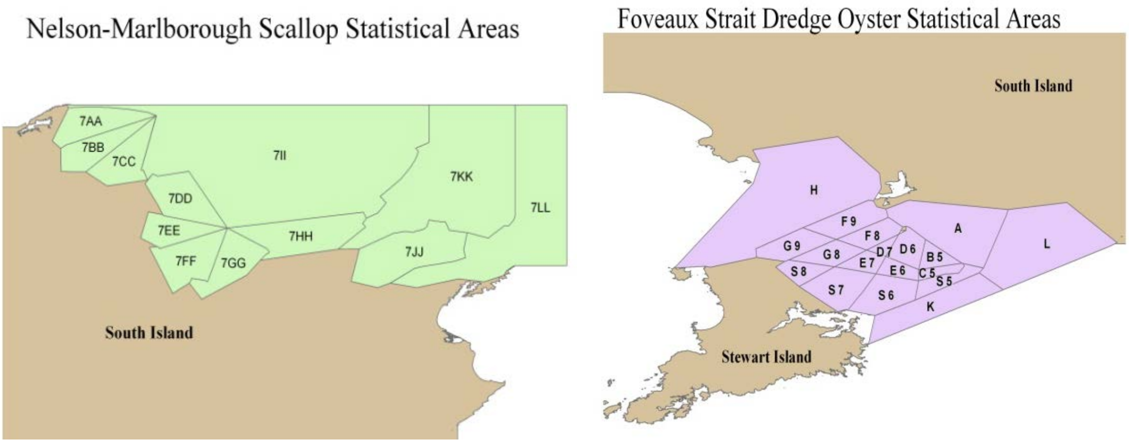


Figure 9.12: Maps taken from Baird et al 2011 of statistical reporting areas for the main oyster and scallop dredge fisheries (scales differ). Note that these reporting areas are generally much smaller than the standard statistical reporting areas used for most finfish reporting. [Continued on next page]

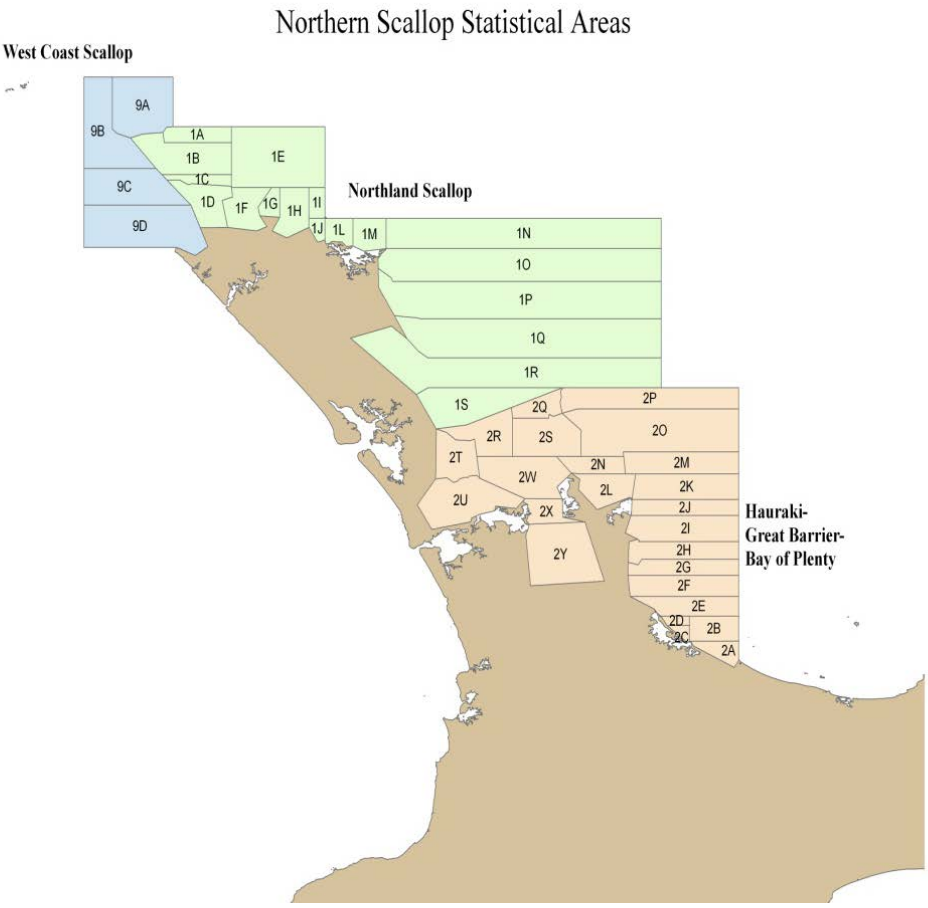


Figure 9.12 [Continued]: Maps taken from Baird et al 2011 of statistical reporting areas for the main oyster and scallop dredge fisheries (scales differ). Note that these reporting areas are generally much smaller than the standard statistical reporting areas used for most finfish reporting.

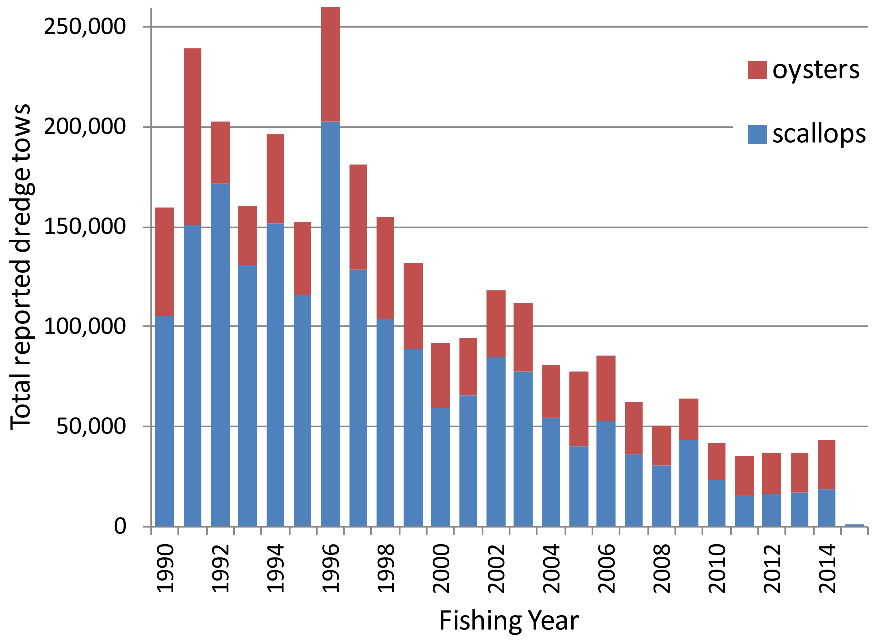


Figure 9.13: The number of dredge tows for scallop or oysters reported on Catch Effort and Landing Returns (CELR) between the 1989–90 (1990) and 2014–15 (2015) fishing years (data from Baird et al 2011 and MPI databases). Data for the 2014–15 year may be incomplete.

9.3.3 OVERLAP OF FISHING AND PREDICTED HABITAT CLASSES

Tuck et al (2014) reviewed a wide range of ecosystem indicators for deepwater fisheries, and concluded that in relation to benthic impact of fishing, indices of fishing footprint and fishing intensity by habitat and gear or fishery were likely to be the most useful. Black et al (2013) overlaid the 1989–90 to 2009–10 fishing year trawl footprint on the 15-class BOMEC to estimate the proportion of each class that had been trawled (and reported on TCEPRs) (Figure 9.14). They found that the size of the footprint and the proportion of each class trawled varied substantially between habitat classes (Figure 9.15, Table 9.3). Class O is the largest BOMEC class but has almost no reported fishing effort. Conversely, class I is one of the smaller classes but has a larger trawl footprint that overlaps 73% of the total class area. Two contrasting classes, together with their trawl footprints, are shown in Figure 9.16, based on analysis up to 2004–05. The trawl footprint from Black et al's analysis overlaps about 15% of the 2.6 million km2 of seafloor covered by the BOMEC, or about 9% of the 4.1 million km2 of seafloor within the New Zealand EEZ boundary (i.e., including the Territorial Sea). However, this overlap and that for some individual BOMEC classes (particularly coastal classes A–E) will be underestimated because of the omission of CELR data from these analyses.

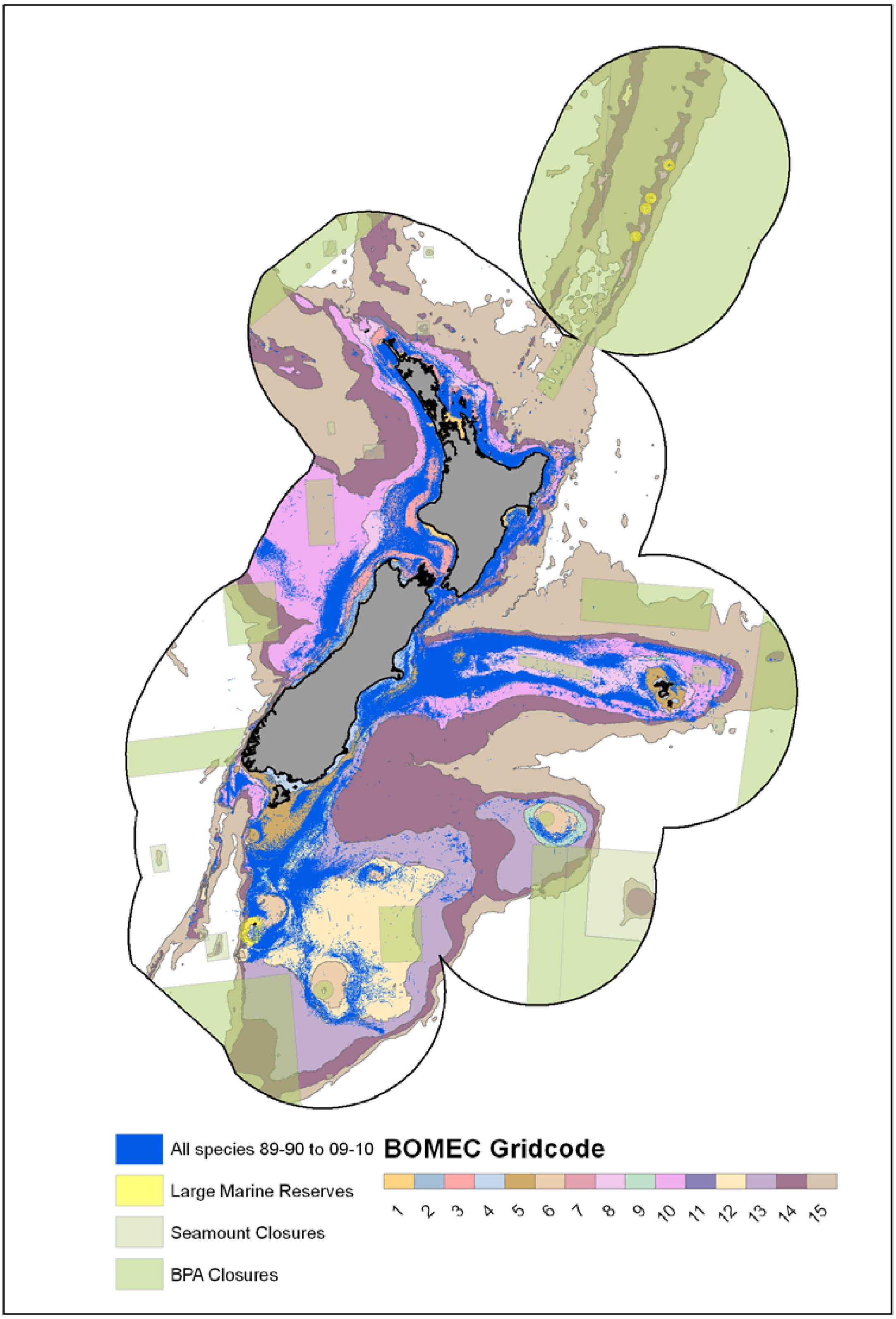


Figure 9.14: Plots from Black et al (2013) of the TCEPR trawl footprint (1989–90 to 2009–10) overlaid onto the 15-class level BOMEC.

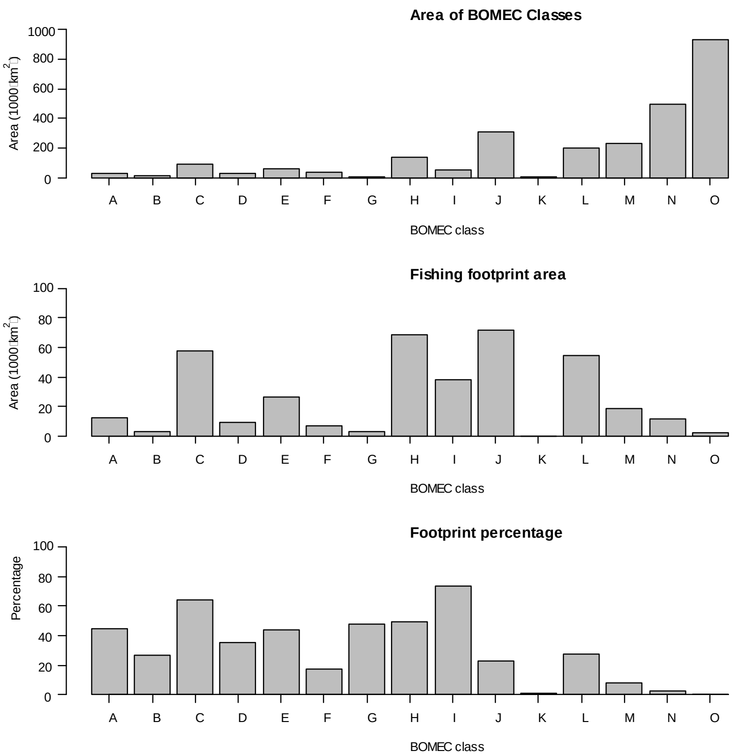


Figure 9.15: Plots from data provided by Black et al (2013) of the areas of each BOMEC Class (top), the fishing footprint up to 2009–10 shown in Figure 9.8 (centre), and percentage of each BOMEC Class area covered by the fishing footprint (bottom).

Table 9.3: Estimated area of each BOMEC class (within the outer boundary of the EEZ), and cumulative footprint from TCEPR over the fishing years 1989–90 to 2009–10 (Black et al 2013).

BOMEC class	Area (km^2)	Footprint area (km^2)	Footprint area (%)
A*	27 557	12 400	45%
B*	12 420	3 324	27%
C*	89 710	57 840	64%
D*	27 268	9 592	35%
E*	60 990	23 612	44%
F	38 608	6 691	17%
G	6 342	3 043	48%
H	138 550	68 389	49%
I	52 224	38 238	73%
J	311 361	71 594	23%
K	1 290	14	1.1%
L	198 577	54 337	27%
M	233 825	18 503	8%
N	493 034	11 369	2%
O	935 315	2 431	0.3%
Total	2 627 073	384 376	15%

* the trawl footprint and proportion overlapped in coastal classes A–E will be grossly underestimated because CELR data are excluded.

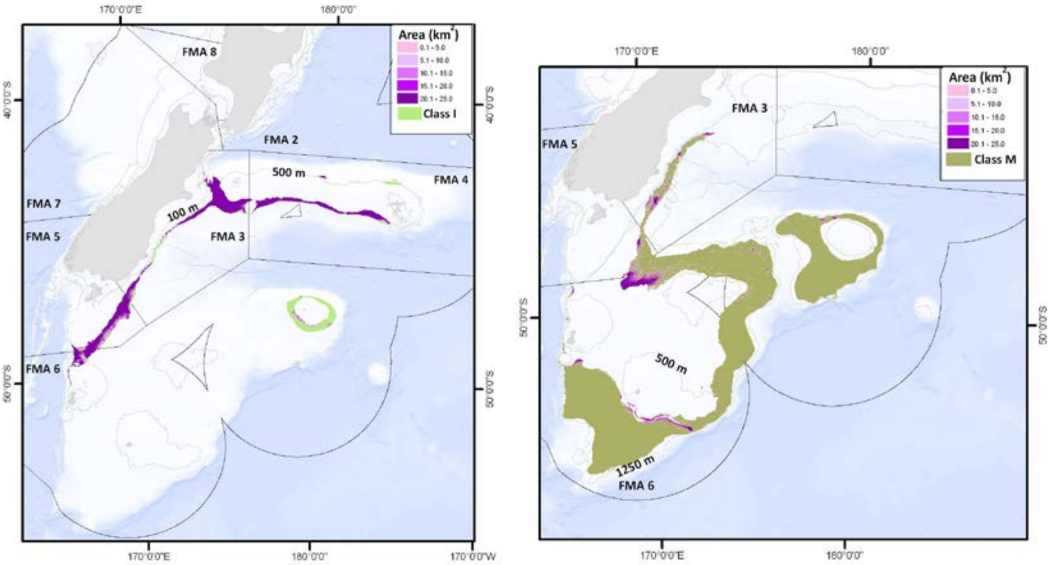


Figure 9.16: Maps from Baird & Wood (2010) showing BOMEC classes I (left) and M (right) overlaid with the footprint of trawls on or near the seafloor reported on TCEPR forms to 2004–05 for each 25-km2 cell.

Baird et al (2014) overlaid the combined TCER and TCEPR 2007–08 to 2011–12 fishing years trawl footprint on a classification for benthic habitats shallower than 250 m (presented in Figure 9.8). As with the offshore data, the size of the footprint and proportion of each class trawled varied between habitat classes (Table 9.4), and ranged from 21% (class F) to 76% (class B). Over the 2007–08 to 2011–12 period, the trawl footprint overlays 48% of the area shallower than 250m.

Table 9.4: Areas* of the separate habitat classes and areas† of the 5-y trawl footprint in each habitat class, for the BOMEC classes, depth zones, and sediment types, and the percentage of the 5-y trawl footprint in each class (see Baird et al. 2014 for more details).

Habitat class descriptors	Habitat class area (km^2)	Total footprint (km^2)	% area with trawl contact
BOMEC class			
A	27 375.2	14 047.1	52.1
B	12 318.8	9 322.3	75.7
C	89 560.4	47 120.0	52.6
D	25 513.1	16 344.7	64.4
E	47 186.8	13 890.6	29.6
F	381.7	73.2	21.1
G	3 898.4	1 902.9	50.8
H	25 204.4	9 228.1	36.8
I	473.2	340.8	72.0
J	133.9	31.3	30.0
L	188.9	121.5	67.6
Depth zone			
< 50 m	50 781.3	29 529.4	58.8
50–100 m	63 493.9	37 375.2	59.1
100–250 m	117 959.8	45 517.9	38.7
Sediment type			
Sand	104 830.2	54 851.9	52.4
Mud	72 518.1	41 001.8	57.0
Gravel	18 530.0	9 339.3	50.6
Sandy mud	203.4	203.4	99.98
Calcareous sand	6 763.7	2 080.7	31.3
Calcareous gravel	29 389.5	4 945.4	17.0
All	232 235.0	112 422.5	48.4

* The area measures for the habitat classes include any seafloor closed to trawling.

† The area measures for the 5-y footprint represent 98.8% of the total footprint.

9.3.4 STUDIES OF THE EFFECTS OF MOBILE BOTTOM FISHING METHODS IN NEW ZEALAND

The widespread nature of bottom trawling suggests that fishing is the main anthropogenic disturbance agent to the seabed throughout most of New Zealand's EEZ. Wind waves are certainly very widespread, but both field studies and modelling (Green et al 1995) suggest that erosion of the seabed deeper than 50 m by waves occurs only very rarely in the New Zealand EEZ. Despite their widespread distribution at the surface, therefore, wind-waves are not a dominant feature of the long-term disturbance regime throughout most of the EEZ. In some places, especially in the coastal zone and in areas close to headlands, straits, or islands, currents and tides may dominate the natural disturbance regime and a community adapted to this type of disturbance will have developed. However, over most of the EEZ between about 100 and 1000 m depth, especially in areas where there are few strong currents, fishing is probably the major broad-scale disturbance agent.

Several studies have been conducted since 1995 in New Zealand, focussing on the effects of various dredge and trawl fishing methods on a variety of different habitats in several geographical locations (Table 9.5). Despite the diversity of these studies, and their different depths, locations, and habitat types, the results are consistent with the global literature on the effects of mobile bottom fishing gear on benthic communities. Generally, there are decreases in the density and diversity of benthic communities and, especially, the density of large, structure-forming epifauna, and long-lived organisms along gradients of increasing fishing intensity. Large, emergent epifauna like sponges and framework-forming corals that provide structured habitat for other fauna are particularly noted as being susceptible to disturbance by mobile bottom fishing methods (Cranfield et al 1999, 2001, 2003, Cryer et al 2000), especially on hard (non sedimentary) seabeds (Clark & Rowden 2009, Clark et al 2010a&b, Williams et al 2011). Even though large emergent fauna seem most susceptible, effects have also been shown in the sandy or silty sedimentary systems usually considered to be most resistant to disturbance (Thrush et al 1995, 1998, Cryer et al 2002). Also reflecting the international literature is a substantial variation in the extent to which individual New Zealand studies have shown clear effects. For instance, in Foveaux Strait, Cranfield et al (1999, 2001, 2003) inferred substantial changes in the benthic system caused by over 130 years of oyster dredging, but Michael et al (2006) did not support such conclusions in the same system. Subsequent review of these studies found much common ground but no overall consensus on the long-term effects of dredging on the benthic community of the strait.

These studies have focussed predominantly on changes in patterns in biodiversity associated with trawling and/or dredging and less work has been done to assess changes in ecological process or to estimate the rate of recovery from fishing. Projects that have started on recovery rates are focussed on relatively few habitats and primarily those that are known to be sensitive to physical disturbance, including by trawling or dredging (e.g., seamounts, project ENV2005/16, and areas of high current and natural biogenic structure, projects ENV9805, ENV2005/23 and BEN2009/02). Thus, the understanding of the consequences of fishing (or of ceasing to fish) for sustainability, biodiversity, ecological integrity and resilience, and fish stock productivity in the wide variety of New Zealand's benthic habitats remains incomplete. Reducing this uncertainty would allow the testing of the utility and likely long-term productivity of a variety of management strategies, and enable a move towards a regime that maximises value to the nation consistent with Fisheries 2030.

Table 9.5: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters [Continued on next page].

Location	Approach	Key findings	References
Mercury Islands sandy sediments. Scallop dredge	Experimental	Density of common macrofauna at both sites decreased as a result of dredging at two contrasting sites; some populations were still significantly different from reference plots after 3 months.	Thrush et al 1995
Hauraki Gulf various soft sediments. Bottom trawl and scallop dredge.	Observational, gradient analysis	Decreases in the density of echinoderms, longlived taxa, epifauna, especially large species, the total number of species and individuals, and the Shannon-Weiner diversity index with increasing fishing pressure (including trawl and scallop dredge). Increases in the density of deposit feeders, small opportunists, and the ratio of small to large heart urchins.	Thrush et al 1998

Table 9.5 [Continued]: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters.

Bay of Plenty continental slope. Scampi and other bottom trawls.	Observational, multiple gradient analyses	Depth and historical fishing activity (especially for scampi) at a site were the key drivers of community structure for large epifauna. The Shannon-Weiner diversity index generally decreased with increasing fishing activity and increased with depth. Many species were negatively correlated with fishing activity; fewer were positively correlated (including the target species, scampi).	Cryer et al 1999 Cryer et al 2002
Foveaux Strait, sedimentary and biogenic reef. Oyster dredge.	Observational, various	Interpretations of the authors differ. Cranfield et al's papers concluded that dredging biogenic reefs for their oysters damages their structure, removes epifauna, and exposes associated sediments to resuspension such that, by 1998, none of the original bryozoan reefs remained. Michael et al concluded that there are no experimental estimates of the effect of dredging in the strait or on the cumulative effects of fishing or regeneration, that environmental drivers should be included in any assessment, and that the previous conclusions cannot be supported. The authors agree that biogenic bycatch in the fishery has declined over time in regularly-fished areas, that there may have been a reduction in biogenic reefs in the strait since the 1970s, and that simple biogenic reefs appear able to regenerate in areas that are no longer fished (dominated by byssally attached mussels or reef-building bryozoans). There is no consensus that reefs in Foveaux Strait were (or were not) extensive or dominated by the bryozoan *Cinctopora*.	Cranfield et al 1999, 2001, 2003 Michael et al 2006
Spirits Bay, sedimentary and biogenic areas. Scallop dredge.	Observational, gradient analysis	In 1999, depth was found to be the most important explanatory variable for benthic community composition but a coarse index of dredge fishing intensity was more important than substrate type for many taxonomic groups. Sponges seemed most affected by scallop dredging, and samples taken in an area once rich in sponges had few species in 1999. This area had probably been intensively dredged for scallops. Analysis of historical samples of scallop survey bycatch showed a marked decline in sponge species richness between 1996 and 1998. In 2006, significant differences were identified between areas within which fishing was or was not allowed. Species contributing to these differences included those identified as being most vulnerable to the effects of fishing. These differences could not be attributed specifically to fishing because of interactions with environmental gradients and uncertainty over the history of fishing. No significant change between 1999 and 2006 was identified. In 2010, analysis of both epifaunal and infaunal community data identified change since 2006, and significant depth, habitat and fishing effects. The combined fishing effects accounted for 15 – 30% of the total variance (about half of the explained variance). Individual species responses to fishing were examined, and those identified as most sensitive to fishing in this analysis had previously been categorised as sensitive on the basis of life history characteristics within the 2006 study.	Cryer et al 2000 Tuck et al 2010 Tuck & Hewitt 2013
Tasman and Golden Bays. Bottom trawl, scallop and oyster dredge	Observational, gradient analysis	A gradient analysis was adopted to investigate the importance of the different factors affecting epifaunal and infaunal communities in Tasman and Golden Bays. Fishing was consistently identified as an important factor in explaining variance in community structure, with recent trawl and scallop effort being more important than other fishing terms. Important environmental variables included maximum current speed, maximum wave height, depth, % mud, and salinity. Fishing accounted for 31–50% of the explained variance in epifaunal and infaunal community composition, species richness, and Shannon-Weiner diversity. Overall, models explained 30–54% of variance, and additional spatial patterns identified in the analysis explained a further 5–16% of variance.	Tuck et al 2011

Table 9.5 [Continued]: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters.

Graveyard complex “seamounts”, northern Chatham Rise. Orange roughy bottom trawl.	Observational, multiple analyses	From surveys in 2001 and 2006, substrate diversity and the amount of intact coral matrix were lower on fished seamounts. Conversely, the proportions of bedrock and coral rubble were higher. No change in the megafaunal assemblage consistent with recovery over 5–10 years on seamounts where trawling had ceased. Some taxa had significantly higher abundance in later surveys. This may be because of their resistance to the direct effects of trawling, their protection in natural refuges, or because these taxa represent the earliest stages of seamount recolonisation.	Clark et al 2010a&b Williams et al 2011

An expert based assessment of 65 threats to 62 marine habitats from saltmarsh to the abyss (MacDiarmid et al 2012) concluded that only 7 of the 20 most important threats to New Zealand marine habitats were directly related to human activities within the marine environment. The most important of these was bottom trawling (ranked third equal most important), but invasive species, coastal engineering, and aquaculture were also ranked highly. However, the two top threats, five of the top six threats, and over half of the 26 top threats stemmed largely or completely from human activities external to the marine environment (the most important being ocean acidification, rising sea temperatures, and sedimentation resulting from changes in land-use). The assessment suggested that the number and severity of threats to marine habitats declines with depth, particularly deeper than about 50 m. Shallow coastal habitats face up to 52 non-trivial threats whereas most deep water habitats are threatened by fewer than five. Coastal and estuarine reef, sand, and mud habitats were considered to be the most threatened habitats whereas slope and deep water habitats were among the least threatened.

9.3.5 CURRENT RESEARCH

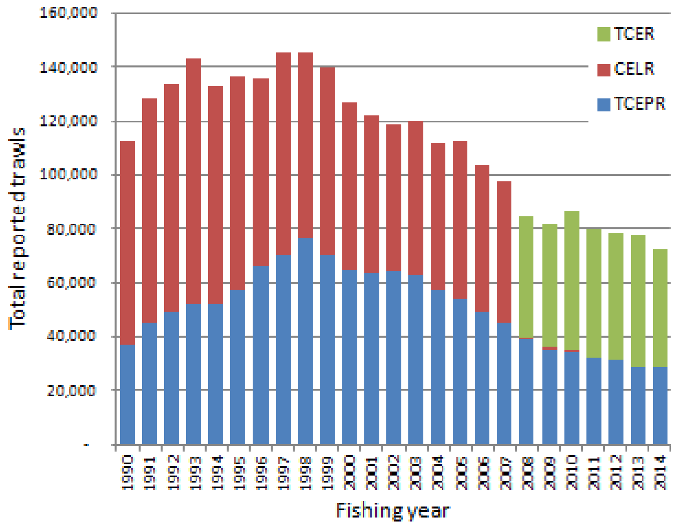
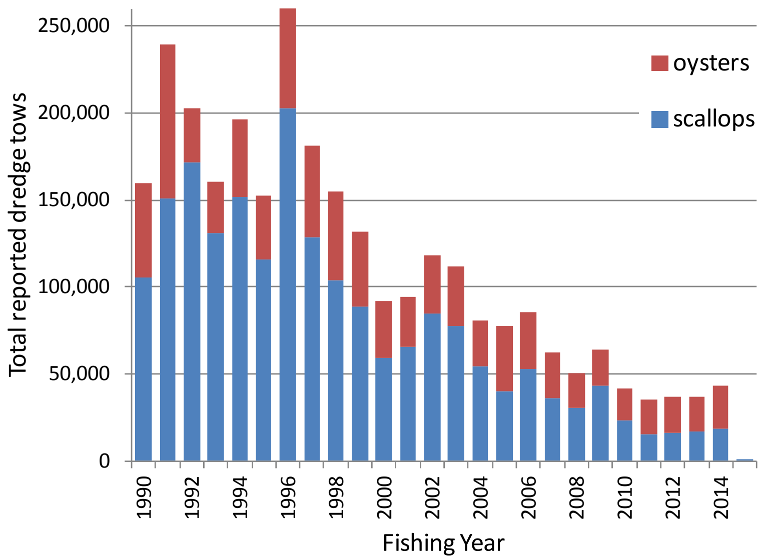
Project BEN2007/01 is a 5-year project to assess the effects of fishing on soft sediment habitat, fauna, and processes across the range of habitat types in the TS and EEZ. Sampling and analytical strategies for such broad-scale assessments have been developed and the project has moved into a phase of data collection, collation, and analysis. Two field-based “case studies” in different habitat types will be assessed, and a variety of existing information will be drawn together and analysed to provide a TS and EEZ-wide perspective. The focus of this study is on the relative sensitivities of different habitats in the TS and EEZ to disturbance by mobile bottom fishing methods.

Project DAE2010/04 provides for an annual assessment of the “footprint” of middle depth and deepwater trawl fisheries, including the overlap of the footprint with various depth ranges and habitat classes. Inshore fisheries, including shellfish dredge fisheries, are not covered under this project, so the focus is on offshore fisheries and habitats.

Project ZBD2012/03 will use data collected from recent Oceans Survey 20/20 sampling on the Chatham Rise to determine whether there are quantifiable effects of variations in seabed trawling intensity on benthic communities, and also conduct seabed mapping and photographic surveys in previously un-sampled areas on the central crest of the rise.

Several MBIE-funded projects also have strong linkages with MPI research on benthic impacts. These include “Vulnerable Deep-Sea Communities” (CO1X0906) which is analysing the time series of data from the “Graveyard seamounts” (surveys in 2001, 2006, 2009, all carried out with support from MFish or the cross-departmental Oceans Survey 20/20 programme), as well as evaluating the relative vulnerability of benthic communities in several deep-sea habitats (e.g., seamounts, canyons, continental slope, hydrothermal vents, seeps) and their risk from bottom trawling.

9.4 INDICATORS AND TRENDS

Annual number of tows	2010–11 fishing year: 86 024 trawl tows 35 150 shellfish dredge tows
Trend in number of tows	Trawl and dredge effort stable or decreasing in recent years:  

Cumulative overlap of TCEPR trawl footprint with BOMEC habitat classes for 1989–90 to 2009–10

BOMEC class	Area (km^2)	Footprint area (km^2)	Footprint area (%)
A*	27 557	12 400	45%
B*	12 420	3 324	27%
C*	89 710	57 840	64%
D*	27 268	9 592	35%
E*	60 990	23 612	44%
F	38 608	6 691	17%
G	6 342	3 043	48%
H	138 550	68 389	49%
I	52 224	38 238	73%
J	311 361	71 594	23%
K	1 290	14	1.1%
L	198 577	54 337	27%
M	233 825	18 503	8%
N	493 034	11 369	2%
O	935 315	2 431	0.3%
Total	2 627 073	384 376	15%

Cumulative overlap of trawl footprint shallower than 250 m with BOMEC habitat classes, depth zones and sediment types for 2007–08 to 2011–12

Habitat class descriptors	Habitat class area (km^2)	Total footprint (km^2)	% area with trawl contact
BOMEC class			
A	27 375.2	14 047.1	52.1
B	12 318.8	9 322.3	75.7
C	89 560.4	47 120.0	52.6
D	25 513.1	16 344.7	64.4
E	47 186.8	13 890.6	29.6
F	381.7	73.2	21.1
G	3 898.4	1 902.9	50.8
H	25 204.4	9 228.1	36.8
I	473.2	340.8	72.0
J	133.9	31.3	30.0
L	188.9	121.5	67.6
Depth zone			
< 50 m	50 781.3	29 529.4	58.8
50–100 m	63 493.9	37 375.2	59.1
100–250 m	117 959.8	45 517.9	38.7
Sediment type			
Sand	104 830.2	54 851.9	52.4
Mud	72 518.1	41 001.8	57.0
Gravel	18 530.0	9 339.3	50.6
Sandy mud	203.4	203.4	99.98
Calcareous sand	6 763.7	2 080.7	31.3
Calcareous gravel	29 389.5	4 945.4	17.0
All	232 235.0	112 422.5	48.4

* the trawl footprint and proportion overlapped in coastal classes A–E will be grossly underestimated because CELR data are excluded.

9.5 REFERENCES

Auster, P J; Langton, R W (1999) The effects of fishing on fish habitat. American Fisheries Society Symposium 22:150–187.

Barnes, P W; Thomas, J P (eds) (2005) Benthic habitats and effects of fishing. American Fisheries Society Symposium 41. American Fisheries Society, Bethesda, MD.

Baird, S J; Bagley, N W; Wood, B A; Dunn, A; Beentjes, M (2002) The spatial extent and nature of mobile bottom fishing methods within the New Zealand EEZ, 1989–90 to 1998–99. Final Research Report for Objective 1 of project ENV2000/05. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J: Hewitt J; Wood B A (2014) Benthic habitats and trawl fishing disturbance in New Zealand waters shallower than 250m. Final Research Report for MPI project BEN201201. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J; Wood, B A (2010) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. Final Research Report for Objective 5 of project BEN2006/01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J; Wood, B A; Bagley, N W (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone 1989/90 to 2004/05. New Zealand Aquatic Environment and Biodiversity Report No. 73. 144 p.

Baird, S J; Wood, B A; Clark, M R; Bagley, N W; McKenzie, A (2006) Description of the spatial extent and nature of disturbances by bottom trawls in Chatham Rise and Southern Plateau fisheries. Final Research Report for project ENV2003/03. 139 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Black, J; Wood, R; Berthelsen, T; Tinley, R. (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–90 to 2009–10. New Zealand Aquatic Environment and Biodiversity Report No. 110. 61 p.

Blyth, R E; Kaiser, M J; Edwards-Jones, G; Hart, P J B (2004) Implications of a zoned fishery management system for marine benthic communities. Journal of Applied Ecology 41: 951–961.

Bowden, D A; Clark, M R; Hewitt, J E; Rowden, A A; Leduc, D; Baird, S J. (2014) Designing a programme to monitor trends in deep-water benthic communities. Final Research Report for project DEE2010/06. 63 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bowden, D A; Compton, T J; Snelder, T H; Hewitt, J E (2011) Evaluation of the New Zealand Marine Environment Classifications using Ocean Survey 20/20 data from Chatham Rise & Challenger Plateau. New Zealand Aquatic Environment and Biodiversity Report No. 77.

Bradshaw, C; Tjensvoll, I; Sköld, M; Allan, I J; Molvaer, J; Magnusson, J; Naes, K; Nilsson, H C (2012) Bottom trawling resuspends sediment and releases bioavailable contaminants in a polluted fjord. Environmental Pollution 170: 232–241.

Bradshaw, C; Veale, L O; Brand, A R (2002) The role of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset. Journal of Sea Research 47: 161–184.

Brodie, S; Clark, M (2003) The New Zealand Seamount Management Strategy – steps towards conserving offshore marine habitat. In: Beumer, J P; Grant, A; Smith, D C (eds). Aquatic Protected Areas: what works best and how do we know? Proceedings of the World Congress on Aquatic Protected Areas, Cairns, Australia, August 2002. Australian Society of Fish Biology, Australia., pp. 664–673. Australian Society of Fish Biology, Cairns, Australia.

Churchill, J H (1989) The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight Continental Shelf. Continental Shelf Research 9: 841–864.

Clark, M R; Bowden, D A; Baird, S J; Stewart, R (2010a) Effects of fishing on the benthic biodiversity of seamounts of the "Graveyard" complex, northern Chatham Rise. New Zealand Aquatic Environment and Biodiversity Report No. 46. 40 p.

Clark, M R; Koslow, J A (2007) Impacts of fisheries on seamounts. Chapter 19. p. 413–441 In: Pitcher, T J; Morato, T; Hart, P J B; Clark, M R; Haggan, N; Santos, R S (eds). Seamounts: ecology, fisheries, and conservation. Blackwell Fisheries and Aquatic Resources Series 12. Blackwell Publishing, Oxford. 527 p.

Clark, M; O'Driscoll, R (2003) Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. Journal of Northwest Atlantic Fishery Science 31: 441–458.

Clark, M R; Rowden, A A (2009) Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. Deep Sea Research I 56: 1540–1554

Clark, M R; Watling, L; Rowden, A A; Guinotte, J M; Smith, C R (2010b) A global seamount classification to aid the scientific design of marine protected area networks. Journal of Ocean and Coastal Management 54: 19–36.

Craeymeersch, J A; Piet, G J; Rijnsdorp, A D; Buijs, J (2000) Distribution of macrofauna in relation to the microdistribution of trawling effort, p 187 in Kaiser, M J; de Groot, S J (eds). The effects of fishing on nontarget species and habitats: biological, conservation, and socio-economic issues. Blackwell Scientific, Oxford, UK.

Cranfield, H J; Carbines, G; Michael, K P; Dunn, A; Stotter, D R; Smith, D J (2001) Promising signs of regeneration of blue cod and oyster habitat changed by dredging in Foveaux Strait, southern New Zealand. New Zealand Journal of Marine and Freshwater Research 35: 897–908.

Cranfield, H J; Manighetti, B; Michael, K P; Hill, A (2003) Effects of oyster dredging on the distribution of bryozoans biogenic reefs and associated sediments in Foveaux Strait, southern New Zealand. Continental Shelf Research 23: 1337–1357.

Cranfield, H J; Michael, K P; Doonan, I J (1999) Changes in the distribution of epifaunal reefs and oysters during 130 years of dredging for oysters in Foveaux Strait, southern New Zealand. Aquatic Conservation of Marine and Freshwater Ecosystems 9: 461–483.

Cryer, M; Coburn, R; Hartill, B H; O'Shea, S; Kendrick, T; Doonan, I (1999) Scampi stock assessment for 1998 and an analysis of the fish and invertebrate bycatch of scampi trawlers. New Zealand Fisheries Assessment Research Document 99/4. 74 p. (Unpublished document held by NIWA library, Wellington.)

Cryer, M; Hartill, B H (2002) Relative impacts on benthic invertebrate community structure of trawl fisheries for scampi and finfish in the Bay of Plenty. Final Research Report for Ministry of Fisheries Research Project ENV2000/05 Objective 2. 28 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Hartill, B H; O'Shea, S (2002) Modification of marine benthos by trawling: toward a generalization for the deep ocean? Ecological Applications 12: 1824–1839.

Cryer, M; O'Shea, S; Gordon, D P; Kelly, M; Drury, J D; Morrison, M A; Hill, A; Saunders, H; Shankar, U; Wilkinson, M; Foster, G (2000) Distribution and structure of benthic invertebrate communities between North Cape and Cape Reinga Final Research Report for Ministry of Fisheries Research Project ENV9805 Objectives 1–4. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Davies, A J; Guinotte, J M (2011) Global habitat suitability for framework-forming cold-water corals. PLoS One 6(4).

Dayton, P K; Thrush, S F; Agardy, M T; Hofman, R J (1995). Environmental effects of fishing. Aquatic Conservation: Marine and Freshwater Ecosystems 5:205–232.

Dayton, P K; Thrush, S F; Coleman, F C (2002) The Ecological Effects of Fishing in Marine Ecosystems of the United States. Arlington, VA: Pew Oceans Comm.

Dichmont, C M; Deng, A; Punt, A E; Ellis, N; Venables, W N; Kompas, T; Ye, Y; Zhou, S; Bishop, J (2008) Beyond biological performance measures: bringing in economics and the effects of trawling on the benthos. Fisheries Research 94: 238–250.

Ellis, N; Pantus, F (2001) Management strategy modelling: tools to evaluate trawl management strategies with respect to impacts on benthic biota within the Great Barrier Reef Marine Park area. Cleveland, Qld.: CSIRO Div. Marine Research. Parts 1 & 2, 132 p. http://www.cmar.csiro.au/e-print/open/ellisn_2001.pdf

Ferrier, S; Drielsma, M; Manion, G; Watson, G (2002) Extended statistical approaches to modelling spatial pattern in biodiversity in north-east New South Wales: II. Community-level modelling. Biodiversity and Conservation 1: 2309–2338.

Ferrier, S; Manion, G; Elith, J; Richardson, K (2007) Using generalised dissimilarity modelling to analyse and predict patterns of beta-diversity in regional biodiversity assessment. Diversity and Distributions 13: 252–264.

Green, M O; Vincent, C E; McCave, I N; Dickson, R R; Rees, J M; Pearsons, N D (1995) Storm sediment transport: observations from the British North Sea shelf. Continental Shelf Research 15: 889–912.

Hall, S J (1994) Physical disturbance and marine benthic communities: life in unconsolidated sediments. Oceanography and Marine Biology Annual Review 32: 179–239.

Hall, S J (1999) The effects of fishing on marine ecosystems and communities. Blackwell Scientific, Oxford, UK.

Helson, J., S. Leslie, G. Clement, R. Wells and R. Wood (2010). "Private rights, public benefits: Industry-driven seabed protection." Marine Policy 34: 557-566.

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. Marine Ecology Progress Series 260: 97–108.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. Canadian Journal of Fisheries and Aquatic Sciences 63:721–736.

Hiddink, J G; Johnson, A F; Kingham, R; Hinz, H (2011) Could our fisheries be more productive? Indirect negative effects of bottom trawl fisheries on fish condition. Journal of Applied Ecology 48: 1–9.

Hinz, H; Hiddink, J G; Forde, J; Kaiser, M J (2008) Large-scale responses of nematode communities to chronic otter-trawl disturbance. Canadian Journal of Fisheries and Aquatic Sciences 65: 723–732.

ICES (1992) Report of the Study Group on Ecosystem Effects of Fishing Activities. ICES CM:1992/G11, 144 p.

ICES (2000a) Report of the Advisory Committee on the Marine Environment 2000. ICES Cooperative Research Report #241.

ICES (2000b) Report of the Working Group on Ecosystem Effects of Fishing Activities . ICES CM 2000/ACME:02.

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. Journal of Animal Ecology 70: 459–475.

Jennings, S; Freeman, S; Parker, R; Duplisea, D E; Dinmore, T A (2005) Ecosystem Consequences of Bottom Fishing Disturbance. American Fisheries Society Symposium 41:73-90.

Jennings, S; Kaiser, M J (1998) The effects of fishing on marine ecosystems. Advances in Marine Biology and Ecology 34:201–352.

Jennings, S; Pinnegar, J K; Polunin, N V C; Warr, K J (2001) Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series 213:127–142.

Jones, J B (1992) Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research 26: 59–67.

Kaiser, M J; Clarke, K R; Hinz, H; Austen, M C V; Somerfield, P J; Karakassis, I (2006) Global analysis of the response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1–14.

Kaiser, M J; Collie, J S; Hall, S J; Jennings, S; Poiner, I R (2003) Impacts of fishing gear on marine benthic habitats. Conference on Responsible Fisheries in the Marine Ecosystem. Reykjavik, Iceland, 1–4 October 2001.

Kaiser, M J; de Groot, S J (2000) Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Blackwell, Oxford, 399 p.

Lambert, G I; Jennings, S; Kaiser, M J; Davies, T W; Hiddink, J G (2014) Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing. Journal of Applied Ecology 51 (5): 1326–1336. DOI: 10.1111/1365-2664.12277

Leathwick, J; Francis, M; Julian, K (2006) Development of a demersal fish community classification for New Zealand's Exclusive Economic Zone. Prepared for Department of Conservation. NIWA Client Report HAM2006-062. Hamilton.

Leathwick, J R; Rowden, A A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2010) Benthic-optimised marine environment classification for New Zealand waters. Final Research Report for Ministry of Fisheries Project BEN2006/01, Objective 5. 52 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Leathwick, J R; Snelder, T; Chadderton, W L; Elith, J; Julian, K; Ferrier, S (2011). Use of generalised dissimilarity modelling to improve the biological discrimination of river and stream classifications. Freshwater Biology 56: 21–38.

Lindeboom, H; deGroot, S J (1998) The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems. Netherlands Institute of Sea Research, Texel, The Netherlands.

Lokkeborg, S (2005) Impacts of trawling and scallop dredging on benthic habitats and communities. FAO Technical Paper 472.

Lundquist, C J; Pritchard M; Thrush S F; Hewitt J; Greenfield B L; Halliday J; Lohrer A M (2013) Bottom disturbance and seafloor community dynamics: Development of a model of disturbance and recovery dynamics for marine benthic ecosystems. New Zealand Aquatic Environment and Biodiversity Report No. 118. 63 p

Lundquist, C J; Thrush, S F; Coco, G; Hewitt, J E (2010) Interactions between disturbance and dispersal reduce persistence thresholds in a benthic community. Marine Ecology Progress Series 413: 217–228.

MacDiarmid, A; McKenzie, A; Sturman, J; Beaumont, J; Mikaloff-Fletcher, S; Dunne, J (2012) Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93.255 p.

Michael, K P; Kroger, K; Richardson, K; Hill, N (2006) Summary of information in support of the Foveaux Strait Oyster Fishery Plan: the Foveaux Strait ecosystem and effects of oyster dredging. Final Research Report for Ministry of Fisheries project ZBD2005/04. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Ministry for the Environment (2010) Fishing Activity: Fish Stocks Environmental Snapshot. Wellington.

McConnaughy, R A; Mier, K L; Dew, C B (2000) An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea. ICES Journal of Marine Science 57: 1377–1388.

Mormede, S.; Dunn, A. (2013) An initial development of spatially explicit population models of benthic impact to inform Ecological Risk Assessments in New Zealand deepwater fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 106. 20 p

National Marine Fisheries Service (2002) Workshop on the effects of fishing gear on marine habitats off the northeastern United States October 23-25, 2001. Northeast Fisheries Science Center Reference Document 02-01.

National Research Council (2002) Effects of trawling and dredging in seafloor habitat. National Academy Press, Washington DC.

O'Driscoll, R L; Clark, M R (2005) Quantifying the relative intensity of fishing on New Zealand seamounts. New Zealand Journal of Marine and Freshwater Research 39: 839–850.

Puig, P; Canals, M; Company, J B; Martin, J; Amblas, D; Lastras, G; Palanques, A; Calafat, A (2012) Ploughing the deep sea floor. Nature 489: 286–289.

Pusceddu, A; Bianchelli, S; Martín, J; Puig, P; Palanques, A; Masqué, P; Danovaro, R (2014) Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. Proceedings of the National Academy of Sciences 111(24): 8861–8866. 10.1073/pnas.1405454111

Reiss, H; Greenstreet, S P R; Siebe, K; Ehrich, S; Piet, G J; Quirijns, F; Robinson, L; Wolff, W J; Kronke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. Marine Ecology Progress Series 394: 201–213.

Rice, J (2006) Impacts of mobile bottom gears on seafloor habitats, species, and communities: a review and synthesis of selected international reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Rowden, A A; Clark, M R; Wright, I C (2005) Physical characterisation and a biologically focused classification of seamounts in the New

Zealand region. New Zealand Journal of Marine and Freshwater Research 39: 1039–1059.

Rowden, A A; Oliver, M D; Clark, M R; MacKay, K (2008) New Zealand's "SEAMOUNT" database: recent updates and its potential use for ecological risk assessment. New Zealand Aquatic Environment and Biodiversity Report No. 27. 49 p.

Rumohr, H (1998) Information on impact of trawling on benthos in Kiel Bay. Annex to Eighth Report of the Benthos Ecology Working Group. ICES, CM: 1989/L19, 80.

Sainsbury, K J; Punt, A E; Smith, A D M (2000) Design of operational management strategies for achieving fishery ecosystem objectives. ICES Journal of Marine Science, 57: 731–741.

Schratzberger, M; Lampadariou, N; Somerfield, P J; Vandepitte, L; Vanden Berghe, E (2009) The impact of seabed disturbance on nematode communities: linking field and laboratory observations. Marine Biology 156:709–724.

Sharp, B; Parker, S; Smith, N (2009) An impact assessment framework for bottom fishing methods in the CCAMLR Convention area. CCAMLR Science 16: 195–210.

Snelder, T H; Leathwick, J R; Dey, K L; Rowden, A A; Weatherhead, M A; Fenwick, G D; Francis, M P; Gorman, R M; Grieve, J M; Hadfield, M G; Hewitt, J E; Richardson, K M; Uddstrom, M J; Zeldis, J R (2006) Development of an ecological marine classification in the New Zealand region. Environmental Management 39: 12–29.

Snelder, T H; Leathwick, J R; Dey, K L; Weatherhead, M A; Fenwick, G D; Francis, M P; Gorman, R M; Grieve, J M; Hadfield, M G; Hewitt, J E; Hume, T; Richardson, K M; Rowden, A A; Uddstrom, M J; Wild, M; Zeldis, J R (2005) The New Zealand Marine Environment Classification. Ministry for the Environment. Wellington.

Snelder, T H; Leathwick, J R; Image, K; Weatherhead, M A; Wild, M (2004) The New Zealand Marine Environment Classification. NIWA Client Report CHC2004-071. 86 p.

Thrush, S F; Dayton, P K (2002) Disturbance to marine benthic habitats by trawling and dredging—implications for marine biodiversity. Annual Reviews in Ecology and Systematics 33:449–73

Thrush, S F; Hewitt, J E; Cummings, V J; Dayton, P K (1995) The impact of habitat disturbance by scallop dredging on marine benthic communities: What can be predicted from the results of experiments? Marine Ecology Progress Series 129:141–150.

Thrush, S F; Hewitt, J E; Cummings, V J; Dayton, P K; Cryer, M; Turner, S J; Funnell, G A; Budd, R G; Milburn, C J; Wilkinson, M R (1998) Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. Ecological Applications 8: 866–879.

Tillin, H M; Hiddink, J G; Jennings, S; Kaiser, M J (2006) Chronic bottom trawling alters the functional composition of benthic invertebrate communities on a sea-basin scale. Marine Ecology Progress Series 318:31–45.

Tuck, I D; Drury, J; Kelly, M; Gerring, P (2010) Designing a programme to monitor the recovery of the benthic community between North Cape and Cape Reinga. New Zealand Aquatic Environment and Biodiversity Report No. 53. 79 p

Tuck, I D; Hewitt, J E (2013) Monitoring change in benthic communities in Spirits Bay. New Zealand Aquatic Environment and Biodiversity Report No. 111. 52 p

Tuck, I D; Hewitt, J E; Handley, S; Willis, T; Carter, M; Hadfield, M; Gorman, R; Cairney, D; Brown, S; Palmer, A (2011) Assessing the effects of fishing on soft sediment habitat, fauna and processes. Progress Report for Ministry of Fisheries research project BEN200701. (Unpublished report held by MPI, Wellington.)

Tuck, I D; Parkinson, D M; Dey, K; Oldman, J; Wadwha, S (2006) Information on benthic impacts in support of the Coromandel scallop fisheries plan. Final Research Report for Ministry of Fisheries Research Project ZBD2005/15 (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Pinkerton, M H; Tracey, D M; Anderson, O A; Chiswell, S M (2014) Ecosystem and Environmental Indicators for Deepwater Fisheries. New Zealand Aquatic Environment and Biodiversity Report No 127. 149 p

Veale, L O; Hill, A S; Hawkins, S J; Brand, A R (2000) Effects of long-term physical disturbance by commercial scallop fishing on subtidal epifaunal assemblages and habitats. Marine Biology 137: 325–337.

Warnken, K W; Gilla, G A; Dellapennaa, T M; Lehmana, R D; Harperb, D E; Allison, M A (2003) The effects of shrimp trawling on sediment oxygen consumption and the fluxes of trace metals and nutrients from estuarine sediments. Estuarine, Coastal and Shelf Science 57: 25–42.

Watling, L; Norse, E A (1998) Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology, 12: 1180–1197.

Williams, A; Dowdney, J; Smith, A D M; Hobday, A J; Fuller, M (2011) Evaluating impacts of fishing on benthic habitats: a risk assessment framework applied to Australian fisheries. Fisheries Research 112: 154–167.

Williams, A; Schlacher, T A; Rowden, A A; Althaus, F; Clark, M R; Bowden, D A; Stewart, R; Bax, N J; Consalvey, M; Kloser, R J (2010) Seamount megabenthic assemblages fail to recover from trawling impacts. Marine Ecology 31 (Suppl. 1):183–199.

THEME 4: ECOSYSTEM EFFECTS

10 NEW ZEALAND'S CLIMATE AND OCEANIC SETTING

Scope of chapter	Overview of primary productivity, oceanography, bentho-pelagic coupling and oceanic climate trends in the SW Pacific region.
Area	New Zealand regional setting
Focal localities	Pan New Zealand waters
Key issues	• Climate and oceanographic variability and long-term changes are of relevance to fisheries and the broader marine environment. • Allows for improved understanding of the links between observed patterns and drivers of biological processes.
Emerging issues	• New Zealand's oceanic climate is changing. • Causal mechanisms that link the dynamics of a variable marine environment to variation in biological productivity, particularly of fisheries and biodiversity, are not well understood in New Zealand. • Need for improved understanding of the linkages between the pelagic and benthic environment (i.e., bentho-pelagic coupling). • The cumulative effects of ocean climate change and other anthropogenic stressors on aquatic ecosystems (productivity, structure and function) are likely to be high. • Some long-term trends in the marine environment are available at a national scale but are not reported. • Growing recognition that stressors will act both individually and interactively, confounding prediction of net effects of climate change.
MPI Research (current)	Projects include ZBD2005-05: Long-term effects of climate variation and human impacts on the structure and functioning of New Zealand shelf ecosystems; ZBD2008-11 Predicting plankton biodiversity & productivity with ocean acidification; ZBD2009-13. Ocean acidification impact on key NZ molluscs; ZBD2010-40. Marine Environmental Monitoring Programme; ZBD2010-41 Deepsea fisheries habitat and ocean acidification.
NZ Government Research (current)	NIWA Coast & Oceans Centre, Climate Centre; University of Otago-NIWA shelf carbonate geochemistry & bryozoans; Munida time-series transect; Geomarine Services-foraminiferal record of human impact; Regional Council monitoring programmes; Statistics New Zealand Environmental Domain review.
Links to 2030 objectives	Environmental Outcome Objective 1; environmental principles of Fisheries 2030; MPI's "Our Strategy 2030": two key stated focuses are to maximise export opportunities and improve sector productivity; increase sustainable resource use, and protect from biological risk.
Related chapters/issues	• Ocean related climate variability and change are predicted to have major implications for fishstock distributions and abundance, reproductive success, ecosystem goods and services, deepsea coral habitat and Habitats of Particular Significance to Fisheries Management, • A significant warming event occurred in the late 1990s, • A regime shift to the negative phase of the IPO occurred in about 2000, which is likely to result in fewer El Niño events for a 20–30 year period, i.e., less zonal westerly winds (already apparent compared to the 1980–2000 period) and increased temperatures; this is the first regime shift to occur since most of our fisheries monitoring time series have started (the previous shift was in the late 1970s), and is likely to impact on fish productivity, • New Zealand trends of increasing air and sea temperatures and ocean acidification are consistent with global trends.

Note: No update has been made to this chapter since the AEBAR 2012, other than the correction of minor typographical errors, text clarification and references

10.1 CONTEXT

Climate and oceanographic conditions play an important role in driving the productivity of our oceans and the abundance and distribution of our fishstocks, and hence fisheries. A full analysis of trends in climate and oceanographic variables in New Zealand is given in Hurst et al (2012) and is now being developed as an Ocean Climate Change Atlas for New Zealand waters (Boyd & Law 2011).

New Zealand is essentially part of a large submerged continent (Figure 10.1).

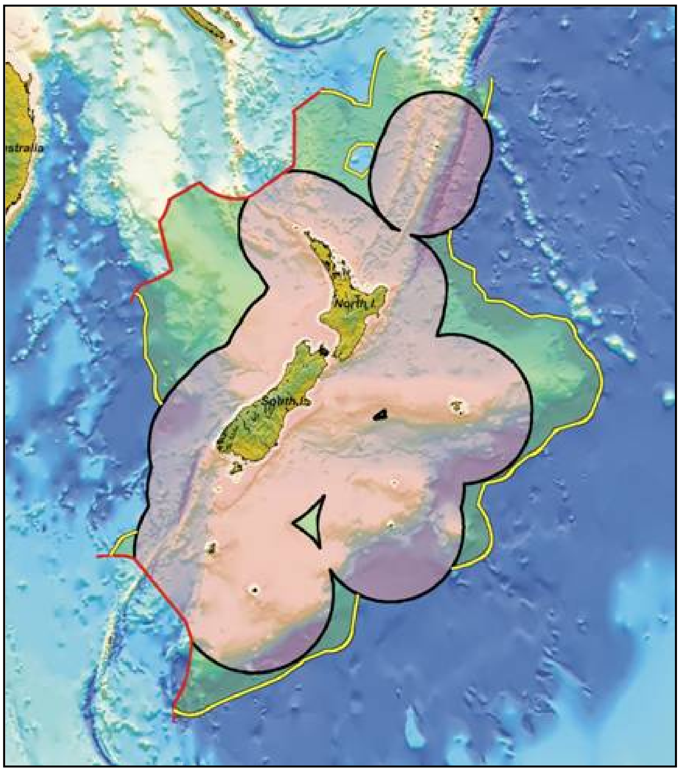


Figure 10.1: New Zealand land mass area 250 000 km2; EEZ & territorial sea area (pink) 4 200 000 km2; extended continental shelf extension area (light green) 1 700 000 km2; Total area of marine jurisdiction 5 900 000 km2. The black line shows the boundary of the New Zealand EEZ, the yellow line indicates the extension to New Zealand's legal continental shelf, and the red line the agreed Australia/New Zealand boundary under UNCLOS Article 76. Image courtesy of GNS.

The territorial sea (TS extending from mean low water shore line to 12 nautical miles) and Exclusive Economic Zone (the EEZ, extending from 12 nautical miles to 200 miles offshore) and the extended continental shelf (ECS) combine to produce one of the largest areas of marine jurisdiction in the world, an area of almost 6 million square kilometres, (Figure 10.1). New Zealand waters straddle more than 25 degrees of latitude from 30º S in warm subtropical waters to 56º S in cooler, subantarctic waters, and 210 degrees of longitude from 161º E in the Tasman Sea to 171º W in the west Pacific Ocean. New Zealand's coastline, with its numerous embayments, is also long, with estimates ranging from 15 000 to 18 000 km, depending on the method used for measurement (Gordon et al 2010).

New Zealand lies across an active subduction zone in the western Pacific plate; tectonic activity and volcanism have resulted in a diverse and varied seascape within the EEZ. The undersea topography comprises a relatively narrow band of continental shelf down to 200 m water depth, extensive continental slope areas from 200 to 1000 m, extensive abyssal plains, submarine canyons and deep sea trenches, ridge systems and numerous seamounts and other underwater topographic features such as hills and knolls. There are three significant submarine plateaus, the Challenger Plateau, the Campbell Plateau in the subantarctic, and the Chatham Rise (Figure 10.2).

Disturbance of current flow across the plateaus and around the New Zealand landmass gives rise to higher ocean productivity than might be expected, given New Zealand's isolated location in the generally oligotrophic western Pacific Ocean (Figure 10.3). Higher ocean colour, reflecting higher levels of productivity, is typically found around the coast and to the east across the Chatham Rise (Figure 10.3; Pinkerton et al 2005). The coastal waters and plateaus support a range of commercial shellfish and finfish fisheries from the shoreline to depths of about 1500 m. Seamounts, seamount chains and ridge structures in suitable depths provide additional localized areas of upwelling and increased productivity sometimes associated with commercial fisheries.

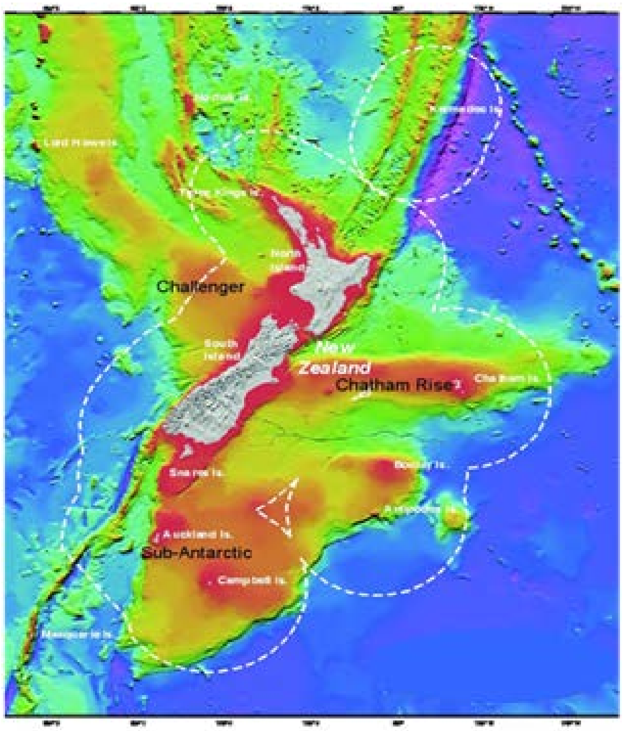


Figure 10.2: Undersea topography of New Zealand (red shallow to blue deep). White dashed line shows the EEZ boundary. Image courtesy of NIWA.

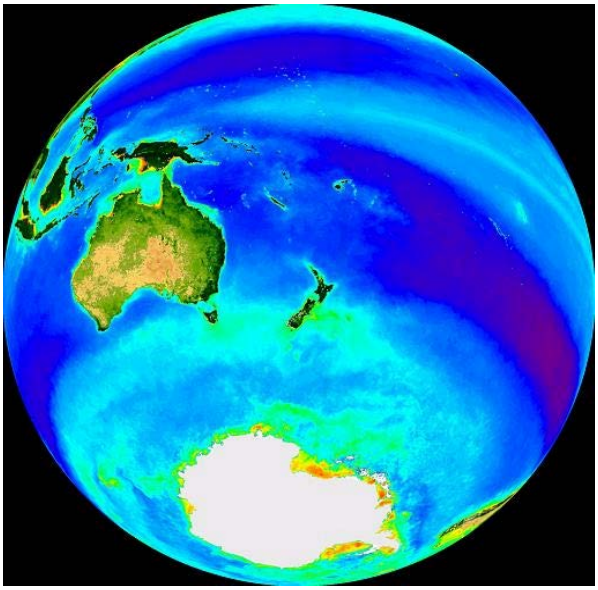


Figure 10.3: SeaWIFS image showing elevated chlorophyll a (green) near New Zealand. Image courtesy of NOAA.

The strongest chlorophyll a and ocean colour are associated with the coastal shelf around New Zealand and the Chatham Rise (Figure 10.3 and Figure 10.4 top panel respectively). Although remote sensing cannot readily distinguish between primary productivity (from phytoplankton) and sediments in freshwater runoff, so interpretation of the relative productivity levels inshore has to be made in conjunction with knowledge of river flow, it is clear that the Chatham Rise has the highest productivity levels in the region. Globally, New Zealand net primary productivity levels in the sea are higher compared with most of Australasia, but lower than most coastal upwelling systems around the world (Willis et al 2007).

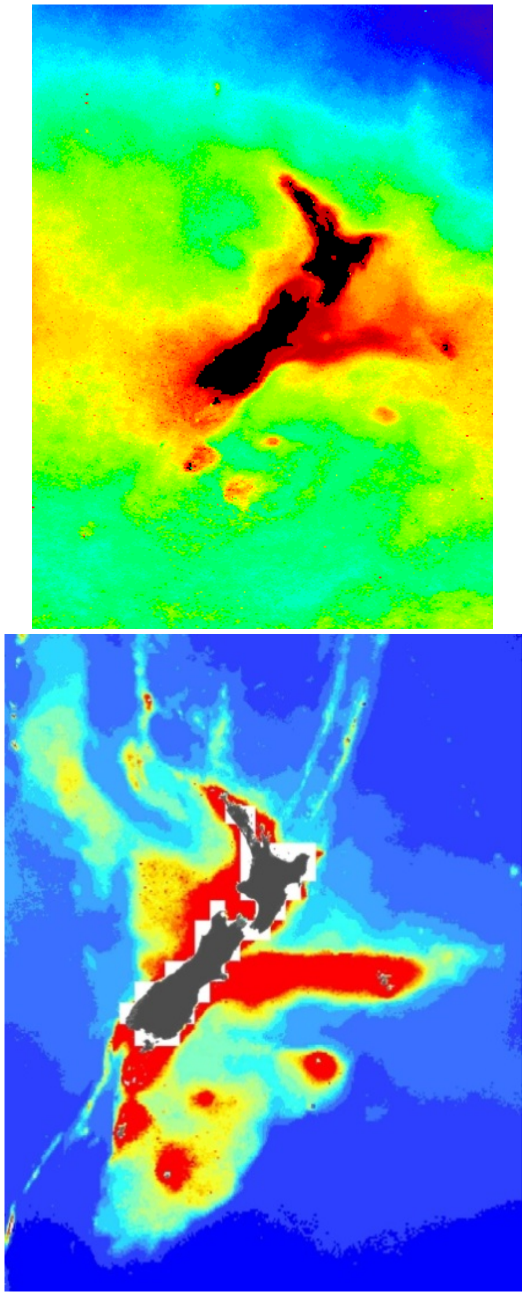


Figure 10.4: Top panel: Ocean colour in the New Zealand region from satellite imagery. Red shows the highest intensity of ocean colour typically associated with higher primary productivity. Bottom panel: The relative concentrations of particulate organic carbon (POC) that reach the seafloor. Red shows the highest levels, which are likely to be associated with areas of enhanced benthic productivity (based on the model of Lutz et al (2007)). Images courtesy of NIWA.

Patterns in surface waters of primary productivity are mirrored to an extent in the amount of "energy" that sinks to the seafloor (Figure 10.4 bottom panel). This POC flux is based on a model which accounts for sinking rates of dead organisms and predation in the water column (Lutz et al 2007). This is a potential surrogate of benthic production, and indicates where bentho-pelagic coupling may be strong. Highest levels of POC flux match with surface productivity to a large extent, with coastal waters (including around the offshore islands) and the Chatham Rise having high estimated production (Figure 10.4 bottom panel).

The Tasman Sea (west of New Zealand) is separated from the South Pacific Gyre by the New Zealand landmass (Figure 10.5). The South Pacific Western Boundary Current, the East Australian Current (EAC) flows down the east coast of Australia, before separating from the Australian landmass in a variable eddy field at about 31 or 32°S (Ridgway & Dunn 2003). The bulk of the separated flow crosses the Tasman Sea as the Tasman Front (Stanton 1981; Ridgway & Dunn 2003), before a portion of the flow attaches to New Zealand, flowing down the northeast coast as the East Auckland Current (Stanton et al 1997). In the southern limit of the Tasman Sea is the Subtropical Front, which passes south of Tasmania and approaches New Zealand at the latitude of Fiordland (Stanton & Ridgeway 1988), before diverting southward around New Zealand, and then northward up the southeast coast of New Zealand where it is locally called the Southland Front (Heath 1985; Chiswell 1996; Sutton 2003).

The water in the eastern central Tasman Sea south of the Tasman Front, east of the influence of the EAC and north of the Subtropical Front is thought to be relatively quiescent. Ridgway & Dunn (2003) show eastward surface flow across the interior of the Tasman Sea sourced from the southernmost limit of the EAC, with the flow bifurcating around Challenger Plateau and, ultimately, New Zealand. Reid's (1986) analysis indicates that a small anticyclonic gyre exists in the western Tasman Sea at 1000–2500 m depth. This gyre is centred at about 35°S, 155°E on the offshore side of the EAC and west of Challenger Plateau. All indications are that the eastern Tasman region overlying Challenger Plateau is not very energetic.

This is in contrast with the east coast of both the North and South Islands, and Cook Strait, which are highly energetic. Campbell Plateau waters are well mixed although nutrient limited (iron), leading to tight coupling between trophic levels (Bradford-Grieve et al 2003). The Subtropical Front lies along the Chatham Rise and turbulence and upwelling results in relatively high primary productivity in the area.

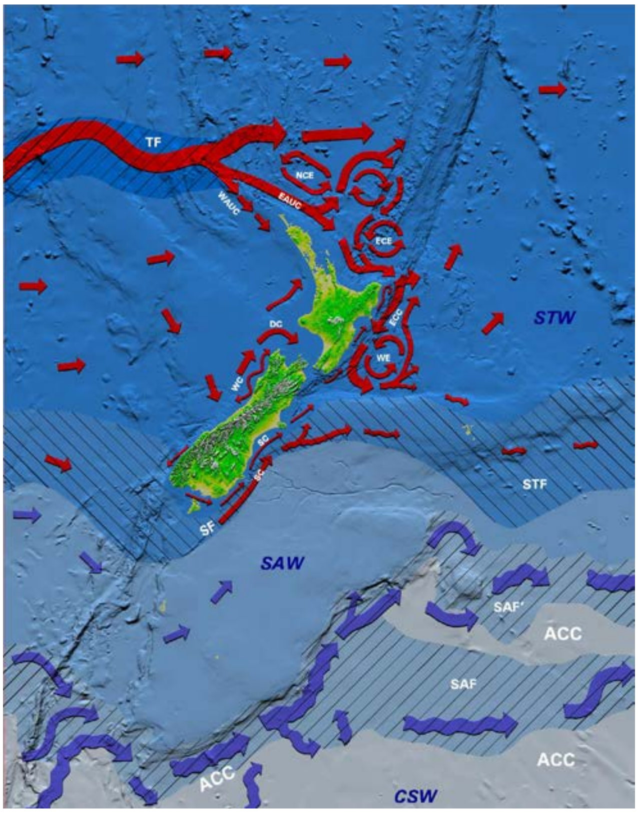


Figure 10.5: Circulation around New Zealand. TF Tasman Front (large red arrows), WAUC West Auckland Current, EAUC East Auckland Current, NCE North Cape Eddy, ECE East Cape Eddy, ECC East Cape Current, WE Wairarapa Eddy, DC D'Urville Current, WC Westland Current, SC Southland Current, SF Southland Front, STW Subtropical Water, STF Subtropical Front (left diagonal hashed area), SAW Subantarctic Water, SAF Subantarctic Front (right diagonal hashed area), ACC Antarctic Circum-Polar Current, CSW Circum-Polar Surface Water, DWBC Deep Western Boundary Current (large purple arrows) (after Carter et al 1998).

10.2 INDICATORS AND TRENDS

10.2.1 SEA TEMPERATURE

Sea surface temperature (SST), sea surface height (SSH), air temperature and ocean temperature to 1000 m depth, all exhibit some correlation with each other over seasonal and inter-annual time scales (Hurst et al 2012). Air temperatures have increased by about 1°C since 1900 (Figure 10.6).

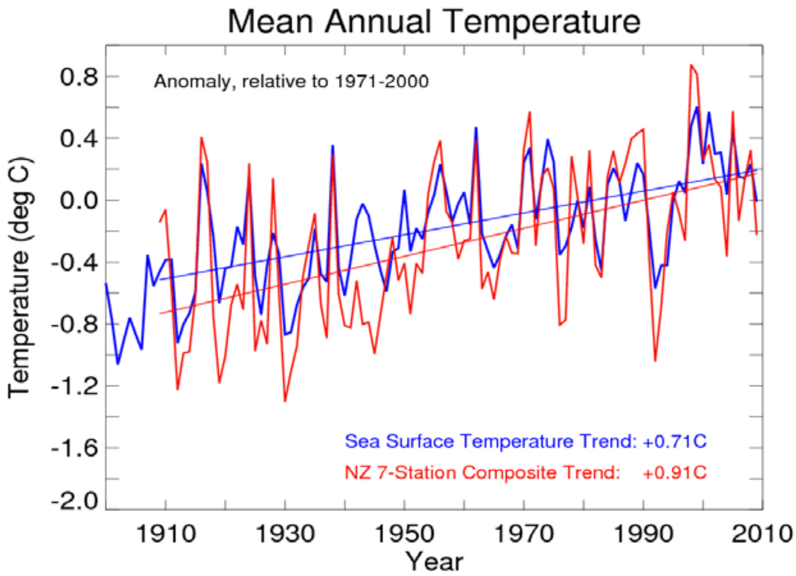


Figure 10.6: Annual time series in New Zealand. NOAA annual mean sea surface temperatures (blue line)[56] and NIWA's seven-station annual mean air temperature composite series (red line), expressed as anomalies relative to the 1971-2000 climatological average. Linear trends over the period 1909-2009, in °C/century, are noted under the graph. (Image Source Mullan et al 2010)

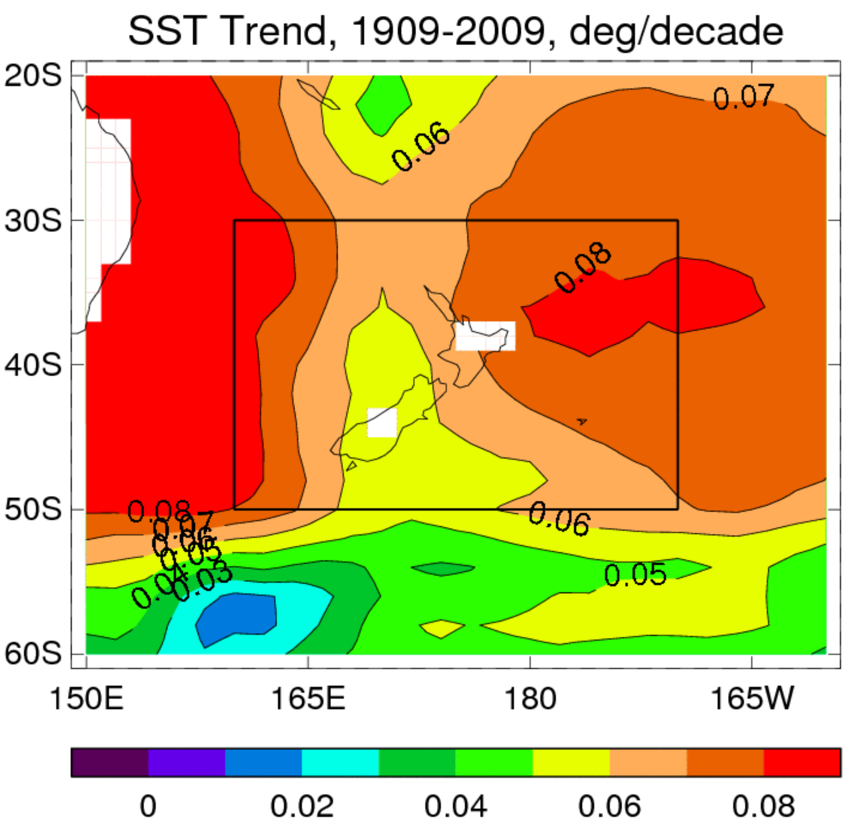


Figure 10.7: Trends in sea surface temperature, in °C/decade over the period 1909–2009, calculated from the NOAA_ERSST_v3 data-set (provided by NOAA's ESRL Physical Sciences Division, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/). The data values are on a 2° latitude-longitude grid. (Image Source Mullan et al 2010.

[56] http://www.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php

Although a linear trend has been fitted to the seven-station temperatures in Figure 10.6, the variations in temperature over time are not completely uniform. For example, a markedly large warming occurred through the periods 1940–1960 and 1990–2010. Higher frequency variations can be related to fluctuations in the prevailing north-south airflow across New Zealand (Mullan et al 2010). Temperatures are higher in years with stronger northerly flow, and are lower in years with stronger southerly flow. One would expect this, since southerly flow transports cool air from the Southern Oceans up over New Zealand.

The unusually steep warming in the 1940–1960 period is paralleled by an unusually large increase in northerly flow during this same period Mullan et al (2010). On a longer timeframe, there has been a trend towards less northerly flow (more southerly) since about 1960 (Mullan et al 2010). However, New Zealand temperatures have continued to increase over this time, albeit at a reduced rate compared with earlier in the twentieth century. This is consistent with a warming of the whole region of the southwest Pacific within which New Zealand is situated (Mullan et al 2010).

Mullan et al 2010 describe the pattern of warming in New Zealand as consistent with changes in sea surface temperature and prevailing winds. Their review shows enhanced rates of warming (in units of °C/decade) along the East Australian coast and to the east of the North Island, and much lower rates of warming south and east of the South Island (Figure 10.7).

Figure 10.8 gives a broader spatial picture at much higher resolution (but a shorter period), since 1982. It is apparent that sea temperatures are increasing north of about 45°S; they are increasing more slowly, and actually decreasing in recent decades, off the Otago coast and south of New Zealand. This regional pattern of cooling (or only slow warming) to the south, and strong warming in the Tasman and western Pacific can be related to increasing westerly winds and their effect on ocean circulation Mullan et al (2010). Thompson & Solomon (2002) discuss the increase in Southern Hemisphere westerlies and the relationship to global warming; Roemmich et al (2007) describe recent ocean circulation changes; Thompson et al (2009) discuss the consequent effect on sea surface temperatures in the Tasman Sea.

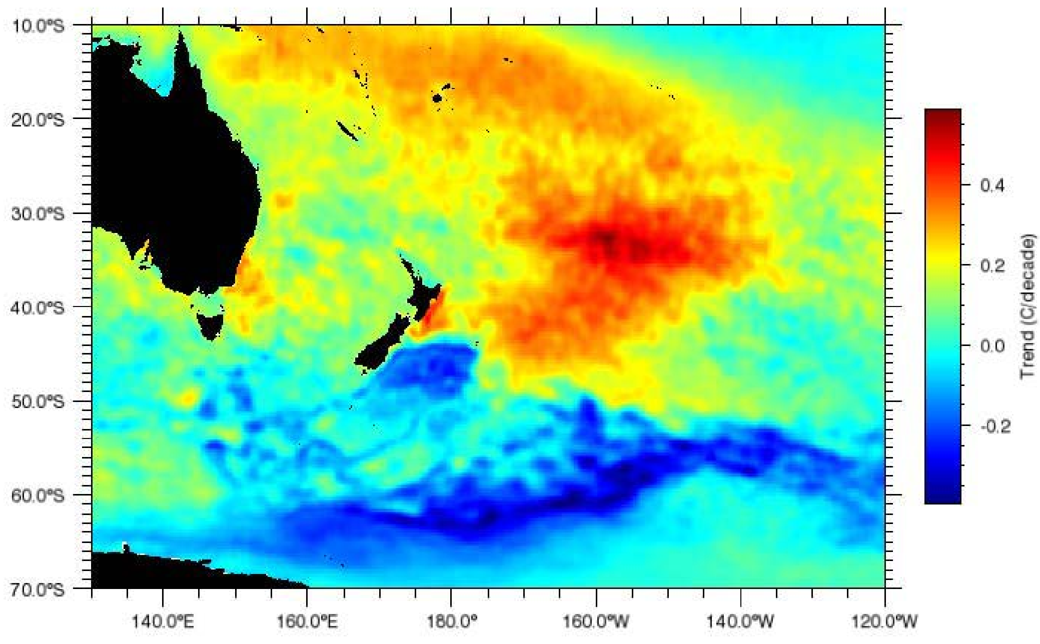


Figure 10.8: Trends in sea surface temperature, in °C/decade over the period 1982–2009. The data are from NOAA based on daily interpolated satellite measurements over a 0.25° grid. See http://www.ncdc.noaa.gov/oa/climate/research/sst/oi-daily.php. (after Reynolds et al (2007).

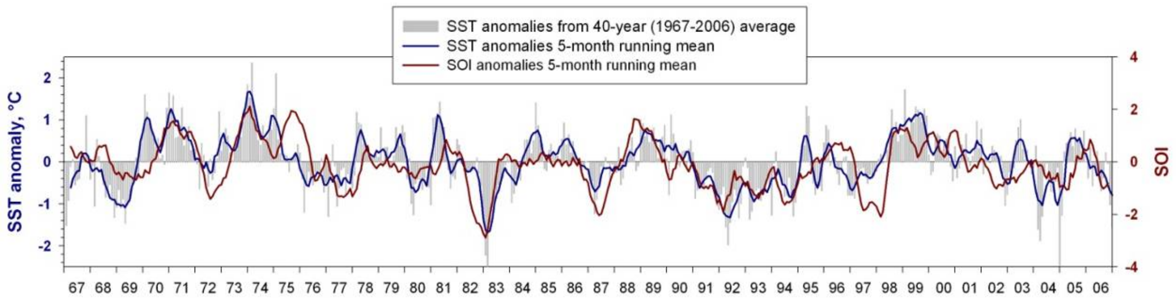


Figure 10.9: Sea surface temperature (SST) anomalies from SST measurements at Leigh (Auckland University Marine Laboratory) and Southern Oscillation Index (SOI) anomalies. (Image from Hurst et al 2012).

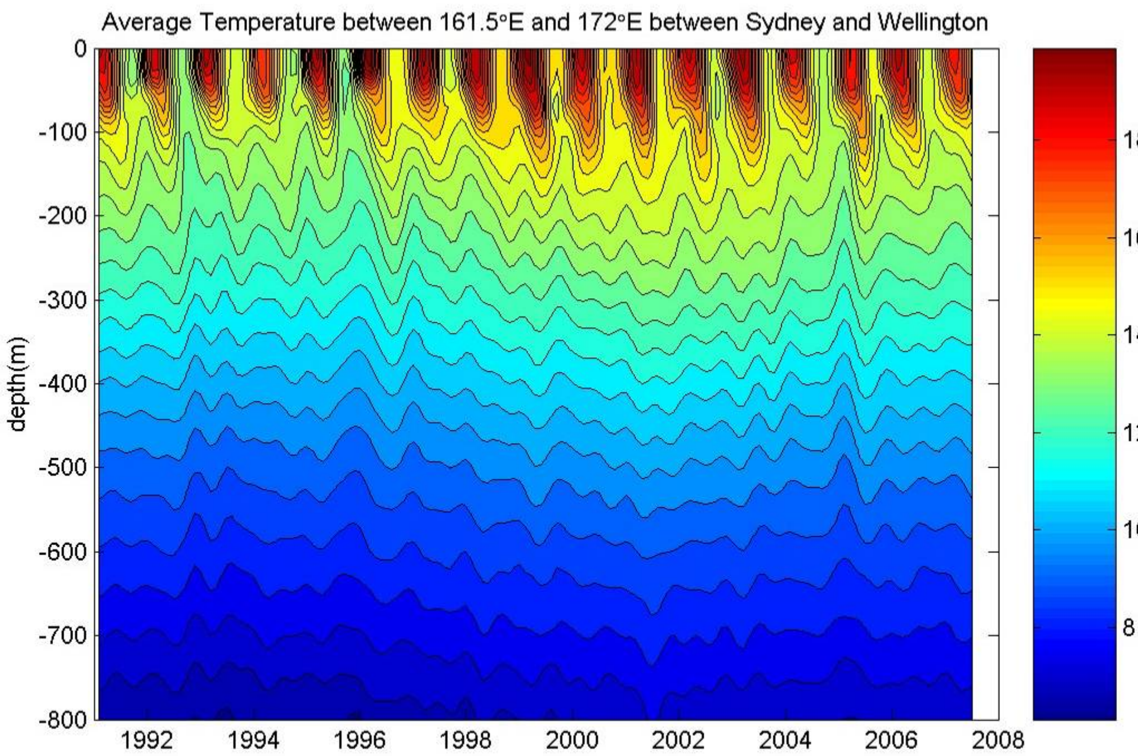


Figure 10.10: Eastern Tasman ocean temperature: Wellington to Sydney 1991–2008. Coloured scale to the right is temperature °C. (Image from Hurst et al 2012, after Sutton et al 2005).

Sea surface temperatures (SST) derived from satellite data have been compared to empirical CTD measurements made from relevant sub-areas of the Chatham Rise and subantarctic during trawl surveys. This showed good correlations, reassuring us that satellite-derived SST provided a realistic measure of sea surface temperature for these regions in years before CTD data were available O'Driscoll et al 2011).

Coastal SST data, particularly the longer time series from Leigh and Portobello, have been used in studies attempting to link processes in the marine environment with temperature. The negative relationship between SST and SOI is broadly consistent across the 40 years of data although the pattern is less clear post 1997 (Figure 10.9). The clearest fisheries example of a link between coastal SST and fish recruitment and growth is for northern stocks of snapper (*Pagras auratus*), where relatively high recruitment and faster growth rates have been correlated with warmer conditions from the Leigh SST series (Francis 1993, 1994a).

Temperature fluctuations also occur at depth in the ocean as demonstrated by changes in temperature down to 800 m in the eastern Tasman Sea between 1992 and 2008 (Figure 10.10).

The ocean temperature between Sydney and Wellington has been sampled about four times per year since 1991. The measurements are made in collaboration with the Scripps Institution of Oceanography. Analyses of the subsurface temperature field using these data include Sutton & Roemmich (2001) and Sutton et al (2005). The index presented for this transect (Figure 10.10) is for the most eastern section closest to New Zealand (161.5°E and 172°E). The eastern Tasman transect is closer to New Zealand, and has less oceanographic variability which can mask subtle interannual changes. The section of the transect shown is along a fairly constant latitude and is therefore unaffected by latitudinal temperature and seasonal cycle variation. The upper panel shows the temperature averaged along the transect between the surface and 800 m and from 1991 to the most recent sampling.

The seasonal cycle is clearly visible in the upper 100–150m. There is a more subtle warming signal that occurred through the late 1990s, which is made apparent by the isotherms increasing in depth through that time period. This warming was significant in that it extended through the full 800 m of the measurements (effectively the full depth of the eastern Tasman Sea). It also began during an El Niño period when conditions would be expected to be relatively cool. Finally, it was thought to be linked to a large-scale warming event centred on 40°S that had hemispheric and perhaps global implications. This warming has been discussed by Sutton et al (2005) who examined the local signals, Bowen et al (2006) who studied the propagation of the signal into the New Zealand area, and Roemmich et al (2007), who examined the broad-scale signal over the entire South Pacific Ocean. Roemmich et al (2007) hypothesized that the ultimate forcing was due to an increase in high latitude westerly winds effectively speeding up the entire South Pacific gyre.

Other phenomena have led to periods of warming that are not as yet fully understood. In particular a period of widespread warming in the Tasman Sea to depths of at least 800 m, 1996–2002 (Sutton et al 2005). Both stochastic environmental variability and predictable cycles of change influence the productivity and distribution of marine biota in our region.

10.2.2 CLIMATE VARIABLES

The Interdecadal Pacific Oscillation (IPO) is a Pacific-wide reorganisation of the heat content of the upper ocean and represents large-scale, decadal temperature variability, with changes in phase (or “regime shifts”) over 10–30 year time scales. In the past 100 years, regime shifts occurred in 1925, 1947, 1977 and 2000 (Figure 10.11). The latest shift should result in New Zealand experiencing periods of reduced westerlies, with associated warmer air and sea temperatures and reduced upwelling on western coasts (Hurst et al 2012).

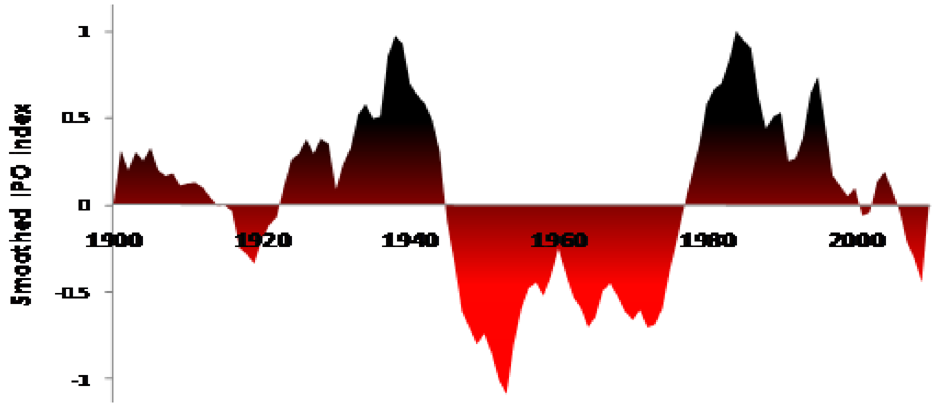


Figure 10.11: Smoothed index of the Interdecadal Pacific Oscillation (IPO) since 1900. (Image source NIWA based on data from the United Kingdom Meteorological Office, UKMO).

The El Niño-Southern Oscillation (ENSO) cycle in the tropical Pacific has a strong influence on New Zealand. ENSO is described here by the Southern Oscillation Index (SOI), a measure of the difference in mean sea-level pressure between Tahiti (east Pacific) and Darwin (west Pacific). When the SOI is strongly positive, a La Niña event is taking place and New Zealand tends to experience more north easterlies, reduced westerly winds, and milder, more settled, warmer anticyclonic weather and warmer sea temperatures (Hurst et al 2012). When the SOI is strongly negative, an El Niño event is taking place and New Zealand tends to experience increased westerly and south-westerly winds and cooler, less settled weather and enhanced along shelf upwelling off the west coast South Island and north east North Island (Shirtcliffe et al 1990, Zeldis 2004, Chang & Mullan 2003). The SOI is available monthly from 1876 onwards (Mullan 1995) (Figure 10.12).

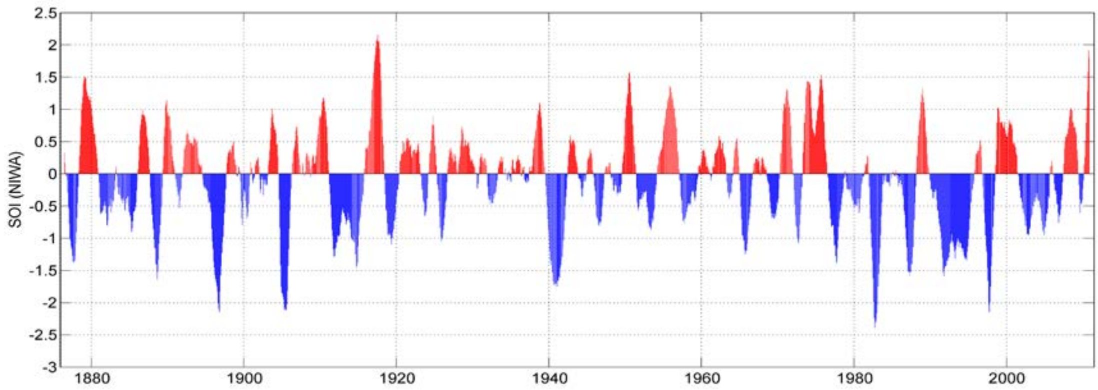


Figure 10.12: Southern Oscillation Index (SOI) 13-month running mean 1876–2010. Red indicates warmer temperatures, blue indicates cooler conditions for New Zealand. (Image courtesy of NIWA.)

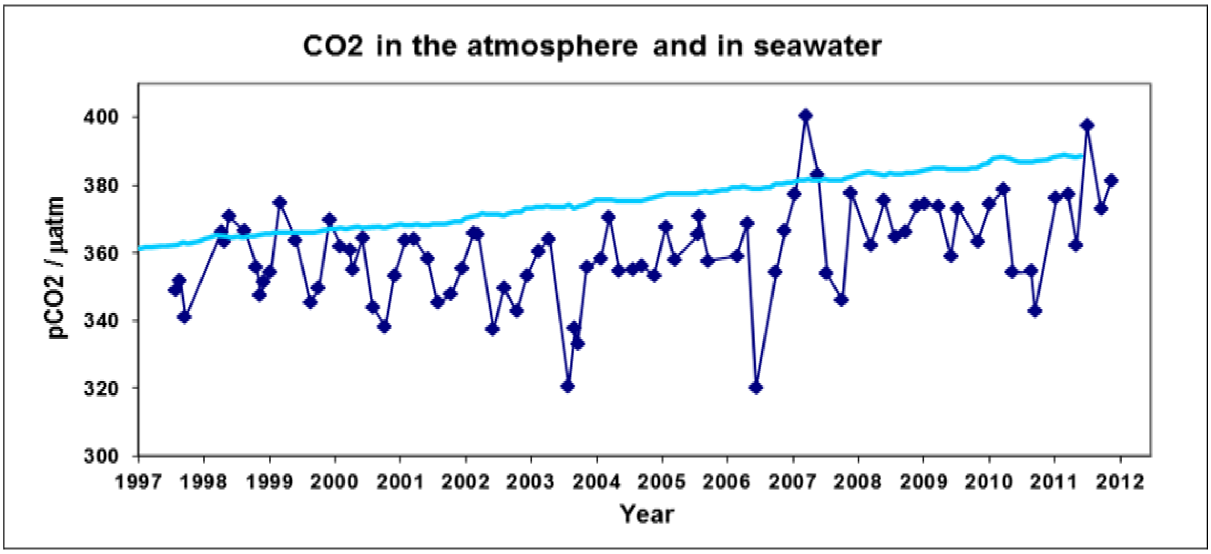


Figure 10.13: pCO_2 (partial pressure of CO_2) in subantarctic surface seawater from the *R.V. Munida* transect, 1998–2012. (Image courtesy of K. Currie, NIWA).

10.2.3 WATER CHEMISTRY: OCEAN ACIDIFICATION

An increase in atmospheric CO2 since the industrial revolution has been paralleled by an increase in CO2 concentrations in the upper ocean (Sabine et al 2004), with global ocean uptake on the order of about 2 gigatonnes (Gt) per annum (about 30% of global anthropogenic emissions, IPCC 5th Report). The anthropogenic CO2 signal is apparent to an average depth of about 1000 m.

The increasing rate of CO2 input from the atmosphere has surpassed the ocean's natural buffering capacity and so the surface of the ocean is becoming more acidic. This is because carbon dioxide absorbed by seawater reacts with H2O to form carbonic acid, the dissociation of which releases hydrogen ions, so raising the acidity and lowering the pH of seawater. Since1850, average surface ocean pH has decreased by 0.1 units, with a further decrease of 0.4 units to 7.9 predicted by 2100 (Houghton et al 2001). The pH scale is logarithmic, so a 0.4 pH decrease corresponds to a 150% increase in hydrogen ion concentration. Both the predicted pH in 2100 and the rate of change in pH are outside the range experienced by the oceans for at least half a million years. In the absence of any decrease in CO2 emissions this trend is likely to continue Caldeira & Wickett, (2003).

In New Zealand, the projected change in surface water pH between 1990 and 2070 is a decrease of 0.15–0.18 pH units (Hobday et al 2006). The only time series of dissolved pCO2 and pH in NZ waters is the bimonthly sampling of a transect across neritic, subtropical and subantarctic waters off the Otago shelf since 1998 (University of Otago/NIWA Munida Otago Shelf Time Series). Dissolved pCO2 shows some indication of an increase although this is not linear and does not correlate with a rise in atmospheric CO2 (Figure 10.13).

The Munida time-series pH data shows a decline in subantarctic surface waters since 1998 (Figure 10.14). Addition of a sine-wave function to the pH data suggests a) a linear decline in surface water pH and b) that winter time pH values are consistent with that expected from equilibrium with atmospheric CO2 as recorded at the NIWA Baring Head atmospheric station (K. Hunter (University of Otago) and K. Currie (NIWA), pers. comm.). The oscillations are primarily due to seasonal changes in water temperature and biological removal of dissolved carbon in the seawater.

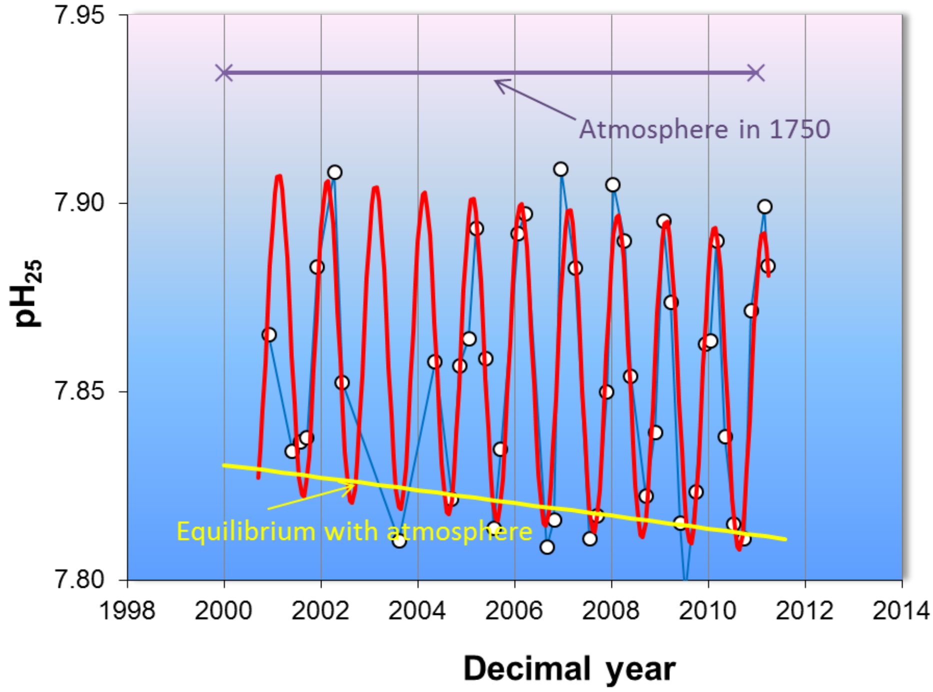


Figure 10.14: pH in subantarctic surface seawater on the R.V. Munida transect, 1998–2006. The blue points and joining lines are the actual measurements, and the red line a best fit to the points using a sine wave function (to represent seasonal change). The black line represents pH assuming equilibrium with the atmosphere concentration in the Year 1750. The yellow line is the pH assuming equilibrium with actual CO2 concentrations measured at the NIWA Baring Head Atmospheric Station. pH25 is the pH measured at 25oC (Image Source: A Southern Hemisphere Time Series for CO2 Chemistry and pH K. Hunter, K.C. Currie, M.R. Reid, H. Doyle. A presentation made at the International Union of Geodesy and Geophysics (IUGG) General Assembly Meeting, Melbourne June 2011.)

Globally, open ocean seawater pH shows relatively low spatial and temporal variability, compared to coastal waters where pH may vary by up to 1 unit in response to precipitation, biological activity in the seawater and sediment and other coastal processes. Surface pH in the open ocean has been determined on a monthly basis at the BATS (Bermuda Time Series Station) in the North Atlantic since 1983 (Bates 2001, 2007), and at HOT (Hawaii Time Series Station) in the North Pacific since 1988 (Brix et al 2004, Dore et al 2009). Both time series records show long term trends of increasing pCO2 (partial pressure of CO2) and decreasing pH, with the pCO2 increasing at a rate of 1.25 µatm per year, and pH decreasing by 0.0012 pH units per annum since 1983 at Bermuda (Figure 10.15). Placed in the context of these longer time series of atmospheric CO2 measurements, the short record of the Munida Subantartcic Water time series shows pCO2 and pH in surface seawater (see Figure 10.14) tracking the atmospheric CO2 (Figure 10.15). In addition, the regional means of seawater pH differ significantly with temperature, with the South Pacific at the lower end (Feely et al 2009).

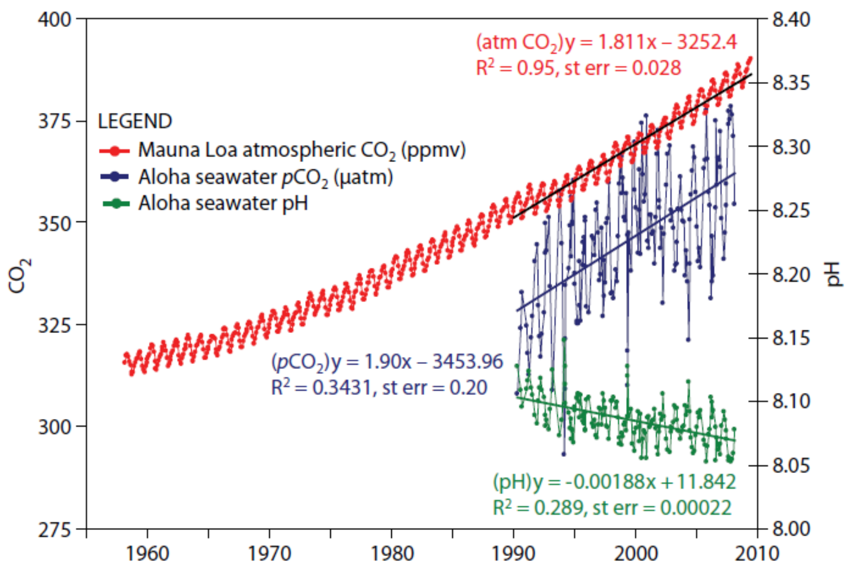


Figure 10.15: Time series of atmospheric carbon dioxide at Moana Loa, seawater carbon dioxide and surface ocean pH at Ocean station ALOHA in the subtropical North Pacific Ocean near Hawaii. pH is shown as in situ pH, based on direct measurements and calculated from dissolved inorganic carbon and alkalinity in the surface layer (after Dore et al 2009). (Image directly sourced from Feely et al 2009 with permission.)

Biological implications of ocean acidification result from increasing dissolved pCO2, increasing hydrogen ions (decreasing pH) and decreasing carbonate availability. The concern about ocean acidification is that the resulting reduction in carbonate availability may potentially impact organisms that produce shells or body structures of calcium carbonate, resulting in a redistribution of an organism's metabolic activity and increased physiological stress. Organisms most likely to be affected are those at the base of the food chain (bacteria, protozoa, plankton), coralline algae, rhodoliths, shallow and deepwater corals, echinoderms, molluscs, and possibly cephalopods (e.g., squids) and high-activity pelagic fish (e.g., tunas) (see Feely et al 2004 and references therein; Orr et al 2005, Langer et al 2006). This is particularly of concern for deep-sea habitats such as seamounts, which can support structural reef-like habitat composed of stony corals (Tracey et al 2011) as well as commercial fisheries for species such as orange roughy (Clark 1999). A shoaling carbonate saturation horizon could push such biogenic structures to the tops of seamounts, or cause widespread die-back (e.g., Thresher et al 2012). This has important implications for the structure and function of benthic communities, and perhaps also for the deep-sea ecosystems that support New Zealand's key deepwater fisheries. Conversely some groups, including phytoplankton and sea-grass, may benefit from the increase in dissolved pCO2 due to increased photosynthesis.

Direct effects of acidification on the physiology and development of fish have also been investigated. This has particularly focussed on the freshwater stages of salmonids (due to the widespread occurrence of pollution-derived acid rain) but increasingly in marine fish, where adverse effects on physiology development have been documented (e.g. Franke & Clemmesen 2011). Such studies highlight the potential for increasing acidification to impact larval growth and development, with implications for survival and recruitment of both forage fish and fish harvested commercially.

10.3 OCEAN CLIMATE TRENDS AND NEW ZEALAND FISHERIES

This section has been quoted almost directly from the summary in Hurst et al (2012). Some general observations on recent trends in some of the key ocean climate indices that have been found to be correlated with a variety of biological processes among fish (including recruitment fluctuations, growth, distribution, productivity and catch rates) are:

- The Interdecadal Pacific Oscillation (IPO): available from 1900; time scale 10–30 years. The IPO has been found to have been correlated with decadal changes ('regime shifts') in northeast Pacific ecosystems (e.g., Alaska salmon catches). In the New Zealand region, there is evidence of a regime shift into the negative phase of the IPO in about 2000. During the positive phase, from the late 1970's to 2000, New Zealand experienced periods of enhanced westerlies, with associated cooler air and sea temperatures and enhanced upwelling on western coasts. Opposite patterns are expected under a negative phase. For most New Zealand fisheries, monitoring of changes in populations began in the late 1970s, so there is little information on how New Zealand fishstocks might respond to these longer-term climatic fluctuations. Some of the recent changes in fish populations since the mid 1990s, for example, low western stock hoki recruitment indices (Francis 2009) and increases in some elasmobranch abundance indices (Dunn et al 2009) may be shorter-term fluctuations that might be related in some way to regional warming during the period and only longer-term monitoring will establish whether they might be related to longer-term ecosystem changes.
- The Southern Oscillation Index: available from 1876; best represented as annual means. Causal relationships of correlations of SOI with fisheries processes are poorly understood but probably related in some way to one or more of the underlying ocean climate processes such as winds or temperatures. When the index is strongly negative, an El Niño event is taking place and New Zealand tends to experience increased westerly and south-westerly winds, cooler sea surface temperatures and enhanced upwelling in some areas (see, for example, the correlation of monthly SST at Leigh and SOI indices, Figure 10.13). Upwelling has been found to be related to increased nutrient flux and phytoplankton growth in areas such as the west coast South Island, Pelorus Sound and north-east coast of the North Island (Willis et al 2007, Zeldis et al 2008). El Niño events are likely to occur on 3–7 year time scales and are likely to be less frequent during the negative phase of the IPO which began in about 2000. This is likely to impact positively on species that show stronger recruitment under increased temperature regimes (e.g., snapper, Francis 1993, 1994a, b).
- Surface wind and pressure patterns: available from the 1940s; variation in patterns can be high over monthly and annual time scales and many of the indices are correlated with each other, and with SOI and IPO indices (e.g., more zonal westerly winds, more frequent or regular cycles in southerlies in the positive IPO, 1977–2000). Correlations with biological process in fish stocks may occur over short time scales (e.g., impact on fish catchability) as well as seasonal and annual scales (e.g., impact on recruitment success). Wind and pressure patterns have been found to be correlated with fish abundance indices for southern gemfish (Renwick et al 1998), hake, red cod and red gurnard (Dunn et al 2009), rock lobster (Booth et al 2000), and southern blue whiting (Willis et al 2007, Hanchet & Renwick 1999). Causal relationships of these correlations are poorly understood but can be factored into hypothesis testing as wind and pressure patterns affect surface ocean conditions through heat flux, upwelling and nutrient availability on exposed coasts.
- Temperature and sea surface height: available at least monthly over long time scales (air temperatures from 1906) or relatively short time scales (ocean temperatures to 800 m, SST and SSH variously from 1987). Ocean temperatures, SST and SSH are all correlated with each other and smoothed air temperatures correlate well with SST in terms of interannual and seasonal variability; there are also some correlations of SST and SSH with surface wind and pressure patterns (see Dunn et al 2009). SST has been found to be correlated with relative fish abundance indices (derived from fisheries and/or trawl surveys) for elephantfish, southern gemfish, hoki, red cod, red gurnard, school shark, snapper, stargazer and tarakihi (Francis 1994a, b, Renwick et al 1998, Beentjes & Renwick 2001, Gilbert & Taylor 2001, Dunn et al 2009). Air temperatures in New Zealand have increased since 1900; most of the increase

occurred since the mid 1940s. Increases from the late 1970s to 2000 may have been moderated by the positive phase of the IPO. Coastal SST records from 1954 (at Portobello) also show a slight increase through the series and, in general, show strong correlations with SOI (i.e., cooler temperatures in El Niño years). Other time series (SSH, ocean temperature to 800 m) are comparatively short but show cycles of warmer and cooler periods on 1–6 year time scales. All air and ocean temperature series show the significant warming event during the late 1990s which has been followed by some cooling, but not to the levels of the early 1990s.

- Ocean colour and upwelling: these will be important time series because they potentially have a more direct link to biological processes in the ocean and are more easily incorporated into hypothesis testing. The ocean colour series starts in late 1997, so is not able to track changes that may have occurred since before the late 1990s warming cycle. These indices also need to be analysed with respect to SST, SSH and wind patterns, at similar locations or on similar spatial scales. The preliminary series developed exhibit some important spatial differences and trends that may warrant further investigation in relation to fish abundance indices. Of note are the increased chlorophyll indices off the west and south-west coast of the South Island in spring/summer during the last 5–6 years and the relatively low upwelling indices off the west coast South Island during winter in the late-1990s (Hurst et al 2012).
- Currents: there are no general indices of trends or variability at present. Improvements in monitoring technology (e.g., satellite observations of SSH; CTD; ADCP; ARGO floats) have resulted in more information becoming available to enable numerical models of ocean currents to be developed. On the open ocean scale, there is considerable complexity in the New Zealand zone (e.g., frontal systems, eddy systems of the east coast). In the coastal zone, this is further complicated in coastal areas by the effects of tides, winds and freshwater (river) forcing, and a more limited monitoring capability. Nevertheless, the importance of current systems is starting to become more recognised and incorporated into analysis and modelling of fisheries processes and trends. Recent examples include the retention of rock lobster phyllosoma (mid-stage larvae) in eddy systems (Chiswell & Booth 2005, 2007), the apparent bounding of orange roughy nursery grounds by the presence of a cold-water front (Dunn et al 2009) and the drift of toothfish eggs and larvae (Hanchet et al 2008).
- Acidification: The increase in atmospheric CO2 has been paralleled by an increase in CO2 concentrations in the upper ocean, resulting in a decrease in pH. Maintenance of the one existing New Zealand monitoring programme for pH and pCO2, and development of new programmes to monitor the impacts of pH on key groups of organisms are critical. Potentially vulnerable groups include organisms that produce shells or body structures of calcium carbonate (corals, molluscs, plankton, coralline algae), and also non-calcifying groups including plankton, squid and high-activity pelagic fishes. Potentially positive impacts of acidification include increased phytoplankton carbon fixation and vertical export and increased productivity of sub-tropical waters due to enhanced nitrogen fixation by cyanobacteria. Secondary effects at the ecosystem level, such as productivity, biomass, community composition and biogeochemical feedbacks, also need to be considered.

Climate change was not specifically addressed as part of the report by Hurst et al (2012), although indices described are an integral part of monitoring the speed and impacts of climate change. As noted under the air temperature section, the slightly increasing trend in temperatures since the mid 1940s is likely to have been moderated by the positive phase of the IPO, from the late 1970s to the late 1990s. With the shift to a negative phase of the IPO in 2000, it is likely that temperatures will increase more steeply. Continued monitoring of the ocean environment and response is critical. This includes not only the impacts on productivity, at all levels, but also on increasing ocean acidification.

For the New Zealand region, key ocean climate drivers in the last decade have been:

- the significant warming event in the late 1990s;

- the regime shift to the negative phase of the IPO in about 2000, which is likely to result in fewer El Niño events for a 20–30 year period, i.e., less zonal westerly winds (already apparent compared to the 1980–2000 period) and increased temperatures; this is the first regime shift to occur since most of our fisheries monitoring time series have started (the previous shift was in the late 1970s); and
- global trends of increasing air and sea temperatures and ocean acidification.

10.4 REFERENCES

Barcelos e Ramos, J; Biswas, H; Schulz, K G; LaRoche, J; Riebesell, U (2007) Effect of rising atmospheric carbon dioxide on the marine nitrogen fixer *Trichodesmium*, Global Biogeochemical Cycles 21. GB2028, doi:10.1029/2006GB002898.

Bates, N R (2001) Interannual variability of oceanic CO2 and biogeochemical properties in the Western North Atlantic subtropical gyre. Deep-Sea Research II. 48:1507–1528.

Bates, N R (2007) Interannual variability of the oceanic CO2 sink in the subtropical gyre of the North Atlantic Ocean over the last 2 decades. Journal of Geophysical Research 112, C09013, doi:10.1029/2006JC003759, 2007

Beentjes, M P; Renwick, J A (2001) The relationship between red cod, *Pseudophycis bachus*, recruitment and environmental variables in New Zealand. Environmental Biology of Fishes 61: 315–328.

Booth, J D; Bradford, E; Renwick, J. (2000). *Jasus edwardsii puerulus* settlement levels examined in relation to the ocean environment and to subsequent juvenile and recruit abundance. New Zealand Fisheries Assessment Report 2000/34.

Bowen, M M; Sutton, P J H; Roemmich, D (2006) Wind-driven and steric fluctuations of sea surface height in the southwest Pacific, Geophysical Research Letters 33, L14617, doi:10.1029/2006GL026160.

Boyd, P W; Law, C S (2011) An Ocean Climate Change Atlas for New Zealand waters A primer for a major new web-based tool to help predict how oceanic species will be affected by climate change NIWA Information Series No. 79.

Bradford-Grieve, J M; Probert, P K; Nodder, S D; Thompson, D; Hall, J; Hanchet, S; et al (2003) Pilot trophic model for subantarctic water over the Southern Plateau, New Zealand: a low biomass, high transfer efficiency system. Journal of Experimental Marine Biology and Ecology 289.2: 223–262.

Brix, H; Gruber, N; Keeling, C D (2004) Interannual variability of the upper ocean carbon cycle at station ALOHA near Hawaii. Global Biogeochemical Cycles 18(4) GB4019 Nov 24 2004.

Caldeira, K; Wickett, M E (2003) Anthropogenic carbon and ocean pH. Nature 425:365.

Carter, L; Garlick, R D; Sutton, P; Chiswell, S; Oien, N A; Stanton, B R (1998) Ocean Circulation New Zealand. NIWA Chart Miscellaneous Series 76.

Chang, F H; Mullan, B (2003) Occurrence of major harmful algal blooms in New Zealand: is there a link with climate variation. The Climate Update 53: 4.

Chiswell, S M (1996) Variability in the Southland Current, New Zealand. New Zealand Journal of Marine and Freshwater Research 30: 1–17.

Chiswell, S M; Booth, J D (2005) Distribution of mid- and late-stage *Jasus edwardsii phyllosomas*: implications for larval transport. New Zealand Journal of Marine and Freshwater Research 39. 1157–1170.

Chiswell, S M; Booth, J D (2007) Sources and sinks of larval settlement in *Jasus edwardsii* around New Zealand: Where do larvae come from and where do they go? Marine Ecology Progress Series 354: 201–217.

Clark, M R (1999) Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. Oceanologica Acta 22(6): 593–602.

Dore, J E; Lukas, R; Sadler, D W; Church, M J; Karl, D M. (2009) Physical and biogeochemical modulation of ocean acidification in the central North Pacific. Proceedings of the National Academy of Sciences of the United States of America 106(30):12 235–12 240.

Dunn, M R; Hurst, R; Renwick, J; Francis, R I C C; Devine, J; McKenzie, A (2009) Fish abundance and climate trends in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 31. 75 p.

Feely, R A; Doney, S C; Cooley, S R (2009) Ocean Acidification. Present conditions and future changes in a high CO2 world. Oceanography 22(4): 36–47.

Feely, R A; Sabine, C L; Lee, K; Berelson, W; Kleypas, J; Fabry, V J; Millero, F J (2004) Impact of Anthropogenic CO2 on the CaCO3 System in the Oceans (abstract). Science 305 (5682): 362–366. doi:10.1126/science.1097329. PMID 15256664

Francis, M P (1993) Does water temperature determine year class strength in New Zealand snapper (*Pagrus auratus*, Sparidae)? Fisheries Oceanography 2(2): 65–72.

Francis, M P (1994a) Growth of juvenile snapper, *Pagrus auratus* (Sparidae). New Zealand Journal of Marine and Freshwater Research 28: 201–218.

Francis, M P (1994b) Duration of larval and spawning periods in *Pagrus auratus* (Sparidae) determined from otolith daily increments. Environmental Biology of Fishes 39: 137–152.

Francis, R I C C (2009) Assessment of hoki (*Macruronus novaezelandiae*) in 2008. New Zealand Fisheries Assessment Report 2009/7. 80 p.

Franke, A; Clemmesen, C (2011) Effect of ocean acidification on early life stages of Atlantic herring (*Clupea harengus* L.). Biogeosciences Discussions, 8, 7097–7126.

Gilbert, D J; Taylor, P R (2001) The relationship between snapper (Pagrus auratus) year class strength and temperature for SNA 2 and SNA 7. New Zealand Fisheries Assessment Report 2001/64. 33 p.

Gordon, D P; Beaumont, J; MacDiarmid, A; Robertson, D A; Ahyong, S T (2010) Marine Biodiversity of Aotearoa New Zealand. PLoS ONE 5(8): e10905. doi:10.1371/journal.pone.0010905

Hanchet, S M; Fenaughty, J M; Dunn, A; Williams, M J H (2008) A hypothetical life cycle for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region CCAMLR Science 15: 35–53.

Hanchet, S M; Renwick, J A (1999) Prediction of year class strength in southern blue whiting (*Micromesistius australis*) in New Zealand waters. New Zealand Fisheries Assessment Research Document 99/51. 24 p. (Unpublished document held by NIWA library.)

Heath, R A (1985) A review of the physical oceanography of the seas around New Zealand –1982. New Zealand Journal of Marine and Freshwater Research 19: 79–124.

Hobday, A J; Okey, T A; Poloczanska, E S; Kunz, T J; Richardson, A J (2006) Impacts of Climate Change on Australian Marine Life. CSIRO Marine and Atmospheric Research report to the Department of the Environment and Heritage.

Houghton, J T; Ding, Y; Griggs, D J; Noguer, M; van der Linden, P J; Dai, X; Maskaell, K; Johnson, C A (2001) Climate change 2001: the scientific basis. Contribution of Working Group I to the third Assessment Report of the International Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Hurst, R J; Renwick, J A; Sutton, P J H; Uddstrom, M J; Kennan, S C; Law, C S; Rickard, G J; Korpela, A; Stewart, C; Evans, J (2012) Climate and oceanographic trends of potential relevance to fisheries in the New Zealand fisheries region. New Zealand Aquatic Environment and Biodiversity Report No. 90. 202 p.

IPCC Fifth Assessment Report http://www.ipcc.ch/report/ar5/wg1/

Langer, G; Geisen, M; Baumann, K-H; Kläs, J; Riebesell, U; Thoms, S; Young, J R (2006) Species-specific responses of calcifying algae to changing seawater carbonate chemistry, Geochemistry Geophysics Geosystems, 7 : Q09006, doi:10.1029/2005GC001227

Lutz, M J; Caldeira, K; Dunbar, R B; Behrenfeld, M J (2007) Seasonal rhythms of net primary production and particulate organic carbon flux to depth describe the efficiency of biological pump in the global ocean. Journal of Geophysical Research Oceans 112:C10011 doi: 10.1029/2006JC003706

Mullan, A B (1995) On the linearity and stability of Southern Oscillation-climate relationships for New Zealand. International Journal of Climatology 15: 1365–1386.

Mullan, A B; Stuart, S J; Hadfield, M G; Smith, M J (2010) Report on the Review of NIWA's 'Seven-Station' Temperature Series. NIWA Information Series No. 78. 175 p.

O'Driscoll, R L; Hurst, R J; Dunn, M R; Gauthier, S; Ballara, S L (2011) Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys. New Zealand Aquatic Environment and Biodiversity Report No. 76.

Orr, J C; Fabry, V J; Aumont, O; Bopp, L; Doney, S C; Feely, R A; Gnanadesikan, A; Gruber, N; Ishida, A; Joos, F; Key, R M; Lindsay, K; Maier-Reimer, E; Matear, R; Monfray, P; Mouchet, A; Najjar, R G ;Plattner, G-K; Rodgers, K B; Sabine, C L; Sarmiento, J L; Schlitzer, R; Slater, R D; Totterdell, I J; Weirig, M-F ;Yamanaka, Y; Yool, A (2005) Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437: 681–686.

Pinkerton, M H; Richardson, K M; Boyd, P W; Gall, M P; Zeldis, J; Oliver, M D; Murphy, R J (2005) Intercomparison of ocean colour band-ratio algorithms for chlorophyll concentration in the Subtropical Front east of New Zealand. Remote Sensing of Environment 97: 382–402.

Reid, J L (1986) On the total geostrophic circulation of the South Pacific Ocean: flow patterns, tracers and transports. Progress in Oceanography 16: 1–61.

Renwick, J A; Hurst, R J; Kidson, J W (1998) Climatic influences on the recruitment of Southern Gemfish (*Rexea solandri*, Gempylidae) in New Zealand waters. International Journal of Climatology 18: 1655–1667.

Reynolds, R W; Smith, T M; Liu, C; Chelton, D B; Casey, K S; Schlax, M G (2007) Daily High-resolution Blended Analyses for sea surface temperature. Journal of Climate, 20, 5473–5496.

Ridgway, K R; Dunn, J R (2003) Mesoscale structure of the mean East Australian Current system and its relationship with topography. Progress in Oceanography 56: 189–222.

Roemmich, D; Gilson, J K; Davis, R; Sutton, P; Wijffels, S; Riser, S (2007) Decadal Spin-up of the South Pacific Subtropical Gyre. Journal of Physical Oceanography 37: 162–173.

Sabine, C L; Feely, R A; Gruber, N; Key, R M; Lee, K; Bullister, J L; Wanninkhof, R; Wong, C S; Wallace, D W; Tilbrook, B; Millero, F J; Peng, T H; Kozyr, A; Ono, T; Rios, A F (2004) The oceanic sink for anthropogenic CO2. Science 305:367–371.

Shirtcliffe, G G L; Moore, M I; Cole, A G; Viner, A B; Baldwin, R; Chapman, B (1990) Dynamics of the Cape Farewell upwelling plume, New Zealand. New Zealand Journal of Marine and Freshwater Research 24: 555–568.

Stanton, B R (1981) An oceanographic survey of the Tasman Front. New Zealand Journal of Marine and Freshwater Research 15: 289–297.

Stanton, B R; Ridgway, N M (1988) An oceanographic survey of the subtropical convergence zone in the Tasman Sea. New Zealand Journal of Marine and Freshwater Research 22: 583–593.

Stanton, B R; Sutton, P J H; Chiswell, S M (1997) The East Auckland Current, 1994–95. New Zealand Journal of Marine and Freshwater Research 31: 537–549.

Sutton, P; Bowen, M; Roemmich, D (2005) Decadal Temperature changes in the Tasman Sea. New Zealand Journal of Marine and Freshwater Research 39(6): 1321–1329.

Sutton, P J H (2003) The Southland Current: a subantarctic current. New Zealand Journal of Marine and Freshwater Research 37: 645–652.

Sutton, P J H; Roemmich, D (2001) Ocean temperature climate off north-east New Zealand. New Zealand Journal of Marine and Freshwater Research 35: 553–565.

Thompson, D W J; Solomon, S (2002) Interpretation of recent Southern Hemisphere climate change. Science, 296, 895–899.

Thompson, P A; Baird, M E; Ingleton, T; Doblin, M A (2009) Long-term changes in temperature Australian waters: implications for phytoplankton. Marine Ecology Progress Series 394, 1–19.

Thresher, R E; Guinotte, J; Matear, R; Fallon, S (2012) Adapting to the effects of climate change on Australia's deep marine reserves. Fisheries Research and Development Corporation (FRDC)/National Climate Change Adaptation Research Fund (NCCARF) Report 2010/510, 68 p.

Tracey, D M; Rowden, A A; Mackay, K A; Compton, T (2011) Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. Marine Ecology Progress Series 430: 1–22.

Willis, T J; Handley, S J; Chang, F H; Morrisey, D J; Mullan, B; Pinkerton, M; Rodgers, K L; Sutton, P H J; Tait, A (2007) Climate change and the New Zealand marine environment. NIWA Client Report for the Department of Conservation: NEL2007-025 October 2007, NIWA Project: DOC08305.

Zeldis, J R (2004) New and remineralised nutrient supply and ecosystem metabolism on the northeastern New Zealand continental shelf. Continental Shelf Research 24: 563–581.

Zeldis, J R; Howard-Williams, C; Carter, C M; Schiel, D R (2008) ENSO and riverine control of nutrient loading, phytoplankton biomass and mussel aquaculture yield in Pelorus Sound, New Zealand. http://www.int-res.com/articles/meps2008/371/m371p131.pdf

11 TROPHIC AND ECOSYSTEM-LEVEL EFFECTS

Scope of chapter	This chapter outlines the global and New Zealand understanding of trophic and ecosystem-level effects of fishing, with respect to types of effects, their causes, the types of ecosystems most likely to be affected, the spatial scales of effects, and indicators of trophic and ecosystem-level effects.
Area	All areas and fisheries
Focal localities	Whole EEZ
Key issues	Organisms in an ecosystem are linked by trophic (feeding) connections. Changes to one organism (by whatever means) can affect other organisms and sometimes large parts of the food-web. Changes occurring across many trophic levels (ecosystem-level changes) can have implications for ecosystem resilience.
Emerging issues	Ecosystem approach to fisheries and how fishing interacts with other stressors of marine ecosystems
MPI Research (current)	ZBD200505 (Long term change in New Zealand coastal ecosystems) HMS2014-05 (Stable isotope analysis of highly migratory species to assess trophic linkages and spatial and temporal movement trends of HMS sharks)
NZ Government Research (current)	• NIWA core funding - Coasts & Oceans centre: “Ecosystem structure and function” and “Marine Biological Resources”; Fisheries centre: “Ecosystem effects of fishing” • Climate Change Impacts and Implications (MBIE Contestable, http://ccii.org.nz/) • Marine Futures (MBIE Contestable, http://www.niwa.co.nz/coasts-and-oceans/research-projects/marine-futures)
Links to 2030 objectives	Increase sustainable resource use, and protect from biological risk
Related chapters/issues	Effects of fishing on ecologically dependent species Benthic impacts of fishing (including habitats of particular significance for fisheries management) Climate and oceanographic context of New Zealand fisheries (including effects of climate variability and change) Land-based effects on fisheries Marine biodiversity Marine biosecurity Other work on fishstocks, marine mammals, seabirds, bycatch, etc.

Note: This chapter is new for the AEBAR 2014.

11.1 CONTEXT

11.1.1 SCOPE OF CHAPTER

This chapter addresses trophic and ecosystem-level effects which may arise from fishing or from other drivers of change on marine ecosystems in the New Zealand region. “Trophic effects” are changes to the structure and function of ecosystems occurring entirely or largely because of changes in the feeding of organisms within a food-web. “Ecosystem-level effects” are defined as changes occurring across several trophic levels[57]. An ecosystem is defined as a biological community of interacting organisms and their physical environment. The region of interest for the purposes of this chapter is the New Zealand marine exclusive economic zone (EEZ) and territorial waters, including coastal and offshore regions. The focus is on wild-caught fisheries rather than aquaculture.

This chapter focuses on trophic and ecosystem-level effects that are relevant to the sustainability and environmental effects of New Zealand fisheries as set out in the relevant New Zealand legislation, current New Zealand government strategic/operational policies, and international best practice. Relevant legislation, policies

[57] “Trophic level” is a measure of the position of an organism within a food-web. Primary producers have trophic level 1, herbivores have trophic level 2, and carnivores have trophic levels between about 3 and 5 in aquatic systems (Lindeman 1942).

and best practices are summarised in Chapter 1 (Sections 1.2 and 1.3). The relevance of these specifically to trophic and ecosystem-level effects include:

- The Fisheries Act 1996 requires that (a) associated or dependent species should be maintained above a level that ensures their long-term viability; (b) biological diversity of the aquatic environment should be maintained.
- Fisheries 2030: environmental principles of Fisheries 2030 include: Ecosystem-based approach; Conserve biodiversity; Environmental bottom lines; Precautionary approach; Responsible international citizen; Inter-generational equity; Best available information; and Respect rights and interests (Ministry of Fisheries 2009). Management of trophic and ecosystem-level effects of fisheries aligns with "Fisheries 2030 Objective 6": Manage impacts of fishing and aquaculture.
- MPI's Strategy "Our Strategy 2030": to increase sustainable resource use, and protect from biological risk.
- FAO best practice requires the application of scientific methods and tools that go beyond the single-species approaches: "Managers and decision-makers must now explicitly consider interactions in the ecosystem" and scientific advice should include ecosystem considerations (FAO 2008).
- Marine Stewardship Council (MSC) Principle 2: "Fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem (including habitat and associated dependent and ecologically related species) on which the fishery depends." (Marine Stewardship Council 2010). This only applies to those fisheries that are MSC certified.

Effects of fishing on target species are considered in the annual New Zealand Fisheries Assessment Plenary (available from the Ministry for Primary Industries website[58]). The Fisheries Assessment Plenary also includes consideration of the effects of fishing on the aquatic environment (under the "environmental and ecosystem considerations" section for each stock). Effects of fishing all stocks on protected species, non-protected bycatch species, and on the benthos are given in other chapters of this AEBAR document. In particular, effects of fishing on seabirds and marine mammals which occur through trophic connections (e.g. fishing affecting the availability of prey for seabirds) are considered in Theme 1 of this report.

11.1.2 WHAT ARE TROPHIC AND ECOSYSTEM-LEVEL EFFECTS?

Trophic and ecosystem-level effects are changes to multiple parts of the foodweb. Such effects can occur in coastal or deepwater ecosystems and can involve a wide range of biological, chemical and physical processes. Because trophic and ecosystem-level effects occur over a range of different organisms and time/space scales, it is often difficult to be sure of the magnitude of the change or its underlying cause. This has led to much speculation and disagreement as to the mechanism or processes involved, and a corresponding high level of disagreement as to what management should have done to prevent it, or should do to respond to the change once it has occurred (Schiermeier 2004; Hilborn 2007; Murawski et al 2007; Schiel 2013). Sometimes controlled experiments are conducted to see if trophic effects can be simulated, but low statistical power is a common problem of this kind of test (Schroeter et al 1993). In general, international research on trophic and ecosystem-level effects is active and one where there are generally more hypotheses than well-accepted empirical demonstrations of the effects. It is probably useful to start with a few examples of some trophic and ecosystem-level effects.

As part of the widespread pattern of collapses of cod (Gadus morhua) populations in the North Atlantic in the late 1980s and the 1990s, cod biomass off the US East Coast dropped by a factor of five, from more than 150 000 metric tons (MT) to about 30 000 t (Mayo et al 1998). With some slight lag, local stocks of the cod's favoured prey, Atlantic herring (*Clupea harengus*), increased over the same period 20-fold, to nearly two million t (NEFSC 1998). Elsewhere, on the opposite side of the Atlantic, a collapse of the cod resource in the Baltic Sea was followed by an eight fold increase in abundance of European sprat (Sprattus sprattus) – a major prey item for cod in that ecosystem (Köster et al 2003b; Casini et al 2008, 2009). In

[58] http://www.mpi.govt.nz/document-vault/3888 http://www.mpi.govt.nz/document-vault/3889 http://www.mpi.govt.nz/document-vault/3890 (October 2014)

these cases, a reduction in the abundance of a piscine predator by fishing led to an increase in the prey species – a large scale "predation release" effect (see Section 11.1.3.1).

In New Zealand, observations in a number of northern marine reserves showed an increase in the abundance and size of red rock lobsters and piscine predators of algal grazing invertebrates which coincided with a gradual decrease in urchin density and an increase in algal cover (Babcock et al 1999; Shears & Babcock 2002, 2003; Salomon et al 2008; Babcock et al 2010). These changes, suggestive of a trophic cascade (see Section 11.1.3.2) are consistent with the results of ecosystem models of the role of rock lobsters in New Zealand rocky reef ecosystems, using both qualitative (Beaumont et al 2009) and quantitative frameworks (Pinkerton et al 2008; Eddy et al 2014; Pinkerton 2012). Shears et al (2008) found that the occurrence of this trophic cascade in northern New Zealand was likely to vary at local and regional scales in relation to abiotic factors. From a New Zealand wide perspective, Schiel (2013) concludes that urchin predators play a role in the dynamics of kelp beds only in some northern localities, and that environmental and climatic influences, species' demographics, and catchment-derived sedimentation are generally more important.

11.1.3 TYPES OF TROPHIC AND ECOSYSTEM-LEVEL EFFECTS

11.1.3.1 FIRST ORDER TROPHIC EFFECTS: PREY AVAILABILITY AND PREDATION RELEASE

Changes to the abundance, size structure and functional type[59] of a species can affect both its predators and prey by trophic interactions (Pace et al 1999). Increasing the abundance of a prey species may positively affect its predators (because they have to work less hard to find food) whereas reducing the abundance of a prey item may have a detrimental effect on the predators (by requiring them to hunt more intensively or by forcing a change in their diet); these are "prey availability" or bottom-up effects (Trillmich et al 1991; Jahncke et al 2004). Alternatively, changing the abundance of a predator may affect the abundance of some or all of its prey by changing their natural mortality rates (a top-down effect, Northcote 1988). Decreasing the abundance of a predator (for example by fishing a predatory fish) may cause the abundance of some or all of its prey to increase (a "predation release" effect, Casini et al 2012). These effects act over one trophic link and are hence called "first order" trophic effects.

11.1.3.2 TROPHIC CASCADES

Changes in the abundance of one species may go on to affect other species that are neither its predators nor its prey. This is a second order trophic effect (occurring via an intermediate organism), often called a "trophic cascade". The awareness of trophic cascades arose originally from work in the marine intertidal zone, and lakes (Hrbácek et al 1961; Shapiro et al 1975; Paine 1980), but has since become the focus of considerable theoretical and empirical research in marine ecosystems (Carpenter et al 1985; McQueen & Post 1988a, b; Christoffersen et al 1993; Pace et al 1999; Frank et al 2005; Borer et al 2005; Daskalov et al 2007; Möllmann et al 2008; Casini et al 2009; Schiel 2013). While the term trophic cascade was originally termed for top-down effects of predators, it is now usually defined as the propagation of indirect effects between nonadjacent trophic levels in a food chain or food web, whatever the direction of forcing (Gruner 2013). Thus, trophic cascades may also occur when changes in the populations of primary producers force changes at higher tropic levels (Beaugrand & Reid 2003; Bakun 2010). The potential for cascading effects of fishing in marine ecosystems is now thought to be as strong as or stronger than in freshwater ecosystems (Pace et al 1999; ICES 2005; Borer et al 2005).

A well-recognised example of a top-down cascade is the sea otter (Enhydra lutris), urchin (*Strongylocentrotus* spp.), kelp (Macrocystis pyrifera and other kelps) cascade in the north-east Pacific where hunting of sea otters in the eighteenth and nineteenth centuries allowed urchin populations to increase leading to over grazing of kelp beds (Szpak et al 2013). Protection of sea otters and subsequent expansion or reintroduction of populations into its former range reversed this cascade (Estes & Palmisano 1974, Estes 1996, Estes & Duggins 1995). The

[59] "Functional type" refers to the collection of life history and ecological characteristics of an organism, including whether it is a herbivore, carnivore or omnivore, its feeding behaviour (including size of prey), location in the water column/benthos, and mobility.

generality of the sea otter-urchin-kelp cascade has been questioned; for example, based on experimental treatments, Carter et al (2007) concluded that "the sea otter-trophic cascade paradigm is not universally applicable across locations or habitat types."

Where ecosystems are subject to stressors acting on different parts of the system together, changes due to cascading trophic effects can be extensive. For example, using field data collected over a 33-year period, Casini et al (2008, 2009) showed a four level community-wide trophic cascade in the open waters of the Baltic Sea. The dramatic reduction of the cod (*Gadus morhua*) population directly affected its main prey, the zooplanktivorous sprat (Sprattus sprattus) and indirectly the summer biomass of zooplankton and phytoplankton. Changes to the stock size of cod also affected the type of ecosystem control at the level of zooplankton. The cod-dominated configuration was characterized by low sprat abundance and independence between zooplankton and sprat variations (zooplankton abundance was controlled by oceanographic forcing). An alternate sprat-dominated configuration also existed in which cod biomass was low and zooplankton were strongly controlled by sprat predation (Casini et al 2009).

11.1.4 REGIME SHIFT AND INVASIVE SPECIES

An ecosystem can change to an alternative state if perturbations are greater than its resilience can accommodate, - this transition is called a regime-shift (Aebischer et al 1990; Estes & Duggins 1995; Beaugrand et al 2002; Daskalov et al 2007). Regime shifts can occur over large scales, affect many parts of the ecosystem and may be hard or slow to reverse ("hysteresis"). It has been suggested that ecosystem-level restructuring may maintain the system in its new state by means of negative feedbacks (Bakun 2006; Casini et al 2009; Möllman et al 2009; Lindegren et al 2010). Well-documented oceanographic-induced regime shifts in marine ecosystems have historically had substantial, long-lasting and typically (but not always) negative effects on fisheries. For example, during the 1980s, the North Sea experienced a change in hydro-climatic forcing that caused a rapid, temperature-driven ecosystem shift (Beaugrand & Ibanez 2004). In the North Sea the new dynamic regime after the late 1980s favoured jellyfish in the plankton and decapods and detritivores (echinoderms) in the benthos (Kirby et al 2008, 2009). The cod stocks in the North Sea and central Baltic Sea collapsed simultaneously with the ecosystem changes caused by the large-scale oceanographic changes (Reid et al 2003; Beaugrand 2004; Weijerman et al 2005; Casini et al 2008; Möllmann et al 2008; Lindegren et al 2010).

In another type of regime shift, there has been much recent debate as to whether in some regions, more intense, more frequent or more extensive blooms of jellyfish [60] are occurring in response to trophic and ecosystem-level changes in ocean ecosystems (Brodeur et al 1999, 2002; Mills 2001; Lynam et al 2006). In an example reported by Bakun & Weeks (2006), a massive ctenophore ("comb jelly") breakout in the early 1990s led to a nearly total collapse of fisheries in the Black Sea. The Black Sea ecosystems' historically dominant zooplanktivore, European anchovy (*Engraulis encrasicolus*), is a small, filter-feeding pelagic fish. In the late 1980s anchovy landings in the Black Sea increased to levels approaching 900 000 tons per year. At their maximum, in 1988, the catch of anchovy represented more than 60% of the total fishery catches taken from the Black Sea. As a result of heavy fisheries exploitation, anchovy spawning biomass in the following year declined by more than 85%. Shiganova (1998) reports that in the year after this drastic reduction in anchovy biomass, zooplankton abundance increased markedly. It was at this point, probably due to the enhanced food source, that the biomass of the ctenophore *Mnemiopsi leidyi* (a gelatinous zooplanktivorous species) in the Black Sea increased to a billion tons.

Condon et al (2013) assembled all available published and unpublished long-term time-series on jellyfish abundance across the oceans (no data from the New Zealand region) and found evidence of an approximately 20 year oscillation in global jellyfish abundance. Although an overall global increase in jellyfish abundance over the whole observational period 1874–2011 could not be detected, there was a weak but significant overall increase in jellyfish abundance since 1970. Gibbons & Richardson (2013) note that it is clear that we currently do not know whether there are really global increases in jellyfish, but that a more relevant question is whether jellyfish

[60] "Jellyfish" is often taken to include Medusozoa, Ctenophora and Thaliacea (Condon et al 2013) but should strictly be limited to Medusozoa and Ctenophora (Gibbons & Richardson 2013).

abundances are increasing in areas that are particularly important for humans - i.e. the coastal zone and important fishing areas – because costs of jellyfish blooms in these areas can be considerable. Recent increases in jellyfish abundance may be linked to one or more of: (a) warmer seas which enhance production, feeding and growth rates of jellyfish (Purcell 2005); (b) overfishing of competitors of jellyfish (Daskalov et al 2007); (c) increased supply of planktonic food for jellyfish associated with eutrophication of coastal waters (Parsons & Lalli 2002); (d) the spread of hypoxia, to which jellyfish exhibit greater tolerance than most other metazoans (Vaquer-Sunyer & Duarte 2008; Purcell, 2012); and (e) increase of artificial structures in coastal zones which may be habitats for jellyfish polyps (Duarte et al 2012).

11.1.4.1 EFFECTS OF CLIMATE CHANGE

Internationally and domestically, there is increasing recognition of the potential impacts of climate change on fisheries (IPCC 2007a, b; Valdes et al 2009; Rice & Garcia 2011). A changing climate may:

- affect individual physiological and behavioural responses of organisms (or some life stages of organisms, Petitgas et al 2013) which could lead to effects at the population level (Rijnsdorp et al 2009; O'Connor et al 2007; Perry et al 2005);
- change species proportions in fish assemblages (Engelhard et al 2011; Fulton 2011);
- lead to ocean acidification which may affect lower food-web structure and adversely impact calcifying organisms such as shellfish and corals (Fabry et al 2008; Cooley & Doney 2009);
- increase climate variability (Collins 2000) which may increase the risk of regime shift (Mullan et al 2001; Beaugrand 2004);
- change species ranges which might destabilize species relationships that help maintain ecosystem processes (Rice & Garcia 2011);
- lead to phonological (timing patterns) mismatches of grazers and predators (Sydeman & Bograd 2009);
- lead to invasive species becoming a greater threat (ICES 2005).

The global scientific understanding of how a changing climate may affect marine ecosystems is largely hypothetical to date, but it seems likely that impacts of climate change are likely to be largely trophic or ecosystem-level effects in nature (reviews by Lehodey et al 2006; Drinkwater et al 2010; Bakun 2010; Portner & Peck 2010; Ottersen et al 2010; Overland et al 2010; Hollowed et al 2013).

11.1.4.2 POTENTIAL FOR RECOVERY FOLLOWING OVER-DEPLETION

It is possible that trophic and system-level effects of fishing can affect the ability of fisheries to recover (rebuild) following over-exploitation, but this is disputed. Some scientists suggest that after a fisheries collapse the collapsed population often takes much longer to recover than expected based on known biological parameters, the previously observed carrying capacity of the habitat, and the fact that each adult female fish may spawn tens of thousands to millions of eggs (Hutchings 2000; Steele & Schumacher 2000). It is argued that something durable and significant can be done to the ecosystem during over-exploitation and that this inhibits recovery even if fishing mortality is reduced. For example, in the mid-1960s the sardine fishery in the northern Benguela collapsed from a high point of annual catches of about 1.5 million tons (Boyer 1996). Meanwhile, the other major fishery resources of the region, hake (Merlucius paradoxus and M. capensis) and horse mackerel (*Trachurus trachurus capensis*) also fell to low abundance levels and have not recovered (Bakun & Weeks 2006). The suggestion is that sardines previously occupied the key central position in the ecosystem structure and that these exploitable species have now been largely replaced by a combination of "jelly predators" and pelagic gobies in a stable, alternative ecosystem state (Boyer & Hampton 2001; Lynam et al 2006; Bakun & Weeks 2006).

One hypothesis for how trophic effects can prevent stock recovery is the "cultivation/ depensation" mechanism (Köster & Möllmann 2000; Walters & Kitchell 2001). In this hypothesis, consider a species X whose adults predate a species Y, but whose recruits are predated by species Y. If adults of X are abundant they can create favourable conditions for their own offspring by reducing the abundance of Y and hence reducing mortality of their pre-recruits. If the abundance of adults of X is reduced by fishing, expansion of Y may prevent re-establishment of the former species by increasing predation on the recruits of X (Folke et al 2004). A less theoretical example is that of Casini et al (2008), based on a 33-year time series in the

Baltic Sea, that showed the reduction of the cod population by fishing led to increases in abundances of sprat. Sprat, besides being preyed upon by cod, prey heavily on cod eggs and early larvae (Casini et al 2004). Some authors have concluded that this predation, together with the likelihood that zooplanktivorous cod larvae may suffer food competition with the high sprat population, was probably a significant factor preventing the resurgence of that cod population (Jarre-Teichmann et al 2002; Köster et al 2003a,b; Casini et al 2009).

However, the prevalence of trophic or ecosystem-level effects slowing or stopping recovery after fisheries collapses is disputed. Cardinale & Svedang (2011) studied the recent recovery of the eastern Baltic cod stock after more than 20 years of low biomass and productivity and concluded that the recovery was driven by a sudden reduction in fishing mortality and occurred in the absence of any exceptionally large year classes. The recovery of the cod stock during a "cod-hostile" ecological regime is taken by Cardinale & Svedang (2011) as indicative of fisheries (rather than climate or food-web effects) being the main regulator of cod population dynamics in the Baltic Sea. Cardinale & Svedang (2011) concluded that single species regulation still seems to be a well-functioning approach in handling natural resources, provided that it includes both temporal and spatial aspects of stock dynamics and fleet behaviour.

11.1.4.3 EFFECTS ON SCAVENGING SPECIES

Offal and discards from fishing vessels can be important sources of food for some marine species, and this constitutes a trophic perturbation to the ecosystem. In addition to scavenging of discards, fish are known to prey on biota damaged or revealed by recent trawling (Kaiser & Spencer 1994). This may include benthic prey items not normally available to the fish (Dunn et al 2009a). Seabird diets (and ecological success) are also potentially affected by availability of offal and discards near the sea surface. Globally, populations of many scavenging seabirds have grown in recent years (e.g., Lloyd et al 1991) and it is likely that some species have significantly benefited from fishery discards (e.g. Furness & Barrett 1985; ICES 2005). However, population growth in scavenging seabirds can lead to displacement of other species because of limited suitable breeding habitat (Howes & Montevecchi 1993). For example, in Europe, many tern species have been displaced by larger gull species (Theissen 1986; Becker & Erdelen 1986). This has led in many instances to the culling of the large gulls in order to allow terns to return to their original nesting sites (Wanless 1988; Wanless et al 1996).

11.2 WHAT CAUSES TROPHIC AND ECOSYSTEM-LEVEL EFFECTS?

As can be seen in the examples given so far, trophic and ecosystem-level effects in marine systems can be caused by a variety of factors, often acting simultaneously. These factors are often called stressors. Stress in this context refers to physical, chemical and biological constraints on the productivity of species, their interdependencies, and on the structure and function of the ecosystem. Stressors can act over various spatial scales (from local to basin-scale) and various time scales (from days to decadal). Stressors can be natural environmental factors or they may result from the activities of humans. Trophic and ecosystem-level effects can occur because of fishing, because of environmental factors entirely disconnected to fishing (especially related to climate variability/change) or by a combination of fishing and environmental variability/change acting together (Mackinson et al 2009; Frank et al 2007; Schiermeier 2004, Schiel 2013). Trophic and system-level effects can also result from outbreaks of disease (Cobb & Castro 2006; Freeman & MacDiarmid 2009; Shields 2011), from the arrival of non-indigenous invasive species (Mead et al 2013) and from eutrophication in estuarine ecosystems (Daskalov et al 2007; Oguz & Gilbert 2007; Osterblom et al 2007; Möllman et al 2008). Some of these causes of trophic and ecosystem-level effects are discussed further below.

11.2.1 ENVIRONMENTAL-DRIVEN CHANGE

Marine ecosystem are intimately linked to environmental (climate) forcing (Fasham et al 2001; Schiermeier 2004; Frank et al 2007; Mackinson et al 2009). Variability of climate forcing of the ocean occurs on a wide range of time scales from seasonal periods, to 1–3 year oscillating but erratic periods, to decadal aperiodic variability at 5–50 years, to centennial and longer periods, and can include sudden, large-scale shifts in environmental forcing (Overland et al 2010). Climate trends (such as due to global warming) are defined as changes that are not cyclical or seasonal and exist over a relatively long period (more than decadal).

There are many examples internationally of trophic and ecosystem-level effects occurring as a result of environmental change affecting the bottom of the food-web (Mackinson et al 2009; Frank et al 2007; Schiermeier 2004). For example, during the 1980s, the North Sea experienced a change in hydro-climatic forcing that caused a rapid, temperature-driven ecosystem shift (Beaugrand & Ibanez 2004). This change in sea surface temperature (SST) altered the plankton and negatively affected the recruitment of cod (Beaugrand & Reid 2003; Heath 2005). Changes in the North Sea plankton, following the ecosystem shift, included an increase in microalgae (Kirby et al 2008), a change in the composition and abundance of zooplankton (Beaugrand et al 2002), increases in the frequency of jellyfish (Kirby et al 2009), increases in the abundance of decapod and echinoderm larvae, and a decrease in bivalve larvae (Kirby et al 2008). Another example of bottom-up effects on upper-trophic-level marine predators is the abrupt decline in local primary and secondary production caused by El Nino/Southern Oscillation (ENSO) events in eastern Pacific boundary currents (Barber & Chavez 1983; Pearcy et al 1985; Arcos et al 2001; Hollowed et al 2001). During these ENSO events, the production of small pelagic fishes can be drastically reduced (Barber & Chavez 1983; Rothschild 1994), and predatory fish, seabirds and pinnipeds, which are dependent on these small pelagic fish have been shown to shift their distributions, suffer reduced productivity, and have increased rates of mortality (Trillmich et al 1991; Jahncke et al 2004).

11.2.2 FISHERIES-DRIVEN CHANGE

To some degree, trophic effects will always arise as a consequence of fisheries. As well as reducing the overall abundance of fish, fishing usually reduces the average size of fish in harvested communities and can change the mix of species in a fish community (Pope & Knights 1982; Pope et al 1987; Dayton et al 1995). Fishing also has effects beyond changes to the abundance and population structure of target and bycatch species, including (a) the introduction of discarded bycatch/offal/bait into the ecosystem, (b) the alteration of fish behaviour (and potentially genetic make-up) as a result of fishing, and (c) the modification of the benthos by fishing gear. Fishing will certainly lead to changes (of greater or lesser magnitude) in predation pressure on prey species. Marine ecosystems seem to be remarkably resilient to even quite large trophic changes of this kind, but there are clearly limits to this resilience. Virtually all well-documented regime shifts seem to have been initiated from large-scale climate or oceanographic changes rather than excessive fishing pressure. In some cases however, ecosystem-level changes (regime shifts) have been demonstrated empirically to occur in very highly impacted (highly overfished/collapsed) systems as a result principally of trophic effects (Estes & Duggins 1995; Daskalov et al 2007). For example, the round sardinella (Sardinella aurita) stock off west Africa collapsed in the 1970s following exceptionally high catches made possible by oceanographic changes (Bakun & Weeks 2006). This collapse resulted in a substantial and widespread outbreak of grey triggerfish (Balistes capriscus) which lasted through the 1970s and 1980s until the sardinella population rebuilt. At that point, grey triggerfish essentially disappeared from the ecosystem again. It seems possible that the juvenile triggerfish, being pelagic plankton feeders, took advantage of the collapse of the sardinella population to temporarily replace it as the dominant nektonic zooplanktivore of the ecosystem through one or more trophic effects. For example: (1) the sardinella collapse may have led to increased zooplanktonic food resources and hence accelerated the production rate of triggerfish; (2) the sardinella collapse may have promoted increased recruitment of triggerfish by reduced predation on their eggs and larvae (Bakun & Weeks 2006).

11.2.3 COMBINED EFFECTS OF FISHING AND ENVIRONMENTAL VARIABILITY/ CHANGE

Although there have been few unequivocal empirical demonstrations of large-scale trophic and system-level effects arising solely from fishing, very many studies have pointed to the potential of fishing to lead to trophic and ecosystem-level effects in concert with other factors, such as environmental variability and change (e.g. Winder & Schindler 2004; Brierley & Kingsford 2009; Kirby et al 2009; Perry et al 2010). The effects of fishing that may lead to reduced ecosystem resilience (see Table 11.1 for definition of “ecosystem resilience”) include:

- **Alteration of demographic structure.** Size-selective removal truncates the population's age structure and lowers the buffering capacity of the population (its ability to withstand long periods of environmental conditions that are adverse for recruitment). This leads to the prediction that the relative importance of recruitment variability will be greater in exploited populations as has been observed in a comparison between exploited and unexploited fishes in the California Current Ecosystem (Hsieh et al 2006).

- **Alteration of spatial structure.** The spatial structures of marine fish populations can encompass a wide range of configurations, including patchy populations, networks, and meta-populations (Kritzer & Sale 2004). Removal or curtailment of population spatial structure by fishing is likely to increase the sensitivity of the overall population to climate fluctuations at interannual to multi-decadal scales (e.g. Ottersen et al 2006).
- **Alteration of life-history traits.** Perry et al (2010) suggest that fishing would be likely to accelerate the response of populations to climate forcing by providing selective pressure to decrease growth rates and decrease age-at-maturity (Law 2000; de Roos et al 2006).
- **Alteration of habitat structure.** Changes to benthic habitat by the direct effects of fishing may lead to a reduction in ecosystem resilience (Thrush & Dayton 2002);
- **Alteration of ecosystem trophic structure.** Theoretically, ecosystems under intense exploitation are likely to evolve towards stronger bottom-up control (Figure 11.1). Exploitation leads to a decrease in stock sizes of piscine predators, which may (a) reverse the control structure in top-down ecosystems to bottom-up control, and (b) amplify the control in already bottom-up controlled ecosystems. Multiple weak interactions and generalist predators may stabilize ecosystems by dampening oscillations caused by strongly interacting species (Shin & Cury 2001; Polunin & Pinnegar 2002; Rooney et al 2006; McCann & Rooney 2009, Johnson et al 2014) and by preferentially consuming competitively dominant prey species (Brose et al 2005). Changes to trophic structure by fishing are hence predicted to increase ecosystem variability and reduce resilience (Jackson et al 2001; Perry et al 2010).

Theoretically therefore, fishing is predicted to strengthen the relation between oceanographic forcing and ecosystem variability and hence reduce ecosystem resilience. There are limited real-world, empirical examples of this. For example, the regime shifts of the North Sea and central Baltic Sea are considered to have been driven by the combined and synergistic effects of intense fishing and climate variability (Weijerman et al 2005; Möllmann et al 2009). Using a 47-year time series, Kirby & Beaugrand (2009) showed that the effects of temperature can be magnified by propagation through indirect pathways in the food-web. This “trophic amplification” can intensify the effect of environmental variability, potentially leading to a new stable or unstable ecosystem state (Scheffer & Carpenter 2003; Muradian 2001; Taylor 2002; Hsieh et al 2005). Elsewhere, Ottersen et al (2006) analysed the Arcto-Norwegian cod stock in the Barents Sea over the last 60 years and found evidence of a strengthening of the climate-cod recruitment link during the last decades.

Table 11.1. Ecosystem resilience.

Fishing can affect ecosystem resilience, the capacity of an ecosystem to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks (Pimm 1982; Holling 1973; Cohen et al 1990; Walker et al 2004). Three measures of ecosystem resilience have been identified:

- Does the ecosystem retain essentially the same function, structure, identity, and feedbacks after perturbation as before (Walker et al 2004)?
- Do perturbations to one part of the ecosystem spread out and affect biota across many trophic levels or remain localised (i.e. are ecosystem-level changes likely)?
- How long does it take a food web to return to its original configuration when perturbed? Stable (resilient) food webs can absorb more perturbation without undergoing wholesale reorganisation, tend to have low tendency for ecosystem-level trophic cascades (food-web perturbations remain local) and have short return times (Walker et al 2004).

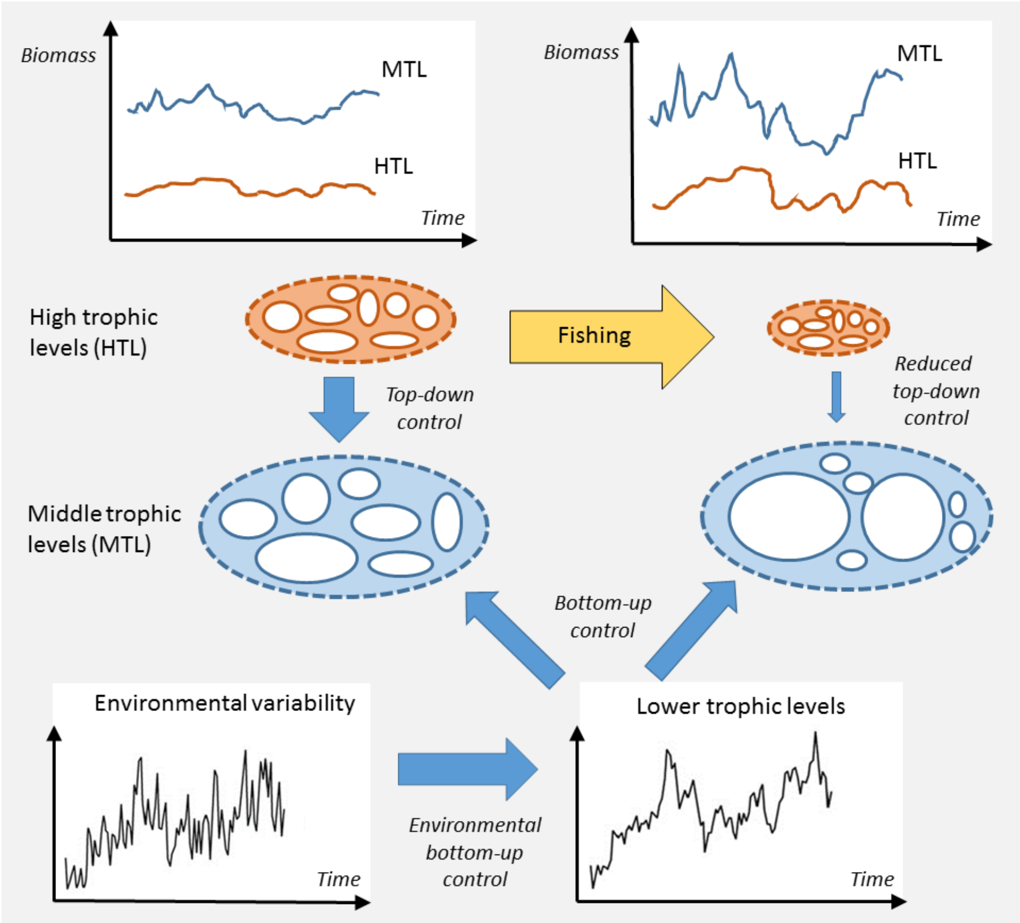


Figure 11.1: Schematic illustrating expected responses of unexploited and exploited marine ecosystems to climate forcing. Left side shows an unexploited ecosystem with multiple high trophic level (HTL) species which have relatively large abundances supported by several mid-trophic level (MTL) species, and how their aggregate biomasses vary through time (top left) in response to environmental variability acting on the lower food-web. The right side illustrates how that same climate forcing is experienced by an ecosystem which has been exploited (top right graph). The abundances of the high trophic level species have decreased due to fishing, weakening the top-down control on the MTL. This is hypothesized to make the mid-trophic level groups less even causing their aggregate biomass to track the environmental forcing more closely. [after Perry et al 2010]

11.3 WHAT TYPES OF ECOSYSTEM ARE LIKELY TO BE MOST AFFECTED?

11.3.1 GLOBAL UNDERSTANDING

The scale and significance of trophic and ecosystem-level effects depend on the particular characteristics of the ecosystem as well as on the drivers of change (Pace et al 1999; Brose et al 2005; Pascual & Dunne 2006; Brander 2010, Jennings & Brander 2010). Ecosystems appear to be prime examples of complex adaptive systems (Levin 1998, 1999); ecosystems typically have non-linear dynamics, with thresholds (also called tipping-points) and positive and negative feedback loops (Hsieh et al 2005). The complex behaviour of ecosystems over a wide range of time and space scales coupled with the myriad nature of stressors means that it is hard to forecast the response of ecosystems or establish quantitative estimates of tipping-points to guide management.

A number of multispecies or ecosystem models have been developed which can be used to investigate the potential for trophic and ecosystem-level effects in ecosystems

(Plagányi 2007; Plagányi et al 2014). These include Ecopath with EcoSim (EwE, Christensen & Walters 2004), Atlantis (Fulton et al 2004, 2005), OSMOSE (Shin et al 2004; Travers et al 2009) and a range of models of intermediate complexity (MICE, Plagányi et al 2014). Multispecies and ecosystem models can provide useful strategic insights for fishery and resource managers (Plagányi 2007; Fulton et al 2005; Smith et al 2011). However, there are often differences in model predictions about ecosystem consequences (or lack thereof) of fishing, especially in ecosystem-scale models, so model outputs need to be used cautiously for tactical decisions (Smith et al 2011). MICE-models (where only part of the ecosystem is modelled) are likely to provide more robust guidance for tactical decision-making (Plagányi et al 2014).

There have also been attempts to use knowledge of the structure of the food-web to suggest types of behaviour and response to fishing and other changes as an alternative to dynamic ecosystem models (Ulanowicz & Puccia 1990; Libralato et al 2006; Pinkerton & Bradford-Grieve 2014). Rice (2001) concluded that trophic and ecosystem-level effects of fishing depend on the overall type of ecosystem forcing structure. Three patterns of ecosystem forcing structure have been described: (a) top-down forced, (b) bottom-up forced, or (c) forced from the middle outwards or wasp-waisted (Table 11.2). These patterns of ecosystem forcing have been the focus of hundreds of research articles. These three patterns should be considered as modes of forcing (rather like principal components); most real ecosystems will be a mixture of these types of forcing that may change over time (Rice 2001). Indeed, Pace et al (1999) cautions that "although there is some descriptive value in the use of top-down or bottom-up control, this motif also creates a false dichotomy." Nevertheless, identifying dominant patterns of ecosystem behaviour may help to predict or explain the types of trophic and ecosystem-level behaviour resulting from the combined effects of fisheries harvesting, climate variability/change and other human activities (Rice 2001). For example, Pinksy et al (2011) uncovered a high incidence of fisheries collapse among small, short-lived, middle trophic-level species of a type that are often the wasp-waist of the ecosystem. Even though short-lived species may recover quickly from excessive fishing mortality (Hutchings 2000), changes to them can have substantial impacts on the food web (Duffy 1983; Frederiksen et al 2004; Crawford 2007).

Table 11.2: Overall types of ecosystem forcing. [Continued on next page]

Bottom-up ecosystem forcing	If the ecosystem-level properties (i.e. across organisms at many trophic levels) respond strongly to changes in the environment (e.g. oceanography, water column structure), the ecosystem is said to show strong bottom-up forcing. There are many examples internationally of trophic and ecosystem-level effects occurring as a result of environmental changes at the bottom of the food-web (Mackinson et al 2009; Frank et al 2007; Schiermeier 2004).
Top-down ecosystem forcing	An ecosystem is said to show strong top-down forcing if it responds strongly to changes in the abundance of top predators (seabirds, marine mammals, high trophic level fishes). Understanding of how predators shape marine ecosystems has arisen largely from experimental studies where the effect of predation is controlled either by removing predators or introducing them to the ecosystem under study, usually in the intertidal or nearshore subtidal zone (Hunt & McKinnell 2006 and references therein). In the open ocean, increases in prey populations upon the removal of their predators (e.g., by fisheries) have been taken as evidence of top-down limitation (e.g., Furness 2002; Worm & Myers 2003; Frank et al 2005). Other evidence of top-down regulation in a marine ecosystem appears where predators are abundant at one site, but largely absent from a similar, nearby site. For example, Birt et al (1987) found that small flatfish populations were depressed in a bay in Newfoundland that was frequented by cormorants compared to a bay that was located farther from the colony. In general, top-down ecosystem forcing is predicted to be stronger in aquatic than terrestrial ecosystems, and strongest in marine ecosystems where the predators are large and mobile with high metabolic rate, where prey species are long-lived, functional predator diversity is low, and predator intra-guild predation is weak or absent (Shurin et al 2002; Borer et al 2005; Heithaus et al 2008).
Middle-out forced (wasp-waisted) ecosystem	Wasp-waist control of energy flow in marine ecosystems occurs when one or a very few species have a substantial influence on the flow of energy through the mid-trophic levels. The term has most frequently been applied to the role of small pelagic fishes that transfer energy from the plankton to larger predatory fish, seabirds and marine mammals (Rice 1995; Bakun 2004; Cury et al 2000, 2004; Bakun 2006). Ecosystems with wasp-waist control are typically coastal, highly productive systems with relatively short food chains. However, waist-controlled ecosystems also include capelin in North Atlantic ecosystems (Lilly 1993; Bogstad & Mehl 1997; Leggett et al 1984; Taggert & Leggett 1987; MacKenzie & Leggett 1991; Fossum 1992), krill in the Antarctic (Murphy et

	al 1998) and, Calanus sp., when functioning as a "gatekeeper" (sensu Steele 1998). When the species at the waist declines abruptly, predators often cannot compensate, at least fully, and suffer reduced growth, survivorship, and reproduction (Mehl & Sunnana 1991; Kjesbu et al 1998; Dutil & Lambert 2000). Predators may control the wasp-waist when they are at intermediate population sizes (Bakun 2006). At other times, year-class strengths of species at the waist demonstrate strong, direct effects of environmental forcing. Wasp-waisted ecosystems typically follow from: (1) a food web containing a highly influential intermediate node which has a strong environmental signal in recruitment (Rice 2001) and/or (2) middle-trophic level fishery.

11.3.2 NEW ZEALAND

11.3.2.1 BOTTOM-UP FORCING

A New Zealand example of bottom-up forcing is the driver of mussel (*Perna canaliculus*) yield in Pelorus Sound in northern South Island. Though this example is from aquaculture, it is likely to also apply to wild mussels. Zeldis et al (2008) correlated physical, chemical and biological data collected within a 9-year time series. Starting in early 1999, farm production in the sound declined by about 25% in terms of per-capita meat yield, followed by yield recovery through to 2002. These changes resulted in substantial economic impacts within the industry. Over-grazing by mussels (i.e., top-down effects on mussel food availability) did not explain the yield minimum. Instead, bottom-up (environmental) effects of nitrogen supply from oceanic and river sources drove the variation by affecting the abundance of seston[61] for the filter-feeding mussels. A subsequent study (Zeldis et al 2013) provided quantitative models for Pelorus Sound mussel per-capita meat yield and elucidated the underlying oceanographic mechanisms. Yield was best predicted using biological variables, including the concentration of seston, based on measurements made next to the mussel farms, but it was also predictable using only physical variables that index large-scale environmental processes (Southern Oscillation Index, along-shelf winds, sea surface temperature and river flow).

11.3.2.2 TOP-DOWN FORCING

In moderately exposed coastal marine reserves in north-eastern New Zealand, predation by recovering populations of snapper (*Pagrus auratus*) and spiny lobsters (*Jasus edwardsii*) have gradually decreased the abundance of the grazing sea urchin (*Evechinus chloroticus*) and allowed turfing algae and kelp (*Ecklonia radiata*) to replace urchin grazed rock flats (Babcock et al 1999, Shears & Babcock 2002, 2003). This is indicative of top-down forcing in the ecosystem. In adjacent areas which are heavily fished there are more urchins, and areas free of turfing algae and kelp are common (Shears et al 2008). It seems that the occurrence of this trophic cascade varies at local and regional scales in relation to abiotic factors, implying some interplay with larger-scale bottom-up forcing (Shears et al 2008).

A long-term study of changes to the ecosystem of the Hauraki Gulf region developed five balanced, quantitative models of the food-web of the region (MPI project ZBD200505: Pinkerton 2012): (1) present day; (2) AD 1950, just prior to onset of industrial-scale fishing; (3) AD 1790, before European whaling and sealing; (4) AD 1500, early Maori settlement phase; (5) AD 1000, before human settlement in New Zealand. These models were used to estimate the strengths of trophic connections between different groups of organisms based on single-step and multiple step measures of trophic importance (Ulanowicz & Puccia 1990; Libralato et al 2006). Before humans arrived in New Zealand, the models suggest that cetaceans and fur seals/sea-lions were the most trophically-important groups in the Hauraki Gulf ecosystem, implying the potential for strong top-down ecosystem control. With the extirpation[62] of seals/sea-lions from the Hauraki Gulf ecosystem before the arrival of Europeans and the reduction in the abundance of cetaceans following European arrival, the trophic importance of these air-breathing predators drastically reduced. The trophic importance of other predators in the models of the Hauraki Gulf ecosystem also reduced over time as a result of human harvesting (rock lobsters and sharks especially) suggesting a transition to a more bottom-up controlled system.

[61] Organisms and non-living matter swimming or floating in a water body.

[62] Made locally extinct

11.3.2.3 MIDDLE-OUT (WASP-WAIST) FORCING

Research into deep-water ecosystems in the New Zealand EEZ is most advanced in the Chatham Rise region. Elevated primary production here is due to the convergence of Subantarctic and Subtropical water (Bradford-Grieve et al 1997; Boyd et al 1999; Murphy et al 2001; Sutton 2001) and supports valuable deep-water fisheries, an unusually rich benthic ecosystem (Probert et al 1996; McKnight & Probert 1997; Bowden 2011), and large seabird populations (Taylor 2000a,b). Ecosystem modelling of the Chatham Rise food-web has been underway since 2006, the most recent version being Pinkerton (2013) (Figure 11.2). Trophic impact matrices (Ulanowicz & Puccia 1990; Libralato et al 2006) were calculated from the balanced model to investigate patterns of trophic interactions. Middle trophic level groups, especially small demersal fishes and mesozooplankton, had some of the highest trophic importances amongst consumers. Mesopelagic fishes, hoki, and arthropods (benthic prawns and shrimps) also had high trophic importances (Pinkerton 2013). These patterns of trophic importance were robust to uncertainties in the model parameterisation and balancing (Pinkerton 2014b). These results suggest some degree of middle-out control in the system, though the number and function diversity of these groups is higher than in other systems characterised in this way.

11.4 OVER WHAT SPATIAL SCALES DO TROPHIC AND ECOSYSTEM-LEVEL CHANGE OCCUR?

11.4.1 GLOBAL UNDERSTANDING

Delineating ecosystems is an important first step towards evaluating trophic and ecosystem-level effects of fishing. There are not usually clear spatial boundaries between different ecosystems. Instead, different parts of ecosystems vary on different spatial scales; higher trophic-level organisms usually move over a greater spatial extent than lower trophic-level organisms. For example, some seabirds and marine mammals may move large distances seasonally and move between different ecosystems. In contrast, most phytoplankton, smaller zooplankton and most benthic invertebrates will live and die within a few kilometres. Some fish move long distances, but others remain in a small area all their lives (e.g. on a reef). Marine ecosystems should hence be viewed as an interlocking matrix of the life ranges of different organisms. As such, it is difficult to unambiguously separate different ecosystems but a number of approaches have been developed to do so. These include: (a) defining ecosystems on the basis of their physical properties, either using a priori thresholds (e.g. fixed depth ranges) or by multivariate clustering of physical properties (Snelder et al 2005; Grant et al 2006); (b) using maps of species occurrence to map biological assemblages (e.g. Leathwick et al 2006); (c) relating community composition to environmental variables (e.g. generalised dissimilarity analysis, Ridgeway 2006, Leathwick et al 2009) and using these relationships to extrapolate spatially.

11.4.2 NEW ZEALAND

The importance of spatial scale in the study of the ecosystem effects of fisheries has been recognised in New Zealand (e.g. Leathwick et al 2006, 2009). In their assessment of the New Zealand hoki fishery for the Marine Stewardship Council (MSC) Akroyd & Pierre (2013) noted that there is currently no specific definition of “regional effects” but MSC is working on adding clarity to the definition of regions and bioregions as part of the work on their current benthic impacts project in recognition that some areas are more vulnerable to impact than others.

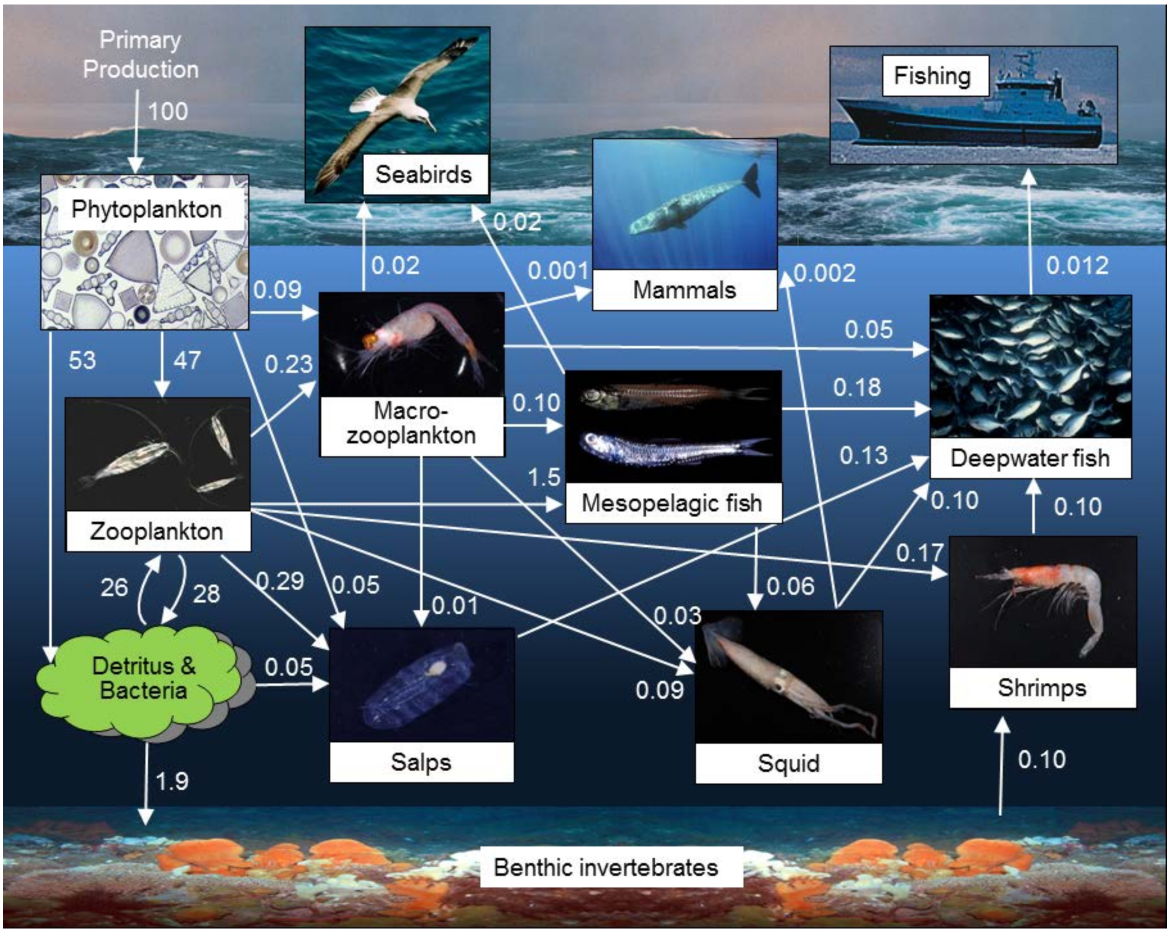


Figure 11.2: Simplified trophic model of the Chatham Rise, New Zealand (based on Pinkerton 2013). The growth of phytoplankton generates organic matter that is the fuel for the marine ecosystem. Figures show the annual flow of energy through unit area of the food-web normalised to a net primary productivity (NPP) of100, based on an equilibrium mass-balance model (similar to Ecopath).

A number of approaches have been developed in New Zealand to identify or describe ecosystem types:

- MacDiarmid et al (2012) identified sixty-two distinct marine habitat types occurring within New Zealand's territorial seas and EEZ as part of an assessment of anthropogenic threats to New Zealand marine habitats. The approach taken by MacDiarmid et al (2012) was to build on Halpern et al's (2007) list of marine habitats used in a global assessment of anthropogenic impacts on the global marine environment.
- New Zealand's Department of Conservation, jointly with MPI, have used a marine habitat classification system based on four depth intervals (intertidal, 0–30 m, 30–200 m, more than 200 m), seven substrate classes (mud, sand, gravel, undefined substrate, mixed sediment and rock, rock, and biogenic), and three exposure categories (exposed, moderate, sheltered). This habitat classification was used to define 58 habitats in the territorial sea alone in order to meet the needs of biodiversity conservation (DOC-MPI 2011).
- New Zealand Marine Environment Classification (MEC, Snelder et al 2005). The MEC is a physically-based classification, determined using multivariate clustering of several spatially explicit data layers that describe the physical environment (including depth, slope, orbital velocity at the sea floor, mean solar radiation, SST amplitude, SST gradient, winter SST, mean tidal current velocity). Large biological datasets were used to tune the classification so that the physically based classes maximised discrimination of variation in biological composition at various levels of classification detail. The classification was not optimised for a specific ecosystem component (e.g., fish

communities or individual species) but sought to provide a general classification that had relevance to a broad range of biological groups. Depending on user requirements the MEC can provide two to 270 classes of classification.

- Leathwick et al (2006) demonstrated how spatial analysis using boosted regression trees could provide distribution maps of over 100 species of demersal fish. Fish were chosen as there were good quality distributional data available from a series of scientific trawl surveys in deep waters. The overall approach used by Leathwick et al (2006) was to fit statistical models relating the distributions of 122 fish species to a set of environmental variables, with the latter chosen for their functional relevance.
- A benthic optimised marine environment classification (BOMEC, Leathwick et al 2009) was developed specifically to identify New Zealand benthic bioregions that can be considered to be ecologically distinct to some degree. BOMEC was developed by combining data on the benthic community (made up of over 100 demersal fish species, and seven groups of invertebrates: asteroids, bryozoans, foraminifera, octocorals, polychaetes, scleractinian corals, sponges), and environmental data including sediment type. A multivariate technique for fitting community compositions to environmental data, Generalised Dissimilarity Analysis, was used (Leathwick et al 2009). BOMEC is restricted to depths less than 3000 m where reasonable amounts of scientific sampling have been conducted (Leathwick et al 2009).
- The Ocean Survey 20/20 Chatham-Challenger biotic habitat classification (Hewitt et al 2011) used benthic invertebrate and environmental data from the Chatham Rise and Challenger to delineate ecosystems in terms of their community and biogenic habitat associations.

Sharp et al (2007) summarised lessons learned from New Zealand's bioregionalisation experience for CCAMLR. The main conclusion was that bioregionalisations based on simple clustering of physical variables are likely to perform poorly in terms of separating assemblages of species (communities or ecosystems); measurements of the actual distributions and abundances of key organisms are needed to use physical environmental data to delineate bioregions effectively.

11.5 HOW CAN TROPHIC AND ECOSYSTEM-LEVEL EFFECTS BE DETECTED?

11.5.1 GLOBAL UNDERSTANDING

There has been increasing recognition over the last two decades that time series are essential to detect and potentially understand a trophic or ecosystem-level change in marine ecosystems. This has led to a high level of interest in the development and interpretation of indicators of the marine environment and its ecosystems. A huge number (more than 300) of marine ecosystem indicators are in use or proposed around the world (Cury et al 2005; Rochet & Rice 2005; Rice 2003), with consensus that a suite of indicators is needed to monitor and understand the impact of human activities on marine ecosystems (Cury & Christensen 2005; Rice & Rochet 2005). Give the multi-trophic nature of ecosystem-level effects, indicators are needed which span the ecosystem, including primary producers, the microbial system, middle trophic levels, fish communities, the benthic community and top predators. A summary of some recommended indicators is given below.

11.5.1.1 MARINE PRIMARY PRODUCTION

The growth of phytoplankton in the upper layers of the ocean provides the vast majority of the energy that fuels marine ecosystems, and most fisheries, worldwide. Only in some (predominantly coastal) areas are other primary producers important: macroalgae (seaweed), seagrass, mangroves, epiphytes, autotrophic periphytes, microphytobenthos and chemosynthesisers. Light, temperature, and nutrient concentrations are major factors controlling net[63] primary production (NPP) by phytoplankton growth in the ocean (Parsons et al 1977, Arrigo 2005). NPP can be measured accurately from ships (typically using radioactive carbon incubations), but because of the high spatial and temporal variability of NPP, ship-based sampling is not adequate for monitoring. Instead, remotely-sensed data from sensors on Earth-observing satellites are typically used to estimate NPP.

[63] "Net" means after allowing for phytoplankton respiration.

There are significant differences between different methods of estimating NPP from satellite data (Campbell et al 2002). Often, the concentration of chlorophyll-a, the ubiquitous pigment in phytoplankton, is used as a proxy for phytoplankton biomass and NPP, because this can be measured remotely with better accuracy than NPP using ocean colour satellite sensors.

11.5.1.2 LOWER FOOD-WEB (MICROBIAL SYSTEM)

Rice (2001) notes that processes which make large alterations to the allocation of production between the microbial loop, benthic detrital pathways and mesopelagic consumers may have much more impact on the dynamics of higher trophic levels than processes which alter NPP. More recently, Friedland et al (2012) examined the relationships between NPP, fisheries yields, and parameters describing the transfer of organic matter through 52 large marine ecosystems and found that chlorophyll-a concentration, the particle-export ratio (p-ratio: the proportion of NPP exported from the surface layer of the ocean) and the ratio of mesozooplankton productivity to NPP (z-ratio) were all significantly related to fisheries yields. Stock & Dunne (2010) suggest that a warmer ocean will lead to lower z-ratio (less mesozooplankton for a given NPP) and Friedland et al (2012) show that lower z-ratios correspond to lower fisheries yields at basin scales.

11.5.1.3 MIDDLE TROPHIC LEVELS

Small mesopelagic[64] and hyperbenthic[65] organisms are an important part of marine ecosystems. They act as the link between the microbial/planktonic system and larger predators such as seabirds, marine mammals, and larger fish. These "middle trophic level" organisms are diverse, and include hard-bodied crustaceans (such as copepods, euphausiids, amphipods, prawns and shrimps), "jellies" (such as jellyfish and salps), cephalopods (squids and octopods), and a range of small fishes (including juveniles of larger species) living in the water column (especially myctophids or lanternfishes) or near the seabed. These species are likely to be affected both by fishing which may reduce top-down predation control, and by climate-driven changes in lower trophic food-web components (Frank et al 2007; Richardson 2008). Middle trophic level species have a key role in ocean ecology (e.g. Banse 1995; Marine Zooplankton Colloquium 2 2001; Smetacek et al 2004; Pinkerton 2013). Studying these middle trophic level organisms is challenging: they are typically diverse, with varied and complex life histories, can be hard to capture, and have abundances that vary over a wide range of space and time scales. Consequently, the factors that affect their dynamics are generally poorly understood. Two methods have been used for monitoring middle trophic levels. First, in other parts of the world, long time-series of measurements of the zooplankton community by the Continuous Plankton Recorder (CPR) has demonstrated change in marine ecosystem (Beaugrand et al 2002; Aebischer et al 1990; Reid et al 1998; Beare & McKenzie 1999), and been recommended as an effective way of monitoring the state of pelagic ecosystems (Beaugrand 2005). Second, multifrequency acoustics have been used to monitor abundances of mesopelagics over extended time and space scales (McClatchie & Dunford 2003; O'Driscoll et al 2009; Trenkel & Berger 2013).

11.5.1.4 DEMERSAL FISH COMMUNITIES

Most of the international effort on developing ecosystem indicators have focussed on those for the demersal fish community, usually based on commercial landings data or, less commonly, on catch data from fisheries surveys. Consequently, very many indicators have been proposed - a selection is discussed below.

- **Marine Trophic Index**: MTI is the mean trophic level of fisheries landings (Pauly & Watson 2005) and was recently recommended for use with commercial catch data by the United Nations Biodiversity Convention as a widely-applicable and cost-effective indicator for monitoring reductions in biodiversity loss in marine ecosystems (CBD 2004). A gradual decline in trophic level of about 0.2 since industrialised fishing began has been observed in many finfish fisheries around the world (Pauly et al 1998a; Christensen et al 2003), ascribed to fisheries targeting high trophic level species and moving on to lower trophic level species as these large species are depleted, a

[64] "Mesopelagic": inhabiting the intermediate depths of the sea, between about 200 and 1000 metres down.

[65] "Hyperbenthic": ecologically associated with the seabed, but living for some time in the lower water column.

change called “fishing down the food web”. Essington et al (2006) noted that “fishing through the food web”, where higher trophic level fish landings are maintained but catch of lower trophic level species increases over time, may occur more often. MTI calculated from total commercial catch will vary with changes in the mix of species targeted by different fisheries over time, the relative importance of different fisheries sectors (e.g. finfish versus invertebrate fisheries), how much of the catch is reported, the quality of identification of species, and for other reasons not necessarily associated with effects of fishing (Caddy et al 1998; Pauly et al 1998b; Tuck et al 2009; Branch et al 2010). As such, MTI based on scientific surveys is likely to be a better indicator of change in fish communities (Branch et al 2010).

- Species-based indicators: Many indices of diversity have been applied to fish communities (e.g. Peet 1974; Warwick & Clarke 1995; Bianchi et al 2000; Greenstreet & Rogers 2006). These diversity indices are joint constructs of how many species are present (richness), and how similar their abundances are (evenness). Some indices give additional emphasis to the most important species in a community (dominance). Measures vary in the relative weight given to each of these factors, and on the metric used for similarity between species (e.g. by including a measure of taxonomic distinctiveness or not; Warwick & Clarke 1995). Fishing rarely causes large-scale extirpation so that measures of total species richness are likely to be less sensitive to change in trophic or ecosystem-level properties than measures of evenness. Different measures of evenness respond variously to fishing; they can increase, reduce or be unaffected by fishing depending on the initial characteristics of the ecosystem. A community initially dominated by k-selected[66] species would be expected to become more even and show increasing diversity metrics due to fishing; fishing would be expected to allow the faster growing (initially minor species) to increase at the expense of the slower growing (initially dominant) species. In contrast, diversity and evenness metrics may be expected to decrease after fishing if the ecosystem were originally dominated by r-selected[67] species.
- Functional group based indicators: Changes to the relative abundance of different functional groups in an ecosystem can indicate trophic or ecosystem-level changes (Fulton et al 2005; Methratta & Link 2007; Shannon et al 2009). Functional groups can be based on various descriptors of ecological niche, such as position in the water column (e.g. pelagic, demersal, benthic), trophic guild / feeding type (e.g. piscivore, pelagic invertebrate feeder, benthic feeder, scavenger), taxonomy (e.g. elasmobranch, gadoid, macrourid), or a combination of multiple ecological and life-history traits (Methratta & Link 2007) which can be combined to suggest high or low resilience (Tuck et al 2009). A simple and commonly used index is the proportion of piscivorous fish to all fish caught. As piscivorous fish tend to be disproportionately impacted by fishing (Caddy & Garibaldi 2000), their relative abundance in fish assemblages is a measure of ecosystem state and may reveal a trophic or system-level impact of fishing.
- Size based indicators: Marine trophic processes tend to be strongly structured by size (Badalamenti et al 2002, Jennings et al 2002). Fishing may lead to substantial modifications in the size structure of exploited populations because (a) high-value, generally larger species are targeted by fisheries, (b) fishing gears are size selective, often designed to catch larger fish and let smaller ones escape, (c) the cumulative effect of fishing (over the life of a cohort) leads to fewer older (larger) fish, and (d) long-lived species tend to be affected more as they have lower potential rates of increase. Several size-based metrics have been used to detect trophic and ecosystem-level changes (e.g. Murawski & Idoine 1992; Pope et al 1987; Pope & Knights 1982; Rice & Gislason 1996). Size-based indicators can be applied at a species or community level. Applied to a given species, possible size-based indicators include: (a) mean length at age; (b) condition (weight at length, e.g.

[66] Those which produce relatively low numbers of offspring, typically growing more slowly and maturing later.

[67] Those which produce high numbers of offspring, typically growing faster and maturing sooner.

Winters & Wheeler 1994); (c) proportion of large fish; and (d) mean length at maturity in the population. Size-based methods at the community level include: (a) mean length in the community; (b) proportion of large individuals in the community; (c) the biomass size-spectrum; and (d) the diversity size spectrum (Rice & Gislason 1996).

- **Spatial distributions**: Fishing and climate/oceanographic variability/change can alter the geographic distribution of fish species (Perry et al 2010) and this can indicate an ecosystem-level change. The percentage area of a research survey in which most (typically 90%) of the population occurs has been used as an ecosystem indicator (e.g. Fisher & Frank 2004; Tuck et al 2009).
- **Diet-based indicators**: The change of diet (or trophic position) of a species of fish may reveal that trophic or ecosystem-level changes have occurred (e.g. Smith & Lucey 2014), but trophic position may change less than the underlying ecosystem structure (Badalamenti et al 2002). "Niche width" measured in terms of the range of carbon and nitrogen isotope ratios occupied by a species has also been suggested as indicative of trophic changes in a marine ecosystem especially in relation to upper trophic level predators (Layman et al 2007), but the utility of this has been questioned (Hoeinghaus & Zeug 2008).

11.5.1.5 TOP PREDATORS

Top predators (upper trophic level consumers) can be used in two ways as indicators of the state of marine ecosystems. First, an OECD core indicator is the overall ecological threat status of species in the ecosystem, often with an emphasis placed on top predators (OECD 2003). Second, particular ecological aspects of selected predator species can be used to indicate changes in ecosystems. For example, top predators are widely used in monitoring the ecosystem effects of fishing krill in the Southern Ocean (Reid et al 2005; Constable 2006), with information on the breeding of penguins, albatross, petrels, and seals collected, summarised and considered in management annually (CEMP 2004; Agnew 1997). Monitoring top predators as "bellweathers" of ecosystem health is also increasingly used elsewhere (Boyd et al 2006; Ainley 2002) as they are recognised as potentially useful downstream integrators of change in the marine ecosystem, exploit marine resources at similar spatial and temporal scales to humans, and receive high public interest. However, given that predators respond in complex ways to many factors simultaneously, ascertaining the appropriate management response to change of a predator-based indicator is difficult (Boyd et al 2006).

11.5.2 NEW ZEALAND

There has been much work in New Zealand on developing indicators of the marine environment. MPI have carried out a number of projects looking at indicators and time-series, including of oceanographic/climate variables (Hurst et al 2008; Dunn et al 2007; Pinkerton et al 2014a), demersal fish communities based on data from scientific trawls (Tuck et al 2009), and a suite of indicators relevant to deepwater fisheries (Tuck et al 2014). Other work in New Zealand on marine ecosystem indicators include reports under NIWA Core funding (Pinkerton 2010) and in relation to national environmental reporting (Gilbert et al 2000; Pinkerton 2007; Pinkerton 2014a).

11.5.2.1 MARINE PRIMARY PRODUCTION

Ocean colour satellite data have been used for more than a decade in New Zealand to investigate spatial and seasonal patterns in phytoplankton abundance and NPP (Murphy et al 2001; Pinkerton 2007). There is a limited amount of data available in New Zealand waters to develop locally-tuned estimates of NPP from satellite data, and the concentration of chlorophyll-a is preferred for the purposes of monitoring change in primary production over time (Pinkerton et al 2014a). Since 2002, mean concentrations of chlorophyll-a in the EEZ have decreased by an average of about 1% per year (Pinkerton, unpublished data). This is likely to be related, at least in part, to oceanographic cycles such as the Interdecadal Pacific Oscillation index[68] and the Southern Oscillation Index[69], as well as potentially to long-term climate change.

[68] The Interdecadal Pacific Oscillation (also called the Pacific Decadal Oscillation) is a 15–30-year cycle that affects parts of the Pacific Basin, causing variability in

11.5.2.2 LOWER FOOD-WEB (MICROBIAL SYSTEM)

Changes to primary production also do not necessarily translate to less food available for higher trophic levels. Virtually all wild-caught seafood in New Zealand are carnivorous, with a mean trophic index of about 4.1 (MacDiarmid et al 2013) The trophic efficiency by which energy passes between trophic levels is often considered to be about 10% (Pauly & Christensen 1995), meaning that only about one tenth of the energy consumed by marine organisms is used to build new body mass. This means that each tonne of wild-caught seafood in New Zealand has been supported by over a thousand tonnes of primary production that has been moved through at least two intermediate levels in the marine food web before being consumed by the target species. A change to the lower and middle parts of the New Zealand food-web hence have the potential to affect food availability for, and potentially yield of, commercially-important fish stocks. At present, there are no data available to monitor for changes in the functioning of the lower trophic levels of New Zealand's marine ecosystems.

11.5.2.3 MIDDLE TROPHIC LEVELS

Middle trophic level organisms in the New Zealand ocean are diverse (more than 21 species of myctophids occur on the Chatham Rise for example; Pinkerton, unpublished data). Although they form the basis of the diet of many commercially-important New Zealand fish species (Dunn et al 2009a), the basic abundance, distribution and ecology of key middle-trophic level groups like myctophids and hyperbenthic arthropods (prawns and shrimps) are generally poorly known. Two time-series of data for middle trophic level organisms in the New Zealand ocean may be useful to investigate trophic and ecosystem-level effects: (a) New Zealand acquired a Continuous Plankton Recorder (CPR) in 2008 and this has been deployed on a transit extending from Oamaru (approximately 45°S) to the Ross Sea annually since summer 2008/09; approximately 1200 km of this transect are in the Subantarctic New Zealand EEZ (Robinson et al 2013); (b) recent work has shown that multifrequency acoustic backscatter data taken from research vessels during the annual surveys of fish on the Chatham Rise can be used to derive indices of abundance of mesopelagic fish and invertebrates (McClatchie & Dunford 2003; O'Driscoll et al 2009; Oeffner et al 2014). Similar acoustic methods could provide time-series of middle trophic level species in the Hauraki Gulf and Subantarctic plateau in the near future.

11.5.2.4 DEMERSAL FISH COMMUNITIES

There are three series of scientific trawls in New Zealand waters that are particularly valuable for understanding ecosystem dynamics and for monitoring for trophic and ecosystem-level effects at the level of the demersal fish community (Tuck et al 2009): (a) a scientific trawl survey has been carried out on the Chatham Rise region approximately annually since 1992; (b) a similar survey has been carried out over the Subantarctic plateau over the same period but less frequently (Bagley & O'Driscoll 2012; Tuck et al 2009); (c) a total of 15 trawl surveys have also been carried out in the Hauraki Gulf region between 1980 and 2000. Each of these trawl surveys used a consistent methodology based on scientific bottom trawl gear. Tuck et al (2009) used these scientific surveys to investigate change in a series of indicators based on the demersal fish community.

Data from Chatham Rise trawl surveys between 1992 and 2007 showed evidence of increasing evenness (reducing diversity) but no evidence that species were being lost from the food-web (Tuck et al 2009). Some size characteristics of fish in research trawls on the Chatham Rise had changed, with fewer fish longer than 30 cm or heavier than 750 g being taken by trawl gear, although the median length of the catch did not change. Preliminary analysis of the mean trophic level index (MTI) in the demersal fish community of the Chatham Rise (Pinkerton 2010) indicated that this also decreased over the same period, and decreased more in the trawl survey data than in the commercial catch data. The proportion of piscivorous fish and of true demersal (rather than bentho-pelagic) species also declined over this period (Tuck et al

climate and oceanography, and has substantial and long-lasting effects on regional ecosystems (Kennedy et al 2002).

[69] The Southern Oscillation Index is related to the strength of the trade winds in the Southern Hemisphere tropical Pacific (Mullan 1995) and SOI values for May-September are often used as an indicator of El Niño-La Niña Southern oscillation (ENSO).

2009). Somewhat counterintuitively, threatened[70] species and species defined by Tuck et al (2009) as "low-resilience", such as dogfish and rays, have increased relative to other species on the Chatham Rise. This was confirmed by independent analyses of Chatham Rise trawl survey data (O'Driscoll et al 2011) and may be due to a combination of a lack of incentive to catch these species by the fishing fleet and an increase in offal and discards which benefit demersal scavengers. There were changes in the spatial distribution of fish species, with 16 out of 47 species showing changes in the proportion of the study area over which 90% of their abundance by weight was caught. Of these, half showed declining range and half showed increasing range. Tuck et al (2009) showed that on the Chatham Rise, the species showing contractions of range were generally the more abundant species whereas the species expanding in spatial range were generally the less abundant species. MPI project ZBD2004/02 (Dunn et al 2009a; Horn & Dunn 2010) examined whether there was evidence of change in the diet of hoki, hake or ling on the Chatham Rise between 1990 and 2009. It appears likely that the importance of fish (primarily myctophids) as a prey item for hoki has increased slightly but steadily between 1990 and 2009, while the importance of euphausiids has declined. In contrast, there were no obvious between-year differences or trends in hake diet from 1990 to 2009 (Horn & Dunn 2010). There were some marked between-year differences in ling diet in this period but no trends detected.

Discards and offal from fisheries is sometimes an important part of the diets of deepwater fish. For example, scavenged fishes accounted for up to a quarter of the diet of smooth skate (*Raja innominata*) in the Chatham Rise region (Dunn et al 2009a; Forman & Dunn 2012). Anderson & Smith (2005) estimated that 11 000–14 000 t per year of non-commercial species and 600–2100 t per year of hoki are discarded by the New Zealand hoki fishery annually, leading to the potential for a significant modification of the diet of scavenging species (Forman & Dunn 2012). Interpreting changes in diet from discards in a way that can inform fisheries management is not straightforward. For the Chatham Rise, the changes covered a period of declining hoki spawning biomass (McKenzie 2013) and occurred at the same times as evidence of climate variation, namely a shift the prevalence of Kidson weather types (Kidson 2000) between 1992 and 2007 (Hurst et al 2012). Disentangling these environmental and fishery drivers of changes to indicators of the demersal fish communities has not yet been attempted in New Zealand although the hypothesis that trophic or environmental factors were responsible for recent changes in hoki recruitment was investigated and was found not to be supported empirically (Francis et al 2006; Bradford-Grieve et al 2011).

[70] Species deemed more vulnerable according to the IUCN Red List (IUCN 2009); see Tuck et al (2009).

11.5.2.5 TOP PREDATORS

Information on indicators of change in upper trophic levels in New Zealand are considered in Theme 1 of this report.

11.6 DISCUSSION

Marine ecosystems are complex, show non-linear dynamics (including potential tipping-points) and are subject to a wide range of impacts, including fishing, climate variability and change, coastal eutrophication and habitat change. Any activities that change the composition of species in the ecosystem (both in terms of size, functional group, ecosystem role, and diversity) will affect other groups in the ecosystem through trophic and other connections. A large range of trophic and ecosystem-level effects in marine systems have been documented internationally and these have generally been associated with negative impacts on fisheries (Garcia & Grainger 2005; Valdes et al 2009; Worm et al 2009). Understanding the scale and causes of these changes remains scientifically challenging (Rice 2001; Brander 2010, Jennings & Brander 2010, ter Hofstede et al 2010). There remains substantial debate about the true extent and magnitude of these changes (Hilborn 2007; Murawski et al 2007) and debate about how to allocate responsibility for these changes among different pressures, including fishing (Benoît & Swain 2008; Holt & Punt 2009; Kotta et al 2009; Noakes & Beamish 2009; Rijnsdorp et al 2009; Rice & Garcia 2011; Schiel 2013). Although ecosystem-level changes have rarely been ascribed solely to fisheries drivers, it appears that fishing is likely to make ecosystems less resilient to variability and change in climate/oceanographic forcing (Winder & Schindler 2004, Kirby et al 2008, 2009). Reduced ecosystem resilience is an ecosystem-level effect that may predominantly occur through trophic mechanisms. Reduced ecosystem resilience may affect the long-term sustainability of harvesting (Hughes et al 2005), increase ecosystem variability (Salomon et al 2010), make fisheries less predictable and harder to manage in a variable and changing climate (Badjeck et al 2010, Brander 2010, McIlgorm et al 2010), reduce the ability of ecosystems to recover from over-fishing (Neubauer et al 2013), and increase the likelihood or consequence of regime shifts or invasive species (Folke et al 2004, Salomon et al 2010).

To date, it has generally not proved possible to realistically (as opposed to theoretically) identify at what point fishing or other pressure may cause serious disruptions in resource productivity or ecosystem function through trophic or ecosystem-level effects. For multi-species fisheries which are managed at a stock level close to BMSY in a way that does not progressively degrade benthic habitat, it is not known whether it is necessary to take trophic and ecosystem-level effects into account more explicitly to ensure long term sustainability of fisheries (ICES 2005). Some studies (e.g. Jackson et al 2001; Jennings et al 2002; Branch 2009), model analyses (Walters et al 2005; Legovic et al 2010; Gecek & Legovic 2012; Legovic & Gecek 2012; Ghosh & Kar 2013), and expert groups (Scientific Committee on Oceanographic Research/ Intergovernmental Oceanographic Commission working group on indicators, Cury & Christensen 2005) have concluded that harvesting many species in an ecosystem at B_{MSY}[71] can lead to increased chance of fisheries collapse in the medium to long term - an effect called "ecosystem erosion" or "ecosystem overfishing" (Murawski 2000; Coll et al 2008).

ICES (2005) concluded that, for fisheries managed at or close to BMSY, the priority was to avoid fishing practices that drastically changed benthic structure, trophic interactions, food-web structures or nutrient cycling (ICES 2005). This is consistent with the widespread consensus that fisheries should be managed within an ecosystem context and by adopting a precautionary approach which includes acknowledging the potentially synergistic effects of fishing and climate change (CBD 2009; Perry et al 2010; Rice & Garcia 2011). However, there is little consensus on what this actually means in practice (FAO 2008; Ecosystem Principles Advisory Panel 1999; Browman & Stergiou 2004, 2005; Garcia & Cochrane 2005; Murawski 2011). Work by NOAA fisheries (Marasco et al 2007) towards a pragmatic approach to ecosystem-based fishery management recommended:

- incorporating a broader array of societal goals and uses for ecosystem products and services within a multiple use multiple stressors framework;
- recognising the significance of ocean-climate conditions;
- emphasising food-web interactions (recognize that harvest of target species has profound impacts on ecosystem structure and function through trophic interactions);
- employing spatial representation (manage stocks consistent with spatial/habitat variation in productivity);
- increasing and expanding focus on characterising and maintaining viable fish habitats;
- expanding scope of research and monitoring (increased focus on understanding biological interactions/processes, and measuring total fishery removals of target and non-target species);
- acknowledging and responding to higher levels of uncertainty (realistically incorporate uncertainty due to trophic and food-web effects into management policy);
- reviewing and improving ecosystem modelling/research.

The role of no-take reserves or marine protected areas (MPAs) in guarding against trophic and ecosystem-level effects remains controversial. A full review of the value of MPAs in this regard is beyond the scope of the present chapter. Suffice to say that some scientists believe strongly that MPAs can be effective at providing an "ecological safety net" for trophic and ecosystem-level effects (Ballantine 2014; Edgar et al 2014) whereas other scientists believe MPAs are too few and too small to have any value in this regard (Kaiser 2005; Mora et al 2006). No-take marine reserves may have the most to contribute to our understanding of trophic and ecosystem effects by providing a "reference ecosystem" in which populations experience low fishing pressure but a full range of other stressors (such as environmental variability/change, sedimentation, and pollution). Ecosystem changes in the reserve can then be contrasted with adjacent ecosystems exposed to the full range of fishing and other impacts (Micheli et al 2005).

[71] The biomass that allows the maximum sustainable yield to be taken.

New Zealand is currently doing better than most countries with regard to many of the recommendations of Marasco et al (2007). Pitcher et al (2009) evaluated the performance of 33 countries for ecosystem-based management (EBM) of fisheries in three fields (principles, criteria and implementation). No country rated overall as "good", only four countries, including New Zealand were "adequate". Specific recommendations from Marasco et al (2007) are relevant to recent research initiatives in New Zealand. The newly announced Sustainable Seas research programme[72] aims to engage more closely with society to ensure that its goals and concerns are heard and addressed. Similarly, the MBIE Marine Futures project led by Dr Simon Thrush has used a multiple use framework to consider how ecosystem resilience can be promoted in the two focus areas of the Hauraki Gulf and Chatham Rise. Hurst et al (2012) and Dunn et al (2009b) considered the impact of ocean-climate interactions on New Zealand fisheries. The Ocean Survey 20/20 voyages had an explicit focus on mapping the distribution of seafloor habitats important to fish stocks and associated species (Hewitt et al 2011). Ecosystem modelling of key New Zealand regions has been an ongoing focus of NIWA core-funded research since 2005, and includes co-funded ecosystem modelling work with MPI (e.g. ZBD2005/05). Data collection towards building up a comprehensive predator-prey database began with the ZBD2004/01 project (Dunn et al 2009) and continues on the Chatham Rise under NIWA core-funding, with a particular focus on middle trophic level organisms that are abundant. MfE aim to include multi-trophic indicators of marine ecological state in the National Environmental Reporting (Pinkerton et al 2014; Pinkerton 2014b), DOC are aiming to develop marine ecological integrity indicators (Freeman, pers. comm.), and MPI are actively developing indicators of change in fish communities (Tuck et al 2009; Tuck et al 2014).

Notwithstanding this progress, most New Zealand stocks are managed on a single-stock basis at close to BMSY (Ministry of Fisheries 2008) irrespective of their role in the ecosystem. The balance of evidence suggests that fishing close to BMSY and in particular using bottom trawling (which impacts on benthic ecosystem function (Thrush & Dayton 2002)) is likely to reduce ecosystem resilience and increase ecosystem variability by trophic and ecosystem-level effects (Brock & Carpenter 2006; Carpenter & Brock 2006; van Nes & Scheffer 2007; Guttal & Jayaprakash 2008) and could increase recruitment variability. Fishing is also likely to strengthen bottom-up control of marine ecosystems and make ecosystems more sensitive to the effects of climate change (Kirby et al 2009; Perry et al 2010). Greater sensitivity of marine ecosystems to climate variability implies a higher potential for regime shift which may or may not be reversible or desirable (Hsieh et al 2006). Stronger environmental (bottom-up) forcing of ecosystems suggests a greater likelihood of unexpected changes to fisheries due to extreme environmental events and that these changes may be more severe (Perry et al 2010; Kirby & Beaugrand 2009).

Time series measurements are crucial to understanding ecosystem function and monitoring for trophic and ecosystem-level effects of fishing. There would seem to be high value in maintaining regular and frequent (annual) surveys of the demersal fish communities of key New Zealand regions (such as the Chatham Rise, Hauraki Gulf and Subantarctic plateau). Information on the catches of all species by the fishing fleet is required to monitor for changes in trophically or ecologically important non-QMS species. A key knowledge gap is information to map and monitor abundances, trophic connections and community structure of middle trophic level species, especially mesozooplankton, mesopelagics and hyperbenthics in key fishing areas, such as the Chatham Rise, Hauraki Gulf and Subantarctic plateau. Knowledge of the abundance and trophic ecology of small demersal fishes in these regions is notably lacking.

11.7 CONCLUSIONS

1. A range of trophic and ecosystem-level effects in marine systems have been documented internationally, and these have generally been associated with negative impacts on fisheries.
2. Trophic and ecosystem-level effects are not usually brought about by fishing alone, but fishing (especially over-fishing but also at or close to BMSY) in multispecies fisheries can make ecosystems less resilient and more sensitive to the effects of environmental variability and change.
3. New Zealand's marine ecosystems are particularly diverse and this provides special challenges in monitoring, understanding and managing fisheries operating in them.

[72] http://www.beehive.govt.nz/release/sustainable-seas-national-science-challenge-launched

4. There is currently no evidence of a large-scale trophic or ecosystem-level effect impacting New Zealand's deepwater fisheries, but the cause of some changes in New Zealand's marine ecosystem EEZ are not known (e.g. changes to hoki recruitment (Francis et al 2006; Bradford-Grieve & Livingston 2011); trends in some demersal-fish indicators on the Chatham Rise and other areas (Tuck et al 2009).
5. It is likely that the reduction in the abundance of sea urchin predators on some rocky reef systems in north-eastern New Zealand due to fishing has contributed to an ecosystem-level effect in these areas, but this effect is unlikely to be widespread in New Zealand coastal areas (Schiel 2013).
6. Multi-species fishing at close to BMSY using predominantly bottom-trawling is likely to make New Zealand's marine ecosystems less resilient (compared to fishing more conservatively compared to BMSY and not using predominantly bottom-trawling) to other anthropogenic disturbance and to environmental variability, including climate change, through trophic and ecosystem-level effects.
7. There are potential, but unknown, trophic and ecosystem-level consequences for fisheries management in New Zealand if populations of marine mammals, such as fur seals, rebuild to levels that some people have suggested existed before humans arrived in New Zealand (see Theme 1 of this report).
8. Time series monitoring of fish communities and middle trophic level species (mesozooplankton, mesopelagics, hyperbenthics) are crucial for understanding and monitoring for trophic and ecosystem-level effects, and the best current sources of these data are trawl surveys to the Chatham Rise, and Subantarctic plateau.

11.8 REFERENCES

Aebischer, N J; Coulson, J C; Colebrook, J M (1990) Parallel long-term trends across four marine trophic levels and weather. Nature 347: 753–755.

Agnew, D J (1997) The CCAMLR Ecosystem Monitoring Programme. Antarctic Science, 9 (3): 235–242.

Ainley, D G (2002) The Adélie penguin. Columbia University Press, New York. 310 p.

Akroyd, J M; Pierre, J P (2013) Surveillance Report New Zealand Hoki Fishery. February 2013, 24 p. Available (1 December 2014) from: www.epa.govt.nz/eez/EEZ000006/EEZ000006_19_03_82085_HOK_surveillance_report_120213.pdf

Anderson, O F; Smith, M H (2005) Fish discards and non-target fish catch in the New Zealand hoki trawl fishery, 1999–2000 to 2002–03. New Zealand Fisheries Assessment Report 2005/3. 37 p.

Arcos, D F; Cubillos, L A; Nunez, S P (2001) The jack mackerel fishery and El Nino 1997–98 effects off Chile. Progress in Oceanography 49: 597–617.

Arrigo, K (2005) Marine microorganisms and global nutrient cycles. Nature 437: 349–355.

Babcock, R C; Kelly, S; Shears, N T; Walker, J W; Willis, T J (1999) Changes in community structure in temperate marine reserves. Marine Ecology Progress Series 189: 125–134.

Babcock, R C; Shears, N T; Alcala, A C; Barrett, N S; Edgar, G J; Lafferty, K D; McClanahan, T R; Russ, G R (2010) Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. Proceedings of the National Academy of Sciences 107: 18256–18261.

Badalamenti, F; D'Anna, G; Pinnegar, J; Polunin, N (2002) Size-related trophodynamic changes in three target fish species recovering from intensive trawling. Marine Biology, 141(3): 561–570.

Badjeck, M C; Allison, E H; Halls, A S; Dulvy, N K (2010) Impacts of climate variability and change on fishery-based livelihoods. Marine Policy 34: 375–383.

Bagley, N W; O'Driscoll, R L (2012) Trawl survey of hoki, hake and ling in the Southland and Sub-Antarctic areas, November-December 2009 (TAN0911). New Zealand Fisheries Assessment Report 2012/05 [Available Dec. 2014 from www.fs.fish.govt.nz/Doc/22976/12_05_FAR.pdf.aspx]

Bakun, A (2004) Chapter 24 – Regime shifts. In: Robinson, A R; McCarthy, J; Rothschild, B J (Editors), The Sea, vol. 13. Harvard University Press, Cambridge, MA, 971–1018.

Bakun, A (2006) Wasp-waist populations and marine ecosystem dynamics: navigating the ''predator pit'' topographies. Progress in Oceanography 68: 271–288.

Bakun, A (2010) Linking climate to population variability in marine ecosystems characterized by non-simple dynamics: conceptual templates and schematic constructs. Journal of Marine Systematics 79: 361–373.

Bakun, A; Weeks, S J (2006) Adverse feedback sequences in exploited marine systems: Are deliberate interruptive actions warranted? Fish and Fisheries 7: 316–333.

Ballantine, B (2014) Fifty years on: Lessons from marine reserves in New Zealand and principles for a worldwide network. Biological Conservation http://dx.doi.org/10.1016/j.biocon.2014.01.014

Banse, K (1995) Zooplankton: Pivotal role in the control of ocean production. ICES Journal of Marine Science, 52: 265–277.

Barber, R T; Chavez, F P (1983) Biological consequences of El Nino. Science 222: 1203–1210.

Beare, D J; McKenzie, E (1999) Connecting ecological and physical time-series: the potential role of changing seasonality. Marine Ecology Progress Series, 178: 307–309.

Beaugrand, G (2004) The North Sea regime shift: evidence, causes, mechanisms and consequences. Progress in Oceanography, 60: 245–262.

Beaugrand, G (2005) Monitoring pelagic ecosystems using plankton indicators. ICES Journal of Marine Science, 62: 333–338.

Beaugrand, G; Ibanez, F (2004) Monitoring marine plankton ecosystems (2): long-term changes in North Sea calanoid copepods in relation to hydro-climatic variability. Marine Ecology Progress Series 284: 35–47.

Beaugrand, G; Reid, P C (2003) Long-term changes in phytoplankton, zooplankton and salmon linked to climate. Global Change Biology 9: 801–817.

Beaugrand, G; Reid, P C; Ibanez, F; Lindley, J A; Edwards, M (2002) Reorganisation of North Atlantic marine copepod biodiversity and climate. Science 296: 1692–1694.

Beaumont, J; MacDiarmid, A; Morrison, M and 10 other co-authors (2009) Rocky reef ecosystems - how do they function? Integrating the roles of primary and secondary production, biodiversity, and connectivity across coastal habitats. Final research report for project ZBD2005-09, (Unpublished report held by Ministry for Primary Industries, Wellington, New Zealand.)

Becker, P H; Erdelen, M (1986) Trends of coastal bird populations of the German Wadden Sea since 1950: aspects relevant to species conservation. Berichte der Deutschen Sektion des Internationalen Rats für Vogelschutz 26: 63–73. [in German]

Benoît, H P; Swain, D P (2008) Impacts of environmental change and direct and indirect harvesting effects on the dynamics of a marine fish community. Canadian Journal of Fisheries and Aquatic Sciences, 65: 2088–2104.

Bianchi, G; Gislason, H; Graham, K; and 8 other co-authors (2000) Impact of fishing on size composition and diversity of demersal fish communities. ICES Journal of Marine Science, 57(3): 558–571.

Birt, V L; Birt, T P; Goulet, D; Cairns, D K; Montevecchi, W A (1987) Ashmole's halo: direct evidence for prey depletion by a seabird. Marine Ecology Progress Series 40: 205–208.

Bogstad, B; Mehl, S (1997) Interactions between Atlantic cod (Gadus morhua) and its prey species in the Barents Sea. In: Forage fishes in marine ecosystems. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems (pp. 591–615). Alaska Sea Grant College Program Report No 97-01. University of Alaska Fairbanks, 1997.

Borer, E T; Seabloom, E W; Shurin, J B; Anderson, K E; Blanchette, C A; Broitman, B ; Cooper, S D; Halpern, B S (2005) What determines the strength of a trophic cascade? Ecology 86: 528–537.

Bowden, D A (2011) Benthic invertebrate samples and data from the Ocean Survey 20/20 voyages to the Chatham Rise and Challenger Plateau, 2007. New Zealand Aquatic Environment and Biodiversity Report No. 65.

Boyd, I L; Wanless, S; Camphuysen, C J (2006) Top predators in marine ecosystems: their role in monitoring and management. Conservation Biology 12. Cambridge University Press. 378 p.

Boyd, P; LaRoche, J; Gall, M; Frew, R; McKay, R M L (1999) The role of iron, light and silicate in controlling algal biomass in sub-Antarctic water SE of New Zealand. Journal of Geophysical Research, 104(C6): 13395–13408.

Boyer, D (1996) Stock dynamics and ecology of pilchard in the northern Benguela. In: O'Toole, M J (Editor). The Benguela Current and Comparable Eastern Boundary Upwelling Ecosystems. Deutsche Gesellschaft fur Techhnische Zusammenarbeit (GTZ) GmbH, Eschborn, Germany, 79–82.

Boyer, D C; Hampton, I (2001) An overview of the living marine resources of Namibia. South African Journal of Marine Science 23: 5–35.

Bradford-Grieve, J M; Chang, F H; Gall, M; Pickmere, S; Richards, F (1997) Size-fractionated phytoplankton standing stocks and primary production during austral winter and spring 1993 in the Subtropical Convergence region near New Zealand. New Zealand Journal of Marine and Freshwater Research, 31: 201–224.

Bradford-Grieve, J M; Livingston, M E (editors) (2011) Spawning fisheries and the productivity of the marine environment off the west coast of the South Island, New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 84. 136 p.

Branch, T A (2009) How do individual transferable quotas affect marine ecosystems? Fish and Fisheries 10(1): 39–57.

Branch, T A; Watson, R; Fulton, E A; Jennings, S; McGilliard, C R; Pablico, G T; Ricard, D; Tracey, S R (2010) The trophic fingerprint of marine fisheries. Nature, 468: 431–435. doi:10.1038/nature09528.

Brander, K (2010) Impacts of climate change on fisheries. Journal of Marine Systems 79: 389–402.

Brierley, A S; Kingsford, M J (2009) Impacts of climate change on marine organisms and ecosystems. Current Biology 19: R602–R614.

Brock, W A; Carpenter, S R (2006) Variance as a leading indicator of regime shift in ecosystem services. Ecology and Society 11(2): 9.

Brodeur, R D; Mills, C E; Overland, J E; Walters, C E; Schumacher, J D (1999) Evidence for a substantial increase in gelatinous zooplankton in the Bering Sea, with possible links to climate change. Fisheries Oceanography 8: 296–306.

Brodeur, R D; Sugisaki, H; Hunt, G L Jr (2002) Increases in jellyfish biomass in the Bering Sea: implications implications for the ecosystem. Marine Ecology Progress Series 233: 89–103.

Brose, U; Berlow, E L; Martinez, N D (2005) Scaling up keystone effects from simple to complex ecological networks. Ecology Letters 8(12): 1317–1325.

Browman, H I; Stergiou, K I (editors) (2004) Perspectives on ecosystem-based approaches to the management of marine resources. Marine Ecology Progress Series, 274: 269–303.

Browman, H I; Stergiou, K I (editors) (2005) Politics and socio-economics of ecosystem-based management of marine resources. Marine Ecology Progress Series 300: 241–296.

Caddy, J; Csirke, J; Garcia, S M; Grainger, R J L (1998) How pervasive is 'Fishing down marine food webs'? Science 282: 1383.

Caddy, J F; Garibaldi, L (2000) Apparent changes in the trophic composition of world marine harvests: the perspective from the FAO capture database. Ocean and Coastal Management, 43: 615–655.

Campbell, J; Antoine, D; Armstrong, R; and 20 other co-authors (2002) Comparison of algorithms for estimating ocean primary production from surface chlorophyll, temperature, and irradiance. Global Biogeochemical Cycles, 16(3): 1035, doi:10.1029/2002GL015068.

Cardinale, M; Svedäng, H (2008) Mismanagement of fisheries: policy or science? Fisheries Research 93: 244–247.

Carpenter, S R; Brock, W A (2006) Rising variance: A leading indicator of ecological transition. Ecology Letters 9(3): 311–318.

Carpenter, S R; Kitchell, J F; Hodgson, J R (1985) Cascading trophic interactions and lake productivity. Bioscience, 35: 634–639.

Carter, S K; VanBlaricom, G R; Allen, B L (2007) Testing the generality of the trophic cascade paradigm for sea otters: a case study with kelp forests in northern Washington, USA. Hydrobiologia 579: 233–249.

Casini, M; Blenckner, T; Möllmann, C; Gårdmark, A; Lindegren, M; Llope, M; Kornilovs, G; Plikshs, M; Stenseth, N C (2012) Predator transitory spillover induces trophic cascades in ecological sinks. Proceedings of the National Academy of Sciences USA 109: 8185–8189.

Casini, M; Cardinale, M; Arrhenius, F (2004) Feeding preferences of herring (Clupea harengus) and sprat (Sprattus sprattus) in the southern Baltic Sea. ICES Journal of Marine Sciences 61: 1267–1277.

Casini, M; Hjelm, J; Molinero, J C; Lövgren, J; Kornilovs, G; Cardinale, M; Bartolino, V; Belgrano, A (2009) Trophic cascades promote threshold-like sudden shifts in the functioning of a pelagic marine ecosystem. Proceedings of the National Academy of Sciences, 106: 197–202.

Casini, M; Lövgren, J; Hjelm, J; Cardinale, M; Molinero, J C; Kornilovs, G (2008) Multi-level trophic cascades in a heavily exploited open marine ecosystem. Proceedings of the Royal Society B, Biological Sciences, 275: 1793–1801.

CBD (2004) Convention on Biological Diversity Annex I, decision VII/30. The 2020 biodiversity target: a framework for implementation, p. 351. Decisions from the Seventh Meeting of the Conference of the Parties of the Convention on Biological Diversity, Kuala Lumpur, 9–10 and 27 February 2004. Montreal: Secretariat of the CBD.

CBD (2009) Findings of the Ad Hoc Technical Expert Group on Biodiversity and Climate Change CBC CBCDD-0202. 100 p.

CEMP (2004) CCAMLR Ecosystem Monitoring Programme, CCAMLR Document, Hobart, Australia. 268 p.

Christensen, V; Guénette, S; Heymans, J J; Walters, C J; Watson, R; Zeller, D; Pauly, D (2003) Hundred-year decline of North Atlantic predatory fishes. Fish and Fisheries, 4: 1–24.

Christensen, V; Walters, C J (2004) Ecopath with Ecosim: methods, capabilities and limitations. Ecological Modelling, 172: 109–139.

Christoffersen, K; Riemann, B; Klysner, A; Søndergaard, M (1993) Potential role of fish predation and natural populations of zooplankton in structuring a plankton community in eutrophic lake water. Limnology and Oceanography 38: 561–573.

Cobb, J S; Castro, K M (2006) Shell disease in lobsters: a synthesis. Report prepared for the New England Lobster Research Initiative, 18 p. In: Cohen, J E; Briand, F; Newman, C M (1990). Community food webs: data and theory. Springer-Verlag, New York.

Cohen, J E; Cohen, F; Briandan, C M (editors) (1990) Community food web: Data and theory. Berlin, Springer-Verlag.

Coll, M; Libralato, S; Tudela, S; Palomera, I; Pranovi, F (2008) Ecosystem Overfishing in the Ocean. PLoS ONE 3(12): e3881. doi:10.1371/journal.pone.0003881.

Collins, M (2000) Understanding the uncertainties in the response of ENSO to greenhouse warming. Geophysical Research Letters 27 3509–3512.

Condon, R H; Duarte, C M; Pitt, K A and 19 other co-authors (2013) Recurrent jellyfish blooms are a consequence of global oscillations. Proceedings of the National Academy of Sciences USA 110(3): 1000–1005, doi: 10.1073/pnas.1210920110.

Constable, A J (2006) Setting management goals using information from predators. In: Boyd, I L; Wanless, S; Camphuysen, C J (Editors). Top predators in marine ecosystems: their role in monitoring and management. Conservation Biology 12. Cambridge University Press. 324–346.

Cooley, S R; Doney, S C (2009) Anticipating ocean acidification's economic consequences for commercial fisheries. Environmental Research Letters 4(2): 1–18.

Crawford, R J M (2007) Food, fishing and seabirds in the Benguela upwelling system. Journal of Ornithology 148: 253–260.

Cury, P; Bakun, A; Crawford, R J M; Jarre-Teichmann, A; Quinones, R A; Shannon, L J; Verheye, H M (2000) Small pelagics in upwelling systems: patterns of interaction and structural changes in ‘‘wasp-waist’’ ecosystems. ICES Journal of Marine Science 210: 603–618.

Cury, P; Freon, P; Moloney, C L; Shannon, L; Shin, Y-J (2004) Processes and patterns of interactions in marine fish populations: an ecosystem perspective. In: Robinson, A R; McCarthy, J; Rothschild, B J (Editors), The Sea, vol. 13. Harvard University Press, Cambridge, MA, 475–533.

Cury, P M; Christensen, V (2005) Quantitative ecosystem indicators for fisheries management. ICES Journal of Marine Science 62(3): 307–310.

Cury, P M; Shannon, L J; Roux, J-P; Daskalov, G M; Jarre, A; Moloney, C L; Pauly, D (2005) Trophodynamic indicators for an ecosystem approach to fisheries. ICES Journal of Marine Science 62: 430–442.

Daskalov, G M; Grishin, A N; Rodionov, S; Mihneva, V (2007) Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. Proceedings of the National Academy of Science USA 104(25): 10518–10523.

Dayton, P K; Thrush, S F; Agardy, T M; Hofman, R J (1995) Environmental-Effects of Marine Fishing. Aquatic Conservation-Marine and Freshwater Ecosystems, 5(3): 205–232.

de Roos, A M; Boukal, D S; Persson, L (2006) Evolutionary regime shifts in age and size at maturation of exploited fish stocks. Proceedings of the Royal Society of London. B 273(1596): 1873–1880.

DOC-MPI (2011) Coastal marine habitats and marine protected areas in the New Zealand Territorial Sea: a broad scale gap analysis. Department of Conservation and Ministry of Fisheries, Wellington, New Zealand. ISBN 978-0-478-14957-9.

Drinkwater, K F; Beaugrand, G; Kaeriyama, M; Kim, S; Ottersen, G; Perry, R I; Pörtner, H-O; Polovina, J; Takasuka, A (2010) On the mechanisms linking climate to ecosystem changes. Journal of Marine Systematics 79: 374–388.

Duarte, C M; Pitt, K A; Lucas, C H; and 17 other co-authors (2012) Is global ocean sprawl a cause of jellyfish blooms? Frontiers in Ecology and the Environment, 11: 91–97.

Duffy, D C (1983) Environmental uncertainty and commercial fishing: Effects on Peruvian guano birds. Biological Conservation 26: 227–238.

Dunn, M; Horn, P; Connell, A; Stevens, D; Forman, J; Pinkerton, M; Griggs, L; Notman, P; Wood, B (2009a) Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project ZBD2004-02, Objectives 1–5. 351 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Dunn, M; Hurst, R; Francis, C; Devine, J; Renwick, J; McKenzie, A (2007) Fish abundance and climate: trends and possible linkages. Final Research Report for Ministry of Fisheries project SAM2005-02 Objective 1. NIWA, Wellington. 164 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Dunn, M R; Hurst, R; Renwick, J A; Francis, R I C C; Devine, J; McKenzie, A (2009b) Fish abundance and climate trends in New Zealand. New Zealand Aquatic Environment and Biodiversity Report 31. 74 p.

Dutil, J D; Lambert, Y (2000) Natural mortality from poor condition in Atlantic cod (Gadus morhua). Canadian Journal of Fisheries and Aquatic Science, 57, 826–836.

Ecosystem Principles Advisory Panel (1999) Ecosystem-based fishery management. National Marine Fisheries Service, Washington, DC.

Eddy, T D; Pitcher, T J; MacDiarmid, A B; Byfield, T T; Tam, J C; Jones, T T; Bell, J J; Gardner, J P A (2014) Lobsters as keystone: only in unfished ecosystems? Ecological Modelling 275: 48– 72.

Edgar, G J; Stuart-Smith, R D; Willis, T J; and 22 other co-authors (2014) Global conservation outcomes depend on marine protected areas with five key features. Nature 506: 216–220, doi:10.1038/nature13022

Engelhard, G H; Ellis, J R; Payne, M R; ter Hofstede, R; Pinnegar, J K (2011) Ecotypes as a concept for exploring responses to climate change in fish assemblages. ICES Journal of Marine Science 68: 580–591.

Essington, T E; Beaudreau, A H; Wiedenmann, J (2006) Fishing through marine food webs. Proceedings of the National Academy of Sciences of the US, 103: 3171–3175.

Estes, J A (1996) The influence of large, mobile predators in aquatic food webs: examples from sea otters and kelp forests. In: Greenstreet, S; Tasker, M (Editors), Aquatic Predators and their Prey. Blackwell, London, 65–72.

Estes, J A; Duggins, D O (1995) Sea otters and kelp forests in Alaska: generality and variation in a community ecological paradigm. Ecological Monographs 65: 75–100.

Estes, J A; Palmisano, J F (1974) Sea otters: their role in structuring nearshore communities. Science 185: 1058–1060.

Fabry, V J; Seibel, B A; Feely; R A; Orr, J C (2008) Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65: 414–432.

FAO (2008) FAO Fisheries Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2, Add. 1. Rome, FAO. 2008. 78 p.

Fasham, M J R; Baliño, B M; Bowles, M C (Editors) (2001) A new vision of ocean biogeochemistry after a decade of the Joint Global Ocean Flux Study (JGOFS). Ambio Special report 10. 4–31.

Fisher, J A D; Frank, K T (2004) Abundance-distribution relationships and conservation of exploited marine fishes. Marine Ecology Progress Series 279: 201–213.

Folke, C; Carpenter, S; Walker, B; Scheffer, M; Elmqvist, T; Gunderson, L; Holling, C S (2004) Regime shifts, resilience, and biodiversity in ecosystem management. Annual Review of Ecology, Evolution and Systematics 35: 557–581.

Forman, J S; Dunn, M R (2012) Diet and scavenging habits of the smooth skate *Dipturus innominatus*. Journal of Fish Biology 80(5): 1546–62. doi: 10.1111/j.1095-8649.2012.03255.x.

Fossum, P (1992) The recovery of the Barents Sea capelin (*Mallotus villosus*) from a larval point of view. ICES Journal of Marine Science 49: 237–243.

Francis, R I C C; Hadfield, M G; Bradford-Grieve, J M; Renwick, J A; Sutton, P J H (2006) Links between climate and recruitment of New Zealand hoki (*Macruronus novaezelandiae*) now unclear. New Zealand Journal of Marine and Freshwater Research 40: 547–560.

Frank, K T; Petrie, B; Choi, J S; Leggett, W C (2005) Trophic cascades in a formerly cod-dominated ecosystem. Science 308: 1621–1623.

Frank, K T; Petrie, B; Shackell, N L (2007) The ups and downs of trophic control in continental shelf ecosystems. Trends in Ecology and Evolution 22: 237–242.

Frederiksen, M; Wanless, S; Harris, M P; Rothery, P; Wilson, L J (2004) The role of industrial fisheries and oceanographic change in the decline of North Sea black-legged kittiwakes. Journal of Applied Ecology 41: 1129–1139.

Freeman, D J; MacDiarmid, A B (2009) Healthier lobsters in a marine reserve: effects of fishing on disease incidence in the spiny lobster, *Jasus edwardsii*. Marine and Freshwater Research 60: 140–145.

Friedland, K D; Stock, C; Drinkwater, K F; Link, J S; Leaf, R T and 4 other co-authors (2012) Pathways between primary production and fisheries yields of large marine ecosystems. PLoS ONE 7(1): e28945. doi:10.1371/journal.pone.0028945.

Fulton, E A (2011) Interesting times: winners, losers, and system shifts under climate change around Australia. ICES Journal of Marine Science 68: 1329–1343.

Fulton, E A; Smith, A D M; Punt, A E (2005) Which ecological indicators can robustly detect effects of fishing? ICES Journal of Marine Science 62: 540–551.

Fulton, E A; Smith, A D M; Webb, H; Slater, J (2004) Ecological indicators for the impacts of fishing on non-target species, communities and ecosystems: Review of potential indicators. AFMA Final Research report R99/1546: 119 p.

Furness, R W (2002) Management implications of interactions between fisheries and sandeel-dependent seabirds and seals in the North Sea. ICES Journal of Marine Science 59: 261–269.

Furness, R W; Barrett, R T (1985) The food requirements and ecological relationships of a seabird community in North Norway. Ornis Scandinavica 16: 305–313.

Garcia, S M; Cochrane, K L (2005) Ecosystem approach to fisheries: a review of implementation guidelines. ICES Journal of Marine Science 62: 311–318.

Garcia, S M; Grainger, R J R (2005) Gloom and doom? The future of marine capture fisheries. Philosophical Transactions Royal Society B., 360: 21–46.

Gecek, S; Legovic, T (2012) Impact of maximum sustainable yield on competitive community. Journal of Theoretical Biology, 307: 96–103.

Ghosh, B; Kar, T K (2013) Possible ecosystem impacts of applying maximum sustainable yield policy in food chain models. Journal of Theoretical Biology, 329: 6–14.

Gibbons, M J; Richardson, A J (2013) Beyond the jellyfish joyride and global oscillations: advancing jellyfish research. Journal of Plankton Research, 35(5): 929–938.

Gilbert, D J; Annala, J H; Johnston, K (2000) Technical background to fish stock indicators for state-of-environment reporting in New Zealand. Marine and Freshwater Research 51: 451–464.

Grant, S; Constable, A; Raymond, B; Doust, S (2006) Bioregionalisation of the Southern Ocean: report of experts workshop. Available (1 December 2014) from: www.wwf.org.au/news_resources/resource_library/?1704/bioregionalisation-of-the-southern-ocean-report-of-experts-workshop-hobart

Greenstreet, S P R; Rogers, S I (2006) Indicators of the health of the fish community of the North Sea: identifying reference levels for an ecosystem approach to management. ICES Journal of Marine Science, 63: 573–593.

Gruner, D S (2013) Trophic Cascades. John Wiley & Sons Ltd, Chichester.

Guttal, V; Jayaprakash, C (2008) Changing skewness: an early warning signal of regime shifts in ecosystems. Ecology Letters 11: 450–460.

Halpern, B S; Selkoe, K A; Micheli, F; Kappel, C V (2007) Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation Biology 21: 1301–1315.

Heath, M R (2005) Changes in the structure and function of the North Sea fish foodweb, 1973–2000, and the impacts of fishing and climate. ICES Journal of Marine Science 62: 847–868.

Heithaus, M R; Frid, A; Wirsing, A J; Worm, B (2008) Predicting the consequences of declines in marine top predators. Trends in Ecology and Evolution 23(4): 202–210.

Hewitt, J E; Julian, K; Bone, E K (2011) Chatham–Challenger Ocean Survey 20/20 Post-Voyage Analyses: Objective 10 – Biotic habitats and their sensitivity to physical disturbance. New Zealand Aquatic Environment and Biodiversity Report 81.

Hilborn, R W (2007) Comment on Worm et al. Science, 316: 1281–1282.

Hoeinghaus, D J; Zeug, S C (2008) Can stable isotope ratios provide for community-wide measures of trophic structure? Comment, Ecology, 89(8): 2353.

Holling, C S (1973) Resilience and stability of ecological systems. Annual Review of Ecology and Systematics, 4, 1–23.

Hollowed, A B; Barange, M; Beamish, R J; and 19 other co-authors (2013) Projected impacts of climate change on marine fish and fisheries. ICES Journal of Marine Science, http://dx.doi.org/10.1093/icesjms/fst081

Hollowed, A B; Hare, S R; Wooster, W S (2001) Pacific basin climate variability and patterns of Northeast Pacific marine fish production. Progress in Oceanography 49: 257–282.

Holt, C A; Punt, A E (2009) Incorporating climate information into rebuilding plans for overfished groundfish species of the U.S. west coast. Fisheries Research, 100: 57–67.

Horn, P; Dunn, M R (2010) Inter-annual variability in the diets of hoki, hake, and ling on the Chatham Rise from 1990 to 2009. New Zealand Aquatic Environment and Biodiversity Report 54. 57 p.

Howes, L A; Montevecchi, W A (1993) Population trends and interactions among terns and gulls in Gros Morne National Park, Newfoundland. Canadian Journal of Zoology 71: 1516–1520.

Hrbácek, J; Dvorakova, M; Korinek, V; Prochazkova, L (1961) Demonstration of the effect of the fish stock on the species composition of zooplankton and the intensity of metabolism of the whole plankton assemblage. Verhandlungen des Internationalen Verein Limnologie 14: 192–195.

Hsieh, C-h; Glaser, S M; Lucas, A J; Sugihara, G (2005) Distinguishing random environmental fluctuations from ecological catastrophes for the North Pacific Ocean. Nature 435: 336–340.

Hsieh, C-h; Reiss, C S; Hunter, J R; Beddington, J R; May, R M; Sugihara, G (2006) Fishing elevates variability in the abundance of exploited species. Nature 443: 859–862.

Hughes, T P; Bellwood, D R; Folke, C; Steneck, R S; Wilson, J (2005) New paradigms for supporting the resilience of marine ecosystems. Trends in Ecology and Evolution, 20(7): 380–386.

Hunt, G L; McKinnell, S (2006) Interplay between top-down, bottom-up, and wasp-waist control in marine ecosystems. Progress in Oceanography 68: 115–124.

Hurst, R; Renwick, J A; Sutton, P; Uddstrom, M J; Kennan, S; Law, C; Rickard, G; Korpela, A; Stewart, C; Evans, J (2012) Climate and ocean trends of potential relevance to fisheries in the New Zealand region. New Zealand Aquatic Environment and Biodiversity Report 90. 90 p.

Hurst, R J; Law, C S; Kennan, S C; Renwick, J A; Rickard, G J; Stewart, C; Sutton, P J H; Uddstrom, M J; Korpela, A; Evans, J (2008) Climate and oceanographic trends relevant to New Zealand fisheries. Final Research Report for Ministry of Fisheries project ENV200704. (Unpublished report held by Ministry for Primary Industries, Wellington.) 92 p.

Hutchings, J A (2000) Collapse and recovery of marine fishes. Nature 406: 882–885.

ICES (2005) Ecosystem effects of fishing: Impacts, metrics, and management strategies. ICES Cooperative Research Report No. 272. J.C. Rice (Ed.). 177 p.

IPCC (2007a) Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M L; Canziani, O F; Palutikof, J P; van der Linden, P J; Hanson, C E (Editors). Cambridge University Press, Cambridge, UK. 976 p.

IPCC (2007b) Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S; Qin, D; Manning, M; Chen, Z; Marquis, M; Averyt, K B; Tignor, M; Miller, H L (Editors) Cambridge University Press, Cambridge, UK. 996 p.

IUCN (2009) IUCN Red list of threatened species. Prepared by IUCN Species Survival Commission. IUCN, Gland, Switzerland. [Available March 2009 from: www.iucnredlist.org]Jackson, J B; Kirby, M X; Berger, W and 16 other co-authors (2001) Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629–638.

Jahncke, J; Checkley, D; Hunt Jr. G L (2004) Trends in carbon flux to seabirds in the Peruvian upwelling system: effects of wind and fisheries on population regulation. Fisheries Oceanography 13: 208–223.

Jarre-Teichmann, A; Wieland, K; MacKenzie, B; Hinrichsen, H-H; Plikhs, M; Aro, E (2002) Stock-recruitment relationships for cod (*Gadus morhua callarias*) in the central Baltic Sea incorporating environmental variability. Archive of Fishery and Marine Research 48: 97–123.

Jennings, S; Brander, K M (2010) Predicting the effects of climate variation and change on marine communities and the consequences for fisheries. Journal of Marine Systems 79: 418–426.

Jennings S; Greenstreet, S P R; Hill, L; Piet, G J; Pinnegar, J K; Warr, K J (2002) Long-term trends in the trophic structure of the North Sea fish community: evidence from stable-isotope analysis, size-spectra and community metrics. Marine Biology 141: 1085–1097.

Johnson, K D; Grabowski, J H; Smee, D L (2014) Omnivory dampens trophic cascades in estuarine communities. Marine Ecology Progress Series 507: 197–206.

Kaiser, M J (2005) Are marine protected areas a red herring or fisheries panacea? Canadian Journal of Fisheries and Aquatic Sciences 62: 1194–1199.

Kaiser, M J; Spencer, B E (1994) Fish scavenging behaviour in recently trawled areas. Marine Ecology Progress Series 112: 41–49.

Kennedy, V S; Twilley, R R; Kleypas, J A; Cowan Jr, J H; Hare, S R (2002) Coastal and marine ecosystems and global climate change: Potential effects on U.S. resources. Pew Center on Global Climate Change. 64 p.

Kidson, J W (2000) An analysis of New Zealand synoptic types and their use in defining weather regimes. International Journal of Climatology 20: 299–316.

Kirby, R R; Beaugrand, G (2009) Trophic amplification of climate warming. Proceedings of the Royal Society B Biological Sciences, 276: 4095–4103.

Kirby, R R; Beaugrand, G; Lindley, J A (2008) Climate-induced effects on the merozooplankton and the benthic-pelagic ecology of the North Sea. Limnology and Oceanography 53: 1805–1815.

Kirby, R R; Beaugrand, G; Lindley, J A (2009) Synergistic effects of climate and fishing in a marine ecosystem. Ecosystems 12: 548–561.

Kjesbu, O S; Witthames, P R; Solemdal, P; Walker, M G (1998) Temporal variations in the fecundity of Arcto- Norwegian cod (*Gadus morhua*) in response to natural changes in food and temperature. Journal of Sea Research 40: 303–321.

Köster, F W; Möllmann, C (2000) Trophodynamic control by clupeid predators on recruitment success in Baltic cod? ICES Journal of Marine Science, 57, 311–323.

Köster, F W; Hinrichsen, H-H; Schnack, D and 8 other co-authors (2003a) Recruitment of Baltic cod and sprat stocks: identification of critical life stages and incorporation of environmental variability into stock-recruitment relationships. Scientia Marina 67 (Suppl. 1), 129–154.

Köster, F W; Möllmann, C; Neuenfeldt, S and 8 other co-authors (2003b) Fish stock development in the central Baltic Sea (1974–1999) in relation to variability in the environment. ICES Marine Science Symposia 219: 294–306.

Kotta, J; Kotta, I S; Pollupuu, M (2009) Separate and interactive effects of eutrophication and climate variables on the ecosystem elements of the Gulf of Riga. Estuarine, Coastal and Shelf Science, 84: 509–518.

Kritzer, J P; Sale, P F (2004) Metapopulation ecology in the sea: from Levins' model to marine ecology and fisheries science. Fish and Fisheries 5: 131–140.

Law, R (2000) Fishing, selection, and phenotypic evolution. ICES Journal of Marine Science 57: 659–668.

Layman, C A; Quattrochi, J P; Peyer, C M; Allgeier, J E (2007) Niche width collapse in a resilient top predator following ecosystem fragmentation. Ecology Letters, 10: 937–944.

Leathwick, J R; Francis, M; Julian, K (2006) Development of a demersal fish community map for New Zealand's Exclusive Economic Zone. NIWA Client Report: HAM2006-062, 21 p.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2009) Development of a benthic-optimised marine environment classification for waters within the New Zealand EEZ. Final Research Report for Ministry of Fisheries project BEN200601. (Unpublished report held by the Ministry for Primary Industries.) 52 p.

Leggett, W C; Frank, K T; Carscadden, J E (1984) Meteorological and hydrographic regulation of year-class strength in capelin (*Mallotus villosus*). Canadian Journal of Fisheries and Aquatic Sciences 41: 1193–1201.

Legovic, T; Gecek, S (2012) Impact of maximum sustainable yield on mutualistic communities. Ecological Modelling, 230: 63–72.

Legovic, T; Klanjscek, J; Gecek, S (2010) Maximum sustainable yield and species extinction in ecosystems. Ecological Modelling, 221: 1569–1574.

Lehodey, P; Alheit, J; Barange, M; Baumgartner, T; Beaugrand, G; Drinkwater, K; Fromentin, J-M; Hare, S; Ottersen, G; Perry, R I; Roy, C; van der Lingen, C D; Werner, F (2006) Climate variability, fish and fisheries. Journal of Climate 19: 5009–5030.

Levin, S A (1998) Ecosystems and the biosphere as complex adaptive systems. Ecosystems 1: 431–436.

Levin, S A (1999) Fragile Dominion: Complexity and the Commons. Reading (MA): Perseus.

Libralato, S; Christensen, V; Pauly, D (2006) A method for identifying keystone species in food web models. Ecological Modelling 195: 153–171.

Lilly, G R (1993) Predation by Atlantic cod on capelin on the southern Labrador and Northeast Newfoundland shelves during a period of changing spatial distributions. In: Jakobson, J and 9 co-editors, Cod and climate change (pp. 600–611). ICES Marine Science Symposium 198.

Lindegren, M; Diekmann, R; Mollman, C (2010) Regime shifts, resilience and recovery of a cod stock. Marine Ecology Progress Series 402: 239–253.

Lindeman, R L (1942) The trophic-dynamic aspect of ecology. Ecology, 23(4): 399–418.

Lloyd, C S; Tasker, M L; Partridge, K (1991) The status of seabirds in Britain and Ireland. Poyser, London.

Lynam, C P; Gibbons, M J; Axelsen, B J; and 19 other co-authors (2006) Jellyfish overtake fish in a heavily fished ecosystem. Current Biology 16(13), R492–R493.

MacDiarmid, A; McKenzie, A; Sturman, J; Beaumont, J; Mikaloff-Fletcher, S; Dunne, J (2012) Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93. 255 p.

MacDiarmid, A B; Law, C S; Pinkerton, M H; Zeldis, J (2013) New Zealand marine ecosystem services. In: Dymond, J R (editor). Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

MacKenzie, B R; Leggett, W C (1991) Quantifying the contribution of small-scale turbulence to the encounter rates between larval fish and their zooplankton prey: effects of wind and tide. Marine Ecology Progressive Series 73: 149–160.

Mackinson, S; Daskalov, G; Heymans, J J; Neira, S; Arancibia, H; Zetina-Rejón, M; Jiang, H; Cheng, H Q; Coll, M; Arreguin-Sanchez, F; Keeble, K; Shannon, L (2009) Which forcing factors fit? Using ecosystem models to investigate the relative influence of fishing and changes in primary productivity on the dynamics of marine ecosystems. Ecological Modelling 220(21): 2972–2987.

Marasco, R; Goodman, D; Grimes, C B; Lawson, P; Punt, A; Quinn, T (2007) Ecosystem-based fishery management; a pragmatic approach. Canadian Journal of Fisheries and Aquatic Science 64: 928–929.

Marine Stewardship Council (2010) MSC Fishery Standard: Principles and Criteria for Sustainable Fishing v1.1. Available (November 2013) from: http://www.msc.org/documents/scheme-documents/msc-standards/

Marine Zooplankton Colloquium 2 (2001) Future marine zooplankton research: a perspective. Marine Ecology Progress Series 222: 297–308.

Mayo, R K; O'Brien, L; Wiggley, S E (1998) Assessment of the Gulf of Maine cod stock for 1998. Northeast Fisheries Science Center Reference Document 98–13.

McCann, K S; Rooney, N (2009) The more food webs change, the more they stay the same. Philosophical Transactions of the Royal Society of London B Biological Sciences 27:1789–1801. doi: 10.1098/rstb.2008.0273.

McClatchie, S; Dunford, A (2003) Estimated biomass of vertically migrating mesopelagic fish off New Zealand. Deep Sea Research I, 50: 1263–1281.

McIlgorm, A; Hanna, S; Knapp, G; Le Floc'H, P; Millerd, F; Pan, M (2010) How will climate change alter fishery governance: insights from seven international case studies. Marine Policy 34: 170–177.

McKenzie, A (2013) Assessment of hoki (*Macruronus novaezelandiae*) in 2012. New Zealand Fisheries Assessment Report 2013/27.

McKnight, D G; Probert, P K (1997) Epibenthic communities on the Chatham Rise, New Zealand. New Zealand Journal of Marine and Freshwater Research, 31:505–513.

McQueen, D; Post, J (1988a) Limnocorral studies of cascading trophic interaction. Verhandlungen - Internationale Vereinigung für Theoretische und Angewandte Limnologie 23: 739–747.

McQueen, D; Post, J (1988b) Cascading trophic interactions: uncoupling at the zooplankton- phytoplankton link. Hydrobiologia 159: 277–296.

Mead, A; Griffiths, C L; Branch, G M; McQuaid, C D; Blamey, L K; Bolton, J J; Anderson, R J; Dufois, F; Rouault, M; Froneman, P W; Whitfield, A K; Harris, L R; Nel, R; Pillay, D; Adams J B (2013) Human-mediated drivers of change — impacts on coastal ecosystems and marine biota of South Africa. African Journal of Marine Science 35:403–425.

Mehl, S; Sunnana, K (1991) Changes in growth of Northeast Arctic cod in relation to food consumption in 1984–1988. ICES Journal of Marine Science 193: 109–112.

Methratta, E T; Link, J S (2007) Evaluation of quantitative indicators for marine fish communities. Ecological Indicators, 6: 575–588.

Micheli, F; Benedetti-Cecchi, L; Gambaccini, S; Bertocci, I; Borsini, C; Osio, G C; Romano, F (2005) Cascading human impacts, marine protected areas, and the structure of Mediterranean reef assemblages. Ecological Monographs 75: 81–102.

Mills, C E (2001) Jellyfish blooms: are populations increasing globally in response to changing ocean conditions? Hydrobiologia, 451, 55–68.

Ministry of Fisheries (2008) Harvest Strategy Standard for New Zealand Fisheries. October 2008. 30 p. Available (1 December 2014) from http://fs.fish.govt.nz/Page.aspx?pk=104

Ministry of Fisheries (2009) Fisheries 2030: New Zealanders maximising benefits from the use of fisheries within environmental limits. Ministry of Fisheries. 15 p. http://www.fish.govt.nz/en-nz/Fisheries+2030/default.htm

Möllmann, C; Diekmann, R; Müller-Karulis, B; Kornilovs, G; Plikshs, M; Axe, P (2009) Reorganization of a large marine ecosystem due to atmospheric and anthropogenic pressure: a discontinuous regime shift in the Central Baltic Sea. Global Change Biology, 15: 1377–1393. doi: 10.1111/j.1365-2486.2008.01814.x

Möllmann, C; Müller-Karulis, B; Kornilovs, G; St. John, M A (2008) Effects of climate and overfishing on zooplankton dynamics and ecosystem structure regime shifts, trophic cascade and feedback loops in a simple ecosystem. ICES Journal of Marine Science 65(3):302–310, doi:10.1093/icesjms/fsm197

Mora, C; Andréfouët, S; Costello, M J; Kranenburg, C; Rollo, A; Veron, J; Gaston, K J; Myers, R A (2006) Coral reefs and the global network of marine protected areas. Science 312: 1750–1751.

Mullan, A B (1995) On the linearity and stability of Southern Oscillation-climate relationships for New Zealand. International Journal of Climatology 15(12): 1365–1386.

Mullan, A B; Wratt, D S; Renwick, J A (2001) Transient model scenarios of climate changes for New Zealand. Weather and Climate 21: 3–34.

Muradian, R (2001) Ecological thresholds: a survey. Ecological Economics 38: 7–24.

Murawski, S; Methot, R; Tromble, G (2007) Biodiversity loss in the ocean: how bad is it? Science, 316: 1281–1284.

Murawski, S A (2000) Definitions of overfishing from an ecosystem perspective. ICES Journal of Marine Science 57: 649–658.

Murawski, S A (2011) Summing up Sendai: progress integrating climate change science and fisheries. ICES Journal of Marine Science 68: 1368–1372.

Murawski, S A; Idoine, J S (1992) Multispecies size composition: a conservative property of exploited fishery systems? Journal of Northwest Atlantic Fisheries Sciences 14: 79–85.

Murphy, E J; Wakins, J L; Reid, K; Trathan, P N; Everson, I; Croxall, J P; Priddle, J; Brandon, M A; Brierley, A S; Hoffman, E (1998) Interannual variability in the South Georgia marine ecosystem: biological and physical sources of variation in the abundance of krill. Fisheries Oceanography 7: 381–390.

Murphy, R J; Pinkerton, M H; Richardson, K M; Bradford-Grieve, J M; Boyd, P W (2001) Phytoplankton distributions around New Zealand derived from SeaWiFS remotely-sensed ocean colour data. New Zealand Journal of Marine and Freshwater Research, 35(2): 343–362.

NEFSC (1998) Report of the 27th Northeast regional Stock Assessment Workshop Stock Assessment review Committee (SARC) consensus summary of assessments. Northeast Fisheries Science Center Reference Document 98-15.

Neubauer, P; Jensen, O P; Hutchings, J A; Baum, J K (2013) Resilience and recovery of overexploited marine populations. Science 340: 347–349.

Noakes, D J; Beamish, R J (2009) Synchrony of marine fish catches and climate and ocean regime shifts in the North Pacific Ocean. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 1: 155–168.

Northcote, T (1988) Fish in the structure and function of freshwater ecosystems: a ‘top-down’ view. Canadian Journal of Fisheries and Aquatic Sciences 45: 361–379.

O’Connor, M I; Bruno, J F; Gaines, S D; Halpern, B S; Lester, S E; Kinlan, B P; Weiss, J M (2007) Temperature control of larval dispersal and the implications for marine ecology, evolution and conservation. Proceedings of the National Academy of Sciences USA 104: 1266–1271.

O'Driscoll, R L; Gauthier, S; Devine, J A (2009) Acoustic estimates of mesopelagic fish: as clear as day and night? ICES Journal of Marine Science 66(6):1310–1317.

O’Driscoll, R L; MacGibbon, D; Fu, D; Lyon, W; Stevens, D W (2011) A review of hoki and middle depth trawl surveys on the Chatham Rise, January 1992–2010. New Zealand Fisheries Assessment Report 2011/47.

OECD (2003) OECD Environmental Indicators: Development, measurement and use. Organization for Economic Cooperation and Development (OECD), Paris, France. 37 p.

Oeffner, J; Gauthier, S; Pinkerton, M H; O’Driscoll, R L (2014, submitted) A decision-tree model for species identification of acoustic marks: moving beyond acoustic indices to estimate mesopelagic biomass. Submitted to Marine Ecology Progress Series.

Oguz, T; Gilbert, D (2007) Abrupt transitions of the top-down controlled Black Sea pelagic ecosystem during 1960–2000: Evidence for regime-shifts under strong fishery exploitation and nutrient enrichment modulated by climate-induced variations. Deep Sea Research Part I: Oceanographic Research Papers 54: 220–242.

Osterblom, H O; Hansson, S; Larsson, U; Hjerne, O; Wulff, F; Elmgren, R; Folke, C (2007) Human-induced trophic cascades and ecological regime shifts in the Baltic Sea. Ecosystems 10: 877–889.

Ottersen, G; Hjermann, D Ø; Stenseth, N C (2006) Changes in spawning stock structure strengthen the link between climate and recruitment in a heavily fished cod (*Gadus morhua*) stock. Fisheries Oceanography 15: 230–243.

Ottersen, G; Kim, S; Huse, G; Polovina, J J; Stenseth, N Chr. (2010) Major routes by which climate may force marine fish populations. Journal of Marine Systematics 79: 343–360.

Overland, J; Alheit, J; Bakun, A; Hurrell, J; Mackas, D; Miller, A (2010) Climate controls on marine ecosystems and fisheries. Journal Marine Systematics 79: 305–315.

Pace, M L; Cole, J J; Carpenter, S R; Kitchell, J F (1999) Trophic cascades in diverse ecosystems. Trends in Ecology and Evolution 14: 483–488.

Paine, R T (1980) Food web linkage, interaction strength and community infrastructure. Journal of Animal Ecology 49: 667–685.

Parsons, T R; Lalli, C M (2002) Jellyfish population explosions: Revisiting a hypothesis of possible causes. La Mer, 40: 111–121 [in English].

Parsons, T R; Takahashi, M; Hargrave, B (1977) Biological oceanographic processes. Pergamon Press, Oxford. 332 p.

Pascual, M; Dunne, J A (2006) Ecological Networks: Linking Structure to Dynamics in Food Webs. Oxford University Press. 371 p.

Pauly, D; Christensen, V (1995) Primary production required to sustain global fisheries. Nature 374: 225–257.

Pauly, D; Christensen, V; Dalsgaard, J; Froese, R; Torres, F (1998a) Fishing down marine food webs. Science 279: 860–863.

Pauly, D; Froese, R; Christensen, V (1998b) How pervasive is "Fishing down marine food webs": response to Caddy et al. Science 282: 1383.

Pauly, D; Watson, R (2005) Background and interpretation of the "Marine Trophic Index" as a measure of biodiversity. Philosophical Transactions of the Royal Society B 360: 415–423.

Pearcy, W; Fisher, J; Brodeur, R D; Johnson, S (1985) Effects of the 1983 El Nino on coastal nekton off Oregon and Washington. In: Wooster, W S; Fluharty, D L (Editors), El Nino North. Washington Sea Grant Program, University of Washington, Seattle, USA, pp. 188–204.

Peet, R K (1974) The measurement of species diversity. Annual Review of Ecology and Systematics 5: 285–307.

Perry, A L; Low, P J; Ellis, J R; Reynolds, J D (2005) Climate change and distribution shifts in marine fishes. Science 308: 1912–1915.

Perry, R I; Cury, P; Brander, K; Jennings, S; Möllmann, C; Planque, B (2010) Sensitivity of marine systems to climate and fishing: concepts, issues and management responses. Journal of Marine Systems 79: 427–435.

Petitgas, P; Rijnsdorp, A D; Dickey-Collas, M; Engelhard, G H; Peck, M A; Pinnegar, J K; Drinkwater, K; Huret, M; Nash, R D M (2013) Impacts of climate change on the complex life cycles of fish. Fisheries Oceanography 22: 121–139.

Pimm, S L (1982) Food webs. Chapman and Hall, London.

Pinkerton, M H (2007) Oceanic Primary Productivity in the New Zealand EEZ. In: State of the New Zealand Environment: Oceans, report ENZ-07, Ministry for the Environment, New Zealand.

Pinkerton, M H (2010) Headline indicators for the New Zealand ocean. NIWA unpublished report, 42 p. [Available Dec. 2014: www.niwa.co.nz/sites/niwa.co.nz/files/headline_indicators_59.pdf]

Pinkerton, M H (2012) Trophic modelling of a New Zealand marine shelf ecosystem since AD 1000. Draft final research report to MPI, 342 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Pinkerton, M H (2013) Ecosystem Modelling of the Chatham Rise. Research report prepared for Chatham Rock Phosphate, April 2013. NIWA Client Report No: WLG2013-17. 183 p.

Pinkerton, M H (2014a) Three potential Marine State statistics for the 2015 National Environment Reporting Synthesis Report: (1) Marine Trophic Index; (2) Acoustic Backscatter Index; (3) Zooplankton Index. NIWA unpublished report for MfE. 13 p.

Pinkerton, M H (2014b) Food-web modelling of the Chatham Rise: Additional work requested by the expert conference on ecosystem effects. Letter to CRP and DMC, 14 October 2014. 23 p.

Pinkerton, M H; Bell, R; Chiswell, S M; Currie, K; Mullan, A B; Rickard, G; Stevens, C; Sutton, P (2014) Reporting on the state of the marine environment: recommendations for tier 1 oceanic statistics. Draft report for project ZBD2012-02. 82 p. June 2014.

Pinkerton, M H; Bradford-Grieve, J M (2014) Characterizing foodweb structure to identify potential ecosystem effects of fishing in the Ross Sea, Antarctica. ICES Journal of Marine Science; doi: 10.1093/icesjms/fst230.

Pinkerton, M H; Lundquist, C J; Duffy, C A J; Freeman, D J (2008) Trophic modelling of a New Zealand rocky reef ecosystem using simultaneous adjustment of diet, biomass and energetic parameters. Journal of Experimental Marine Biology and Ecology 367: 61–266.

Pinsky, M L; Jensen, O P; Ricard, D; Palumbi, S R (2011) Unexpected patterns of fisheries collapse in the world's oceans. Proceedings of the National Academy of Sciences of the US, 108(20): 8317–8322; doi:10.1073/pnas.1015313108.

Pitcher, T J; Kalikoski, D; Short, K; Varkey, D; Pramoda, G (2009) An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries. Marine Policy 33: 223–232.

Plagányi, E E (2007) Models for an ecosystem approach to fisheries. FAO Fisheries Technical Paper, 477, FAO, Rome (Italy).

Plagányi, E E; Punt, A E; Hillary, R; and 12 other co-authors (2014) Multispecies fisheries management and conservation: tactical applications using models of intermediate complexity. Fish and Fisheries, 15(1): 1–22.

Polunin, N V C; Pinnegar, J K (2002) Trophic ecology and the structure of food webs. In: Hart, P J B; Reynolds, J D (Editors) Handbook of Fish and Fisheries, Vol. 1. Blackwell, Oxford, UK.

Pope, J G; Knights, B J (1982) Comparison of the length distributions of combined catches of all demersal fishes in surveys in the North Sea and at Faroe Bank. In: Multispecies approaches to fisheries management advice, pp. 116–118. Ed. by M. C. Mercer. Canadian Special Publication of Fisheries and Aquatic Sciences, 59.

Pope, J G; Stokes, T K; Murawski, S A; Idoine, J S (1987) A comparison of fish size composition in the North Sea and on Georges Bank.

In: Wolff, W; Soeder, C-J; Drepper, F R (Editors) Ecodynamics – Contributions to theoretical ecology, pp. 146–152. Springer-Verlag, Berlin.

Portner, H O; Peck, M A (2010) Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. Journal of Fish Biology 77: 1745–1779.

Probert, P K; Grove, S L; McKnight, D G; Read, G B (1996) Polychaete distribution on the Chatham Rise, Southwest Pacific. Internationale Revue der Gesamten Hydrobiologie 81:577–588. [In English]

Purcell, J E (2005) Climate effects on formation of jellyfish and ctenophore blooms: A review. Journal of the Marine Biological Association of the UK, 85(3): 461–476.

Purcell, J E (2012) Jellyfish and ctenophore blooms coincide with human proliferations and environmental perturbations. Annual Review of Marine Science, 4: 209–235.

Reid, K; Croxall, J P; Briggs, D R; Murphy, E J (2005) Antarctic ecosystem monitoring: quantifying the response of ecosystem indicators to variability in Antarctic krill. ICES Journal of Marine Science 62(3): 366–373.

Reid, P C; Edwards, M; Beaugrand, G; Skogen, M D; Stevens, D (2003) Periodic changes in the zooplankton of the North Sea during the 20th century linked to oceanic inflow. Fisheries Oceanography 12: 260–269.

Reid, P C; Edwards, M; Hunt, H G; Warner, A J (1998) Phytoplankton changes in the North Atlantic. Nature, London, 391: 546.

Rice, J (1995) Food web theory, marine food webs, and what climate change may do to northern fish populations. In: Beamish, R J (Editor). Climate Change and Northern Fish Populations, Canadian Special Publication in Fisheries and Aquatic Science 121: 561–568.

Rice, J (2001) Implications of variability on many time scales for scientific advice on sustainable management of living marine resources. Progress in Oceanography 49:189–209.

Rice, J (2003) Environmental health indicators. Ocean & Coastal Management 46(3–4): 235–259.

Rice, J; Gislason, H (1996) Patterns of change in the size spectra of numbers and diversity of the North Sea fish assemblage, as reflected in surveys and models. ICES Journal of Marine Science 53: 1214–1225.

Rice, J C; Garcia, S M (2011) Fisheries, food security, climate change, and biodiversity: characteristics of the sector and perspectives on emerging issues. ICES Journal of Marine Science 68(6), 1343–1353.

Rice, J C; Rochet, M-J (2005) A framework for selecting a suite of indicators for fisheries management. ICES Journal of Marine Science 62: 516–527.

Richardson, A J (2008) In hot water: zooplankton and climate change. ICES Journal of Marine Science, 65(3): 279–295.

Ridgeway, G (2006) Generalized Boosted Models: A guide to the gbm package. Gbm library for R.

Rijnsdorp, A D; Peck, M A; Engelhard, G H; Möllmann, C; Pinnegar, J K (2009) Resolving the effect of climate change on fish populations. ICES Journal Marine Science 66: 1570–1583.

Robinson, K V; Pinkerton, M H; Hall, J A; Hosie, G W (2013) Continuous Plankton Recorder Time Series. New Zealand Aquatic Environment and Biodiversity Report No. 128. 76 p.

Rochet, M-J; Rice, J (2005) Do explicit criteria help in selecting indicators for ecosystem-based fisheries management? ICES Journal of Marine Science 62: 528–539.

Rooney, N; McCann, K S; Gellner, G; Moore, J C (2006) Structural asymmetry and the stability of diverse food webs. Nature 442: 265–269.

Rothschild, B J (1994) Decadal transients in biological productivity, with special reference to cod populations of the North Atlantic. ICES Marine Science Symposia 198: 333–345.

Salomon, A K; Gaichas, S K; Shears, N T; Smith, J E; Madin, E M P; Gaines, S D (2010) Key features and context-dependent effects of fishery-induced trophic cascades. Conservation Biology 24: 382–394.

Salomon, A K; Shears, N T; Langlois, T J; Babcock, R C (2008) Cascading effects of fishing can alter carbon flow through a temperate coastal ecosystem. Ecological Applications 18: 1874–1887.

Scheffer, M; Carpenter, S R (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. Trends Ecology. Evolution 18: 648–656.

Schiel, D R (2013) The other 93%: trophic cascades, stressors and managing coastlines in non-marine protected areas. New Zealand Journal of Marine and Freshwater Research 47: 374–391, DOI: 10.1080/00288330.2013.810161

Schiermeier, Q (2004) Climate findings let fishermen off the hook. Nature 428: doi:10.1038/428004a.

Schroeter, S C; Dixon, J D; Kastendiek, J; Smith, R O; Bence, J R (1993) Detecting the ecological effects of environmental impacts: a case study of kelp forest invertebrates. Ecological Applications, 331–350.

Shannon, L J; Coll, M; Neira, S (2009) Exploring the dynamics of ecological indicators using food web models fitted to time series of abundance and catch data. Ecological Indicators 9: 1078–1095.

Shapiro, J; Lammara, V; Lynch, M (1975) Biomanipulation: an ecosystem approach to lake restoration. In: Brezonik, P L; Fox, J L (Editors), Water quality management through biological control pp. 85–96, University of Florida.

Sharp, B; Pinkerton, M H; Smith, A; Leathwick, J (2007) Marine Classification: Lessons from the New Zealand Experience. CCAMLR document WS-BSO-07-06, Hobart, Australia. CCAMLR Bioregionalisation of the Southern Ocean Experts workshop, Brussels 13–17 August 2007.

Shears, N T; Babcock, R C (2002) Marine reserves demonstrate top-down control of community structure on temperate reefs. Oecologia 132: 131–142.

Shears, N T; Babcock, R C (2003) Continuing trophic cascade effects after 25 years of no-take marine reserve protection. Marine Ecology Progress Series 246: 1–16.

Shears, N T; Babcock, R C; Salomon, A K (2008) Context-dependent effects of fishing: variation in trophic cascades across environmental gradients. Ecological Applications 18: 1860–1873.

Shields, J D (2011) Diseases of spiny lobsters: a review. Journal of Invertebrate Pathology 106: 79–91.

Shiganova, T A (1998) Invasion of the Black Sea by the ctenophore *Mnemiopsis leidyi* and recent changes of pelagic community structure. Fishery Oceanography 7: 305–310.

Shin Y-J; Cury, P (2001) Exploring fish community dynamics through size-dependent trophic interactions using a spatialized individual based model. Aquatic Living Resources, 14(2): 65–80. http://dx.doi.org/10.1051/alr:2005001

Shin, Y-J; Shannon, L J; Cury, P M (2004) Simulations of fishing effects on the southern Benguela fish community using an individual based model: learning from a comparison with ECOSIM. In: Shannon, L J; Cochrane, K L; Pillar, S C (Editors). Ecosystem Approaches to Fisheries in the Southern Benguela. African Journal of Marine Science 26: 95–114.

Shurin, J B; Borer, E T; Seabloom, E W; Anderson, K; Blanchette, C A; Broitman, B R; Cooper, S D; Halpern, B (2002) A cross-ecosystem comparison of the strength of trophic cascades. Ecology Letters 5: 785–791.

Smetacek, V; Assmy, P; Henjes, J (2004) The role of grazing in structuring Southern Ocean pelagic ecosystems and biogeochemical cycles. Antarctic Science 16(4): 541–558.

Smith, B E; Lucey, S M (2014) Using fish diets as ecosystem indicators: are fish feeding down the food web on Georges Bank? Proceedings of the 144th American Fisheries Society annual meeting, August 17–21 August 2014, Quebec, Canada.

Smith, S G; Aulta, J S; Bohnsack, J A; Harper, D E; Luoa, J ; McClellan, D B (2011) Multispecies survey design for assessing reef-fish stocks, spatially explicit management performance, and ecosystem condition. Fisheries Research, 109: 25–41.

Snelder, T; Leathwick, J; Dey, K; Weatherhead, M; Fenwick, G; Francis, M (2005) The New Zealand marine environment classification. Ministry for the Environment. Available (October 2014) at: http://www.niwa.co.nz\ncco\mec

Steele, J (1998) From carbon flux to regime shift. Fisheries Oceanography 7, 176–181.

Steele, J H; Schumacher, M (2000) Ecosystem structure before fishing. Fisheries Research 44: 201–205.

Stock, C; Dunne, J (2010) Controls on the ratio of mesozooplankton production to primary production in marine ecosystems. Deep Sea Research Part I, 57(1): 95–112.

Sutton, P (2001) Detailed structure of the Subtropical Front over Chatham Rise, east of New Zealand. Journal of Geophysical Research 106 (C12): 31045–31056.

Sydeman, W J; Bograd, S J (2009) Marine ecosystems, climate and phenology: introduction. Marine Ecological Progress Series 393: 185–188.

Szpak, P; Orchard, T J; Salomon, A K; Gröcke, D R (2013) Regional ecological variability and impact of the maritime fur trade on nearshore ecosystems in southern Haida Gwaii (British Columbia, Canada): evidence from stable isotope analysis of rockfish (*Sebastes* spp.) bone collagen. Archaeological and Anthropological Sciences 5: 159–182.

Taggert, C T; Leggett, W C (1987) Short-term mortality in post-emergent larval capelin *Mallotus villosus*. 1.Analysis of multiple in situ estimates. Marine Ecology Progressive Series, 41: 205–217.

Taylor, A H (2002) North Atlantic climatic signals and the plankton of the European continental shelf. In: Sherman, K; Skjoldal, H R (Editors) Changing states of the large marine ecosystems of the North Atlantic. Elsevier Science, Amsterdam, 3–26.

Taylor, G A (2000a) Action Plan for Seabird Conservation in New Zealand. Part A: Threatened Seabirds. Threatened Species Occasional Publication 16. 234 p.

Taylor, G A (2000b) Action Plan for Seabird Conservation in New Zealand. Part B: Non-Threatened Seabirds. Threatened Species Occasional Publication 17. 201 p.

ter Hofstede, R; Hiddink, J G; Rijnsdorp, A D (2010) Regional warming changes the species richness of marine fish in the eastern North Atlantic Ocean. Marine Ecology Progress Series 414: 1–9.

Theissen, H (1986) Population dynamics of gulls (Laridae) and terns (Sternidae) in Schleswig-Holstein – and thoughts on the so-called gull-problem. Seevogel 7: 1–12.

Thrush, S F; Dayton, P K (2002) Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity. Annual Review of Ecology and Systematics, 449–473.

Travers, M; Shin, Y-J; Jennings, S; Machu, E; Huggett, J A; Field, J G; Cury P M (2009) Two-way coupling versus one-way forcing of plankton and fish models to predict ecosystem changes in the Benguela. Ecological Modelling 220(21): 3089–3099.

Trenkel, V; Berger, L (2013) A fisheries acoustic multi-frequency indicator to inform on large scale spatial patterns of aquatic pelagic ecosystems. Ecological Indicators, 30: 72–79.

Trillmich, F; Ono, K A; Costa, D P; DeLong, R L; Feldkamp, S D; Francis, J M; Gentry, R L; Heath, C B; LeBoeuf, B J; Majluf, P; York, A E (1991) The effects of El Nino on pinniped populations in the eastern Pacific. In: Trillmich, F F; Ono, K A (Editors), Pinnipeds and El Nino: Responses to Environmental Stress. Springer-Verlag, Berlin, 247–270.

Tuck, I; Cole, R; Devine, J A (2009) Ecosystem indicators for New Zealand fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 42. 180 p.

Tuck, I; Pinkerton, M H; Tracey, D; Anderson, O A; Chiswell, S M (2014) Ecosystem and Environmental Indicators for Deepwater Fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 127. 143 p.

Ulanowicz, R E; Puccia, C J (1990) Mixed trophic impacts in ecosystems. Coenoses, 5: 7–16.

Valdes, L; Peterson,W; Church, J; Brander, K; Marcos, M (2009) Our changing oceans: conclusions of the first international symposium on the effects of climate change on the world's oceans. ICES Journal of Marine Science 66: 1435–1438.

van Nes, E H; Scheffer, M (2007) Slow recovery from pertubations as a genetic indicator of a nearby catastrophic shift. American Naturalist 169: 738–747.

Vaquer-Sunyer, R; Duarte, C M (2008) Thresholds of hypoxia for marine biodiversity. Proceedings of the National Academy of the Sciences USA, 105(40): 15452–15457.

Walker, B; Holling, C S; Carpenter, S R; Kinzig, A (2004) Resilience, adaptability and transformability in social–ecological systems. Ecology and Society, 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

Walters, C J; Christensen, V; Martell, S J; Kitchell, J F (2005) Possible ecosystem impacts of applying MSY policies from single-species assessment. ICES Journal of Marine Science, 62: 558–568.

Walters, C J; Kitchell, J F (2001) Cultivation/depensation effects on juvenile survival and recruitment: implications for the theory of fishing. Canadian Journal Fisheries and Aquatic Science. 58:1–12.

Wanless, S (1988) The recolonisation of the Isle of May by common and arctic terns. Scottish Birds 15: 1–8.

Wanless, S; Harris, M P; Calladine, J; Rothery, P (1996) Modelling responses of herring gull and lesser black-backed gull populations to reduction of reproductive output: implications for control measures. Journal of Applied Ecology 33: 1420–1432.

Warwick, R; Clarke, K R (1995) New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. Marine Ecology Progress Series 129: 301–305.

Weijerman, M; Lindeboom, H J; Zuur, A (2005) Regime shifts in marine ecosystems of the North Sea and Wadden Sea. Marine Ecology Progress Series 289: 21–39.

Winder, M; Schindler, D E (2004) Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology 85(8): 2100–2106.

Winters, G H; Wheeler, J P (1994) Length-specific weight as a measure of growth success of adult Atlantic herring (Clupea harengus). Canadian Journal of Fisheries and Aquatic Sciences 51: 1169–1179.

Worm, B; Hilborn, R; Baum, J K; and 18 other co-authors (2009) Rebuilding global fisheries. Science, 325(5940): 578–585.

Worm, B; Myers, R A (2003) Meta-analysis of cod–shrimp interactions reveals top-down control in oceanic food webs. Ecology 84: 162–173.

Zeldis, J; Hadfield, M; Booker, D (2013) Influence of climate on Pelorus Sound mussel aquaculture yields: correlations and underlying mechanisms. Aquaculture Environment Interactions. DOI: 10.3354/aei00066.

Zeldis, J R; Howard-Williams, C; Carter, C M; Schiel, D R (2008) ENSO and riverine control of nutrient loading, phytoplankton biomass and mussel aquaculture yield in Pelorus Sound, New Zealand. Marine Ecology Progress Series 371: 131–142.

12 HABITATS OF PARTICULAR SIGNIFICANCE FOR FISHERIES MANAGEMENT

Scope of chapter	This chapter highlights subject areas that might contribute to the management of HPSFM and hence provides a guide for future research in the absence of an approved policy definition of HPSFM
Area	All of the New Zealand EEZ and territorial sea (inclusive of the freshwater and estuarine areas).
Locality hotspots	None formally defined, but already identified likely candidates include areas of biogenic habitat, e.g. Separation Point and Wairoa Hard, and areas identified with large catches and/or vulnerable populations of juveniles, e.g. Hoki Management Areas, packhorse crayfish legislated closures and toheroa beaches.
Key issues	Defining and identifying likely HPSFM and potential threats to them.
Emerging issues	Connectivity and intra-population behaviour variability, multiple use
MPI Research (current)	Biogenic habitats as areas of particular significance for fisheries management (HAB2007/01), Toheroa abundance (TOH2007/03), Research on Biogenic Habitat-Forming Biota and their functional role in maintaining Biodiversity in the Inshore Region (5-150M Depths) (ZBD2008/01 – this is also part-funded by Oceans Survey 2020, NIWA and MBIE) , Habitats of particular significance for fisheries management: Kaipara Harbour (ENV2009/07), Habitats of particular significance for inshore finfish fisheries management (ENV2010/03) Spatial Mixing of GMU1 using Otolith Microchemistry (GMU2009/01).
NZ Government Research (current)	Ministry of Business, Innovation and Employment (MBIE) funded programmes (Coastal Conservation Management: protecting the functions of marine coastal habitats that support fish assemblages at local, regional and national scales (C01X0907) Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region (C01X1229) and Impacts of resource use on vulnerable deep-sea communities (C01X0906). NIWA Core funding in the 'Managing marine stressors' area under the 'Coasts and Oceans' centre, specifically the programme 'Managing marine resources' and the project 'Measuring mapping and conserving (C01X0505)'
Links to 2030 objectives	Under the Environment Outcome habitats of special significance to fisheries need to be protected.
Related chapters/issues	Land-based impacts on fisheries and supporting biodiversity, bycatch composition, marine environmental monitoring.

Note: No update has been made to this chapter since the AEBAR 2012.

12.1 CONTEXT

The Fisheries Act 1996, in Section 9 (Environmental principles) states that:

"All persons exercising or performing functions, duties, or powers under this Act, in relation to the utilisation of fisheries resources or ensuring sustainability, shall take into account the following environmental principles:

c. *Associated or dependent species should be maintained above a level that ensures their long-term viability:*

d. *Biological diversity of the aquatic environment should be maintained:*

e. ***Habitat of particular significance for fisheries management should be protected."***

No policy definition of habitat of particular significance for fisheries management (HPSFM) exists, although work is currently underway to generate one. Some guidance in terms of defining HPSFM is provided by Fisheries 2030 which specifies as an objective under the Environment Outcome that *"habitats of special significance to fisheries are protected"*. This wording suggests that a specific focus on habitats that are important for fisheries production should be taken rather than a more general focus that might also include other habitats that may be affected by fishing.

Fisheries 2030 re-emphasises that HPSFM should be protected. No specific strategic actions are proposed to implement this protection in Fisheries 2030; although Action 6.1 "To implement a revised MPA policy and legal framework" could potentially be relevant to protecting HPSFM. The management of activities other than fishing, such as land-use and vehicle traffic, are outside the control of the Ministry for Primary Industries but Fisheries 2030 specifies actions to "Improve fisheries sector input to processes that manage RMA-controlled effects on the marine and freshwater environment" (Action 8.1) and to "Promote the development and use of RMA national policy statements, environmental standards, and regional coastal and freshwater plans" (Action 8.2). This suggests that the cooperation of other parties outside of the fisheries sector may be necessary in some cases to protect HPSFM.

In the absence of a policy definition of HPSFM this chapter will focus on examples of habitats shown to be important for fisheries and concepts likely to be important to HPSFM. Examples of potential HPSFM include: sources of larvae; larval settlement sites; habitat for juveniles; habitat that supports important prey species; migration corridors; and spawning, pupping or egg-laying grounds. Some of these habitats may be important for only part of the life cycle of an organism, or for part of a year.

The relative importance of habitats, compared with other limiting factors, is largely unknown for most stocks. For example, some stocks may be primarily habitat limited, whereas others may be limited by oceanographic variability, food supply, predation rates (especially during juvenile phases), or a mixture of these and other factors. In the case of stocks that are habitat limited, a management goal might be to preserve or improve some aspect of the habitat for the stock.

Hundreds of legislated spatial fisheries restrictions already apply within New Zealand's territorial sea and exclusive economic zone (www.nabis.govt.nz), but until further policy work and research is conducted we cannot be sure of what contribution they make to protecting HPSFM. Examples of these are listed below:

- Separation Point in Tasman Bay, and the Wairoa Hard in Hawke Bay, were created to protect biogenic habitat which was believed to be important as juvenile habitat for a variety of fish species (Grange et al 2003).
- An area near North Cape is currently closed to packhorse lobster fishing to mitigate sub-legal handling disturbance in this area. This closure was established because of the small size of lobsters caught there and a tagging study which showed movement away from this area into nearby fished areas (Booth 1979).
- The largest legislated closures are the Benthic Protection Areas (BPAs) which protect about 1.2 million square km (about 31% of the EEZ) outside the territorial sea from contact of trawl and dredge gear with the bottom (Helson et al 2010).
- Commercial fishers must not use New Zealand fishing vessels or foreign-owned New Zealand fishing vessels over 46 m in overall length for trawling in the territorial sea.

In addition to legislated closures, a number of non-regulatory management measures exist. For example:

- Spatial closures:
  - Trawlers greater than 28 m in length are excluded from targeting hoki in four Hoki Management Areas – Cook Strait, Canterbury Banks, Mernoo Bank, and Puysegur Bank (Deep Water Group 2008). These areas were chosen because of the larger number of juveniles caught, relative to adults in these areas.
  - Trawling and pair trawling are both closed around Kapiti Island.
- Seasonal closures
  - A closure to trawling exists from 1st November until 30th April each year in Tasman Bay.
  - A closure to commercial potting exists for all of CRA 3 for the whole of the month of December each year.

The high-level objectives and actions in Fisheries 2030 have been interpreted in the highly migratory, deepwater and middle-depths (deepwater) inshore national fish plans. The highly migratory fish plan addresses HPSFM in environment outcome 8.1 "Identify and where appropriate protect habitats of particular significance to highly migratory species, especially within New Zealand waters". In the deepwater fish plan the Ministry proposes in management objective 2.3 "to develop policy guidelines to determine what constitutes HPSFM then apply these policy guidelines to fisheries where necessary". Inshore fisheries management plans (freshwater, shellfish and finfish) all contain references to identifying and managing HPSFM. These plans recognise that not all impacts stem from fisheries activities, therefore managing them may include trying to influence others to better manage their impacts on HPSFM. Work is underway on a policy definition of HPSFM that will assist in implementing these outcomes and objectives.

12.2 GLOBAL UNDERSTANDING

This section focuses upon those habitats protected overseas for their value to fisheries and discusses important concepts that may help gauge the importance of any particular habitat to fisheries management. This information may guide future research into HPSFM in New Zealand and any subsequent management action.

12.2.1 HABITATS PROTECTED ELSEWHERE FOR FISHERIES MANAGEMENT

Certain habitats have been identified as important for marine species including: shallow sea grass meadows, wetlands, seaweed beds, rivers, estuaries, rhodolith beds, rocky reefs, crevices, boulders, bryozoans, submarine canyons, seamounts, coral reefs, shell beds and shallow bays or inlets (Kamenos et al 2004; Caddy 2008, Clark 1999, Morato et al 2010a). Discrete habitats (or parts of these) may have extremely important ecological functions, and/or be especially vulnerable to degradation. For example, seabeds with high roughness are important for many fisheries and can be easily damaged by interaction with fishing gear (Caddy 2008). Examples of these include:

1. The *Oculina* coral banks off Florida were protected in 1994 as an experimental reserve in response to their perceived importance for reef fish populations (Rosenberg et al 2000). Later studies confirmed that this area is the only spawning aggregation site for gag (*Mycteroperca microlepis*) and scamp (*M. phenax*) (both groper species), and other economically important reef fish in that region (Koenig et al 2000). The size of the area within which bottom-tending gears were restricted was subsequently increased based on these findings (Rosenberg et al 2000).
2. Lophelia cold-water coral reefs are now protected in at least Norway (Fosså et al 2002), Sweden (Lundälv & Jonsson 2003) and the United Kingdom (European Commission 2003) due to their importance as habitat for many species of fish (Costello et al 2005).
3. The Western Pacific Regional Fishery Management Council identified all escarpments between 40 m and 280 m as Habitat Areas of Particular Concern (HAPC) for species in the bottom-fish assemblage. The water column to a depth of 1000 m above all shallow seamounts and banks was categorised as HAPC for pelagic species. Certain northwest Hawaiian Island banks shallower than 30 m were categorised as HAPC for crustaceans, and certain Hawaiian Island banks shallower than 30 m were classified as Essential Fish Habitat (EFH) for precious corals. Fishing is closely regulated in the precious-coral EFH, and harvest is only allowed with highly selective gear types which limit impacts, such as manned and unmanned submersibles (Western Pacific Fisheries Management Council 1998)

Examples of habitats protected for their freshwater fishery values also exist. For example, the U.S. Atlantic States Interstate fishery management plan (Atlantic States Marine Fisheries Commission 2000) notes the Sargasso Sea is important for spawning, and that seaweed harvesting provides a threat of unknown magnitude to eel spawning. Habitat alteration and destruction are also listed as probably impacting on continental shelves and estuaries/rivers, respectively, but the extent to which these are important is unknown.

It is also possible that HPSFM may be defined by the functional importance of an area to the fishery. For example, large spawning aggregations can happen in mid-water for set periods of time (Schumacher & Kendall 1991, Livingston 1990) these could also potentially qualify as HPSFM.

12.2.2 CONCEPTS POTENTIALLY IMPORTANT FOR HPSFM

Many nations are now moving towards formalised habitat classifications for their coastal and ocean waters, which may include fish dynamics in the classifcation, and could potentially help to define HPSFM. Such systems help provide formal definitions for management purposes, and to 'rank' habitats in terms of their relative values and vulnerability to threats. Examples include the Essential Fish Habitat (EFH) framework being advanced in North America (Benaka 1999, Diaz et al 2004, Valavanis et al 2008), and in terms of habitat, the developing NOAA Coastal and Marine Ecological Classification Standard for North America (CMECS) (Madden et al 2005, Keefer et al 2008), and the European Marine Life Information Network (MarLIN) framework which has developed habitat classification and sensitivity definitions and rankings (Hiscock & Tyler-Walters 2006).

Habitat connectivity (the movement of species between habitats) operates across a range of spatial scales, and is a rapidly developing area in the understanding of fisheries stocks. These movements link together different habitats into 'habitat chains', which may also include 'habitat bottlenecks', where one or more spatially restricted habitats may act to constrain overall fish production (Werner et al 1984). Human driven degradation or loss of such bottleneck habitats may strongly reduce the overall productivity of populations, and hence ultimately reduce long-term sustainable fisheries yields. The most widely studied of these links is between juvenile nursery habitats and often spatially distant adult population areas. Most studies published have been focussed on species that use estuaries as juveniles; e.g. blue grouper *Achoerodus viridis* (a large wrasse) (Gillanders & Kingsford 1986) and snapper *Pagrus auratus* (Hamer et al 2005) in Australia; and gag (Mycteroperca Microlepis) in the United States (Ross & Moser 1995) which make unidirectional ontogenetic habitat shifts from estuaries and bays out to the open coast as they grow from juveniles to adults. The extent of wetland habitats in the Gulf of Mexico has also been linked to the yield of fishery species dependent on coastal bays and estuaries. Reduced fishery stock production (of shrimp and the fish menhaden) followed wetland losses and, conversely, stock gains followed increases in the area of wetlands (Turner & Boesch 1987). Juvenile production was limited by the amount of available habitat but, equally, reproduction, larval settlement, juvenile or adult survivorship, or other demographic factors could also be limited by habitat loss or degradation, and these could have knock-on effects to stock characteristics such as productivity and its variability. Other examples include movements which may be bidirectional and regular in nature e.g., seasonal migrations of adult fish to and from spawning and/or feeding grounds, e.g. grey mullet *Mugil cephalus* off Taiwan (Chang et al 2004).

How habitats are spatially configured to each other is also important to fish usage and associated fisheries production. For example, Nagelkerken et al (2001) showed that the presence of mangroves in tropical systems significantly increases species richness and abundance of fish assemblages in adjacent seagrass beds. Jelbart et al (2007) sampled Australian temperate seagrass beds close to (within 200 m) and distant from (more than 500 m from) mangroves. They found seagrass beds closer to mangroves had greater fish densities and diversities than more distant beds, especially of juveniles. Conversely, the densities of fish species in seagrass at low tide that were also found in mangroves at high tide were negatively correlated with the distance of the seagrass bed from the mangroves. This shows the important daily habitat connectivity that exists through tidal movements between mangrove and seagrass habitats. Similar dynamics may occur in more sub-tidal coastal systems at larger spatial and temporal scales. For example, Dorenbosch et al (2005) showed that adult densities of coral reef fish, whose juvenile phases were found in mangrove and seagrass nursery habitats, were much reduced or absent on coral reefs located far distant from such nursery habitats, relative to those in closer proximity.

A less studied, but increasingly recognised theme is the existence of intra-population variability in movement and other behavioural traits. Different behavioural phenotypes within a given population have been shown to be very common in land birds, insects, mammals, and other groups. An example of this is a phenomenon known as 'partial migration', where part of the overall population migrates each year, often over very large distances, while another component does not move and remains resident. By definition, this partial migration also results in differential use of habitats, often over large spatial scales. Recent work on white perch (*Morone americana*) in the United States shows that this population is made up of two behavioural components: a resident natal freshwater contingent; and a dispersive brackish-water contingent

(Kerr et al 2010). The divergence appears to be a response to early life history experiences which influence individuals' growth (Kerr 2008). The proportion of the overall population that becomes dispersive for a given year class ranges from 0% in drought years to 96% in high-flow years. Modelling of how differences in growth rates and recruitment strengths of each component contributed to the overall population found that the resident component contributed to long-term population persistence (stability), whereas the dispersive component contributed to population productivity and resilience (defined as rebuilding capacity) (Kerr et al 2010). Another species, winter flounder *Pseudopleuronectes americanus*, has also shown intra-population variability in spawning migrations; one group stays coastally resident while a second smaller group migrates into estuaries to spawn (DeCelles & Cadrin 2010). The authors went on to suggest that coastal waters in the Gulf of Maine should merit consideration in the assignment of Essential Fish Habitat for this species.

Kerr & Secor (2009) and Kerr et al (2010) argue that such phenotypic dynamics are probably very common in marine fish populations but have not yet been effectively researched and quantified. The existence of such dynamics would have important implications for fisheries management, including the possibility of spatial depletions of more resident forms and variability in the use of potential HPSFM between years. For instance, recent work on snapper in the Hauraki Gulf has shown that fish on reef habitats are more resident (ie have less propensity to migrate) than those of soft sediment habitats, and can experience higher fishing removals (Parsons et al 2011).

The most effective means of protecting a HPSFM in terms of the benefit to the fishery may differ depending on the life-history characteristics of the fish. A variety of modelling, theoretical, and observational approaches have led to the conclusion that spatial protection performs best at enhancing species whose adults are relatively sedentary but whose larvae are broadcast widely (Chiappone & Sealey 2000, Murawski et al 2000, Roberts 2000, Warner et al 2000). The sedentary habit of adults allows the stock to accrue the maximum benefit from the protection, whereas the broadcasting of larvae helps 'seed' segments of the population outside the protection. However, the role of spatial protection in directly protecting juveniles after they have settled to seafloor habitats (via habitat protection/recovery, and/or reduced juvenile bycatch), or their interaction with non-fisheries impacts has not yet been explicitly considered.

12.3 STATE OF KNOWLEDGE IN NEW ZEALAND

12.3.1 POTENTIAL HPSFM IN NEW ZEALAND

Important areas for spawning, pupping, and egg-laying are potential HPSFM. These areas (insofar as these are known) have been identified and described using science literature and fisheries databases and summarised within two atlases, one coastal (less than 200 m) and one deepwater (more than 200 m). Coastally, these HPSFM areas were identified for 35 important fish species by Hurst et al (2000b). This report concluded that virtually all coastal areas were important for these functions for one species or another. The report also noted that some coastal species use deeper areas for these functions, either as juveniles, or to spawn (e.g., red cod, giant stargazer) and some coastal areas are important for juveniles of deeper spawning species (e.g., hake and ling). Some species groupings were apparent from this analysis. Elephant fish, rig, and school shark all preferred to pup or lay eggs in shallow water, and very young juveniles of these species were found in shallow coastal areas. Juvenile barracouta, jack mackerel (*Trachurus novaezelandiae*), kahawai, rig, and snapper were all relatively abundant (at least occasionally) in the inner Hauraki Gulf. Important areas for spawning, pupping, and egg-laying were identified for 32 important deepwater fish species (200 to 1500 m depth), 4 pelagic fish species, 45 invertebrate groups, and 5 seaweeds (O'Driscoll et al 2003). This study concluded that all areas to 1500 m deep were important for either spawning or for juveniles of one or more species studied. The relative significance of areas was hard to gauge because of the variability in the data, however the Chatham Rise was identified as a "hotspot".

Areas of high juvenile abundances of certain species may be useful indicators of HPSFM for some species. A third atlas (Hurst et al 2000b) details species distributions (mainly commercial) of adult and immature stages from trawl, midwater trawl and tuna longline where adequate size information was collected. No conclusions are made in this document, and generalisations across species are inherently difficult, therefore like the previous two atlases, this document is probably best examined for potential HPSFM in a species specific way.

Certain locations within New Zealand already seem likely to qualify as HPSFM under any likely definition. The Kaipara Harbour has been identified as particularly important for the SNA 8 stock. Analysis of otolith chemistry showed that, for the 2003 year-class, a very high proportion of new snapper recruits to the SNA 8 stock were sourced as juveniles from the Kaipara Harbour (Morrison et al 2008). This result is likely to be broadly applicable into the future as the Kaipara provides most of the biogenic habitat available for juvenile snapper on this coast. The Kaipara and Raglan harbours also showed large catches of juvenile rig and the Waitemata, Tamaki and Porirua harbours moderate catches (Francis et al 2012). Recent extensive fish-habitat sampling within the Kaipara harbour in 2010 as part of the MBIE Coastal Conservation Management programme showed juvenile snapper to be strongly associated with sub-tidal seagrass, horse mussels, sponges, and an introduced bryozoan. Negative impacts on such habitats have the potential to have far-field effects in terms of subsequent fisheries yields from coastal locations well distant from the Kaipara Harbour. Beaches that still retain substantive toheroa populations, e.g. Dargaville and Oreti beaches, may also potentially qualify as HPSFM (Beentjes 2010).

Consistent with the international literature, biogenic (living, habitat forming) habitats have been found to be particularly important juvenile habitat for some coastal fish species in New Zealand. For example: bryozoan mounds in Tasman Bay are known nursery grounds for snapper, tarakihi and john dory (Vooren 1975); northern subtidal seagrass meadows fulfil the same role for a range of fish including snapper, trevally, parore, garfish and spotties (Francis et al 2005, Morrison et al 2008, Schwarz et al 2006, Vooren 1975); northern horse mussel beds for snapper and trevally (Morrison et al 2009); and mangrove forests for grey mullet, short-finned eels, and parore (Morrisey et al 2010). Many other types of biogenic habitats exist, and some of their locations are known (e.g. see Davidson et al 2010 for biogenic habitats in the Marlborough Sounds), but their precise role as HPSFM remains to be quantified. Examples include open coast bryozoan fields, rhodoliths, polychaete (worm) species ranging in collective form from low swathes to large high mounds, sea pens and sea whips, sponges, hydroids, gorgonians, and many forms of algae, ranging from low benthic forms such as Caulerpa spp. (sea rimu) through to giant kelp (*Macrocystis pyrifera*) forests in cooler southern waters. Similarly, seamounts are well-known to host reef-like formations of deep-sea stony corals (e.g., Tracey et al 2011), as well as being major spawning or feeding areas for commercial deepwater species such as orange roughy and oreos (e.g., Clark 1999, O'Driscoll & Clark 2005). However, the role of these benthic communities on seamounts in supporting fish stocks is uncertain, as spawning aggregations continue to form even if the coral habitat is removed by trawling (Clark & Dunn 2012). Hence the oceanography or physical characteristics of the seamount and water column may be the key drivers of spawning or early life-history stage development, rather than the biogenic habitat.

Freshwater eels are reliant upon rivers as well as coastal and oceanic environments. GIS modelling estimates that for longfin eels, about 30% of longfin habitat in the North Island and 34% in the South Island is either in a reserve or in rarely/non-fished areas, with about 49% of the national longfin stock estimate of about 12 000 tonnes being contained in these waterways (Graynoth et al 2008). More regional examination of the situation for eels also exists, e.g., for the Waikato Catchment (Allen 2010). Shortfin eels prefer slower-flowing coastal habitats such as lagoons, estuaries, and lower reaches of rims (Beentjes et al 2005). In-stream cover (such as logs and debris) has been identified as important habitat, particularly in terms of influencing the survival of large juvenile eels (Graynoth et al 2008). Short-fin eel juveniles and adults have also been found to be relatively common in estuarine mangrove forests, and their abundance positively correlated with structural complexity (seedlings, saplings, and tree densities) (Morrisey et al 2010). In addition oceanic spawning locations are clearly important for eels, the location of these are unknown, although it has been suggested that these may be northeast of Samoa and east of Tonga for shortfins and longfins respectively (Jellyman 1994).

Many of the potential HPSFM are threatened by either fisheries or land-based effects, the reader should look to the land-based effects chapter in this document and the eel section of the Stock assessment plenary report for further details.

12.3.2 HABITAT CLASSIFICATION AND PREDICTION OF BIOLOGICAL CHARACTERISTICS

Habitat classification schemes focused upon biodiversity protection have been developed in New Zealand at both national and regional scales, these may help identify larger habitats which HPSFM may be selected from, but are unlikely to be useful in isolation for determining HPSFM. The Marine Environment Classification (MEC), the demersal fish MEC and the benthic optimised MEC (BOMEC) are national scale classification schemes that have been developed with the goal of aiding biodiversity protection (Leathwick et al 2004, 2006, 2012). A classification scheme also exists for New Zealand's rivers and streams based on their biodiversity values to support the Department of Conservations Waters of National Importance (WONI) project (Leathwick & Julian 2008). Regional classification schemes also exist such as ones mapping the Marine habitats of Northland, or Canterbury in order to assist in Marine Protected Area planning (Benn 2009; Kerr 2010).

Another tool which may help in terms of identifying HPSFM is the predictions of richness, occurrence and abundance of small fish in New Zealand estuaries (Francis et al 2011). This paper contains richness predictions for 380 estuaries and occurrence predictions for 16 species. This could help minimise the need to undertake expensive field surveys to inform resource management, although environmental sampling may still be needed to drive some models.

12.3.3 CURRENT RESEARCH

Prior to 2007 research within New Zealand was not explicitly focused on identifying HPSFM. However, in line with international trends, this situation has changed in recent times, with recognition of some of the wider aspects of fisheries management and the move towards an ecosystem approach foreshadowed in Fisheries 2030.

A number of Ministry and other research projects were commissioned concerning HPSFM in the 2010/11 year. Project ENV200907, "Habitat of particular significance to fisheries management: Kaipara Harbour", is underway and has the overall objective of identifying and mapping areas and habitats of particular significance in the Kaipara Harbour which support coastal fisheries; and identifying and assessing threats to these habitats. Included in this work is the reconstruction of environmental histories through interviews of long time local residents who have experience of the harbour, and associated collation and integration of historical data sources (e.g., catch records, photographs, diaries, maps, and fishing logs). Another output of this work will be recommendations on the best habitats and methods of monitoring to detect change to HPSFM within Kaipara harbour.

Biogenic habitats on the continental shelf from about 5 to 150 m depths are currently being characterised and mapped through the biodiversity project ZBD2008/01, this will also provide new information on fisheries species utilisation of these habitats. Interviews with 50 retired fishers have provided valuable information on biogenic habitat around New Zealand. A national survey to examine the present occurrences and extents of these biogenic habitats was completed in 2011 in collaboration with Oceans Survey 2020, NIWA and Ministry of Business, Innovation and Employment (MBIE) funding.

A number of other national scale projects are also underway. A desktop review is collating information on the importance of biogenic habitats to fisheries across the entire Territorial Sea and Exclusive Economic Zone (project HAB2007/01). A project has been approved to review the literature and recommend the relative urgency of research on habitats of particular significance for inshore finfish species (project ENV2010/03).

The Ministry of Business, Innovation and Employment (MBIE) funded project Coastal Conservation Management started in 2009 and runs for six years. This programme aims to integrate and add to existing fish-habitat association work to develop a national scale marine fish-habitat classification and predictive model framework. This project will also attempt to develop threat assessments at local, regional and national scales. MPI is maximising the synergies between its planned research and this project. As part of this synergy, work on the connectivity and stock structure of grey mullet (Mugil cephalus) is underway in collaboration with MPI project GMU2009/01. Otolith chemistry is being assessed for its utility in partitioning the GMU 1 stock into more biologically meaningful management units, and in quantifying the suspected existence of source and sink dynamics between the various estuaries that hold juvenile grey mullet nursery habitats.

In 2012 MBIE also funded the three year project delivered by NIWA entitled "Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region". The development of predictive models of species occurrence under this project may also aid in identifying HPSFM. Identification of biogenic habitat has been part of the MBIE project "Vulnerable deep-sea communities" since 2009 (and its predecessor seamount programme) which includes surveys of a range of habitats that may be important for various life-history stages of commercial fish species: seamounts, canyons, continental slope, hydrothermal vents and seeps.

12.4 INDICATORS AND TRENDS

As no HPSFM are defined this section cannot be completed.

12.5 REFERENCES

Allen, D (2010) Eels in the Waikato Catchment. Client report prepared for Mighty River Power Ltd. 105 p.

Allen, M; Rosell, R; Evans, D (2006) Predicting catches for the Lough Neagh (Northern Ireland) eel fishery based on stock inputs, effort and environmental variables. Fisheries Management and Ecology (13): 251–260.

Atlantic States Marine Fisheries Commission (2000) Interstate Fishery Management Plan for American Eel. Fishery Management Report No. 36 of the Atlantic States Marine Fisheries Commission. 93 p.

Benaka, L (Ed.) (1999) Fish habitat: essential fish habitat and rehabilitation, American Fisheries Society, Bethesda, MD. 45 p.

Beentjes, M (2010) Toheroa survey of Oreti Beach, 2009, and review of historical surveys. New Zealand Fisheries Assessment Report 2010/6. 40 p.

Beentjes, M; Boubée, J; Jellyman, J.D; Graynoth, E (2005) Non-fishing mortality of freshwater eels (Anguilla spp.). New Zealand Fisheries Assessment Report 2005/34. 38 p.

Benn, L (2009) Marine Protected Areas (MPA): Habitat Maps for Canterbury. Internal Report for the Canterbury Conservancy.

Booth, J (1979) North Cape - a 'nursery area' for the packhorse rock lobster, *Jasus verreauxi* (*Deeapoda: Palinuridae*). New Zealand journal of Marine & Freshwater Research (13): 521–528.

Caddy, J F (2008) The importance of "Cover" in the life histories of demersal and benthic marine resources: A neglected issue in fisheries assessment and management. Bulletin of Marine Science (83): 7–52.

Chang, C; Iizyuka, Y; Tzeng, W (2004) Migratory environmental history of the grey mullet *Mugil cephalus* as revealed by otolith Sr:Ca ratios. Marine Ecology Progress Series. 269: 277–288.

Chiappone, M; Sealey, K M S (2000) Marine reserve design criteria and measures of success: Lessons learned from the Exuma Cays Land and Sea Park, Bahamas. Bulletin of Marine Science (66): 691–705.

Clark, M R (1999) Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. Oceanologica Acta 22: 593–602.

Clark, M R; Dunn, M R (2012) Spatial management of deep-sea seamount fisheries: balancing exploitation and habitat conservation. Environmental Conservation 39(2): doi:10.1017/S0376892912000021

Clark, M R; Rowden, A A (2009) Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. Deep Sea Research I 56: 1540–1554.

Costello, M; McCrea, M; Freiwald, A; Lundälv, T; Jonsson, L; Bett, B; van Weering, T; de Haas, H; Roberts, J; Allen, D (2005) Role of cold-water *Lophelia pertusa* coral reefs as fish habitat in the NE Atlantic. In: Freiwald, A., JM, R. (Eds.), Cold-water Corals and Ecosystems. Springer-Verlag Berlin pp 771–805.

Davidson, R; Richards, L; Duffy, C; Kerr, V; Freeman, D; D'Archino, R; Read, G; Abel, W (2010) Location and biological attributes of biogenic habitats located on soft substrata in the Marlborough Sounds. Prepared by Davidson Environmental Ltd. for Department of Conservation and Marlborough District Council. Survey and monitoring report no. 575.

De Celles, G R; Cadrin, S X (2010) Movement patterns of winter flounder (*Pseudopleuronectes americanus*) in the southern Gulf of Maine: observations with the use of passive acoustic telemetry. Fisheries Bulletin 108:408-419.

Diaz, R; Solan, M; Valente, R (2004) A review of approaches for classifying benthic habitats and evaluating habitat quality. Journal of Environmental Management 73: 165–181.

Deep Water Group (2008) Operational Procedures: Hoki Fishery. 27 p.

Dorenbosch, M; Grol, M; Christianen, M; Nagelkerken, I; van der Velde, G (2005) Indo-Pacific seagrass beds and mangroves contribute to fish density coral and diversity on adjacent reefs. Marine Ecology Progress Series. 302: 63–76.

Ellingsen, K; Hewitt, J; Thrush, S (2007) Rare species, habitat diversity and functional redundancy in marine benthos. Journal of Sea Research 58: 291–301.

European Commission (2003) Commission Regulation (EC) No 1475/2003 of 20 August 2003 on the protection of deep-water coral reefs from the effects of trawling in an area north west of Scotland. Official Journal L 211, 14–15.

Fosså, J; Mortensen, P; Furevik, D (2002) The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fisheries impacts. Hydrobiologia 471, 1–12.

Francis, R I C C; Hadfield, M G; Bradford-Grieve, J M; Renwick, J A; Sutton, P J H (2005) Environmental predictors of hoki year-class strengths: an update. New Zealand Fisheries Assessment Report 2005/58. 22 p.

Francis, M; Lyon, W; Jones, E; Notman, P; Parkinson, D; Getzlaff, C (2012) Rig nursery grounds in New Zealand: a review and survey, New Zealand Aquatic Environment and Biodiversity Report No. 95.

Francis, M; Morrison, M; Leathwick, J; Walsh, C (2011) Predicting patterns of richness, occurrence and abundance of small fish in New Zealand estuaries. Marine and Freshwater Research 62, 1327–1341.

Gillanders, B; Kingsford, M (1986) Elements in otoliths may elucidate the contribution of estuarine recruitment to sustaining coastal reef populations of a temperate reef fish. Marine Ecology Progress Series 141: 13–20.

Grange, K; Tovey, A; Hill, A F (2003) The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay. Marine Biodiversity Biosecurity Report No. 4. 22 p.

Graynoth, E; Francis, R; Jellyman, D (2008) Factors influencing juvenile eel (Anguilla spp.) survival in lowland New Zealand streams. New Zealand Journal of Marine and Freshwater Research (42): 153–172.

Hall-Spencer, J; Kelly, J; Maggs, C (2008) Assessment of maerl beds in the OSPAR area and the development of a monitoring program. Department of Environment, Heritage and Local Government: Ireland.

Hamer, P; Jenkins, G; Gillanders, B (2005) Chemical tags in otoliths indicate the importance of local and distant settlement areas to populations of a temperate sparid, *Pagrus auratus*. Canadian Journal of Fisheries and Aquatic Sciences. 62: 623–630.

Haro, A; Richkus, W; Whalen, K; Hoar, A; Busch, W D; Lary, S; Brush, T; Dixon, D (2000) Population decline of the American eel: Implications for research and management. Fisheries (25): 7–16.

Helson, J; Leslie, S; Clement, G; Wells, R; Wood, R (2010) Private rights, public benefits: Industry-driven seabed protection. Marine Policy (34): 557–566.

Hewitt, J E; Thrush, S F; Halliday, J; Duffy, C (2005) The importance of small-scale habitat structure for maintaining beta diversity. Ecology (86): 1619–1626.

Hiscock, K; Tyler-Walters, H (2006) Assessing the seabed species and biotopes- the Marine Life Information Network (MarLIN). Hydrobiologica. 555: 309–320.

Hurst, R; Bagley, N; Anderson, O; Francis, M; Griggs, L; Clark, M; Paul, L; Taylor, P (2000a) Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. NIWA Technical Report No. 84. 11 p.

Hurst, R; Stevenson, M; Bagley, N; Griggs, L; Morrison, M; Francis, M (2000b) Areas of importance for spawning, pupping or egg-laying and juveniles of New Zealand coastal fish. Final Research Report for Ministry of Fisheries Research Project ENV1999/03 Objective 1. 56.

Inland Fisheries Service Tasmania (2009) Tasmanian Freshwater Eel Fishery: Application to the Department of the Environment, Water, Heritage and Arts for the re-assessment of the Tasmanian Freshwater Eel Fishery. 22 p.

Jelbart, J; Ross, P; Connolly, R (2007) Fish assemblages in seagrass beds are influenced by the proximity of mangrove forests. Marine Biology 150: 993–1002.

Jellyman, D (1994) The fishery for freshwater eels (Anguilla spp.) in New Zealand. New Zealand Fisheries Assessment Research Document 94/14. 25 p. (Unpublished report held in NIWA library, Wellington.

Kamenos, N; Moore, P; Hall-Spencer, J (2004) Small-scale distribution of juvenile gadoids in shallow inshore waters; what role does maerl play? ICES Journal of Marine Science 61:422–429.

Keefer, M; Peery, C; Wright, N; Daigle, W; Caudill, C; Clabough, T; Griffith, D; Zacharias, M (2008) Evaluating the NOAA Coastal and Marine Ecological Classification Standard in estuarine systems: A Columbia River Estuary case study. Estuarine, Coastal and Shelf Science. 78: 89–106.

Kerr, L (2008) Cause, consequence, and prevalence of spatial structure of white perch (*Morone americana*) populations in the Chesapeake Bay. Dissertation. University of Maryland, College Park, Maryland, USA.

Kerr, L; Secor, D (2009) Bioenergetic trajectories underlying partial migration in Patuxent River (Chesapeake Bay) white perch *Morone americana*. Canadian Journal of Fisheries and Aquatic Sciences 66:602–612.

Kerr, L A; Cadrin, S X; Secor, D H (2010) The role of spatial dynamics in the stability, resilience, and productivity of an estuarine fish population. Ecological Applications (20): 497–507.

Kerr, V (2010) Marine habitat map of Northland: mangawhai to Ahipara (vers 1). Department of Conservation.

Koenig, C; Coleman, F; Grimes, C; FitzHugh, G; Scanlon, K; Gledhill, C; Grace, M (2000) Protection of fish spawning habitat for the conservation of warm-temperate reef-fish fisheries of shelf-edge reefs of Florida. Bulletin of Marine Science (66): 593–616.

Leathwick, J; Image, K; Snelder, T; Weatherhead, M; Wild, M (2004) Definition and tests of the Marine Environment Classifications of New Zealand's Exclusive Economic Zone and the Hauraki Gulf. NIWA Client Report CHC2004-085. 64 p.

Leathwick, J R; Dey, K; Julian, K (2006) Development of a demersal fish community classification for New Zealands Exclusive Economic Zone. NIWA Client report HAM 2006/062 Prepared for the Department of Conservation. 35 p.

Leathwick, J R; Julian, K (2008) Updated conservation rankings for New Zealand's rivers and streams NIWA Report for Department of Conservation. 39.

Leathwick, J; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S; Hadfield, M; Currie, K; Goh, A (2012) Benthic optimised marine environment classification for New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 89. 52 p.

Livingston, M (1990) Spawning hoki (*Macruronus novaezelandiae* Hector) concentrations in Cook Strait and off the east coast of the South Island, New Zealand, August-September 1987. New Zealand Journal of Marine and Freshwater Research (24): 503–517.

Lundälv, T; Jonsson, L (2003) Mapping of deep-water corals and fishery impacts in the north-east Skagerrak, using acoustical and ROV survey techniques. Proceedings 6th Underwater Science Symposium, Aberdeen, April 2003.

Madden, C; Grossman, D; Goodin, K (2005) Coastal and marine ecosystems of North America; framework for an ecological classification standard: Version II. NatureServe, Virginia, Arlington. 48 p.

Morato, T; Hoyle, S D; Allain, V; Nicol, S J (2010a) Seamounts are hotspots of pelagic biodiversity in the open ocean. Proceedings of the National Academy of Science U S A, 107: 9707–9711. doi:10.1073/pnas.0910290107

Morato, T; Hoyle, S D; Allain, V; Nicol, S J (2010b) Tuna longline fishing around West and Central Pacific seamounts. PloS ONE 5(12): e14453. doi:10.1371/journal.pone.0014453

Morrisey, D; Swales, A; Dittmann, S; Morrison, M; Lovelock, C; Beard, C (2010) The ecology and management of temperate mangroves. Oceanography and Marine Biology 48: 43–160.

Morrison, M; Jones, E; Consalvey, M; Berkenbusch, K (2008) Biogenic habitats and their value to New Zealand fisheries. Water & Atmosphere (16): 20–21.

Morrison, M; Lowe, M; Parsons, D; Usmar, N; McLeod, I (2009) A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 37. 100 p.

Murawski, S A; Brown, R; Lai, H L; Rago, P J; Hendrickson, L (2000) Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges Bank experience. Bulletin of Marine Science (66): 775–798.

Nagelkerken, I; Kleijnen, S; Klop, T; van den Brand, R; de la Moriniere, E; van der Velde, G (2001) Dependence of Caribbean reef fishes on mangroves and seagrass beds as nursery habitats: a comparison of fish faunas between bays with and without mangroves/seagrass beds. Marine Ecology Progress Series 214: 225–235.

North Pacific Fishery Management Council (1998) Omnibus essential fish habitat amendments for groundfish in the Bering Sea, Aleutian Islands, and Gulf of Alaska, king and tanner crab in the Bering Sea and Aleutian Islands, Alaska scallop, and Alaska salmon fishery management plans. North Pacific Fishery Management Council , Alaska.

O'Driscoll, R; Booth, J; Bagley, N; Anderson, O; Griggs, L; Stevenson, M; Francis, M (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. NIWA Technical Report 119. 377 p.

O'Driscoll, R L; Clark, M R (2005) Quantifying the relative intensity of fishing on New Zealand seamounts. New Zealand Journal of Marine and Freshwater Research 39: 839–850.

Parsons, D; Morrison, M; McKenzie, J; Hartill, B; Bian, R; Francis, R I C C (2011) A fisheries perspective of behavioural variability: differences in movement behavior and extraction rate of an exploited sparid, snapper (*Pagrus auratus*). Canadian Journal of Fisheries and Aquatic Sciences. 68: 632–642.

Roberts, C M (2000) Selecting marine reserve locations: Optimality versus opportunism. Bulletin of Marine Science (66): 581–592.

Rosenberg, A; Bigford, T; Leathery, S; Hill, R; Bickers, K (2000) Ecosystem approach to fishery management through essential fish habitat. Bulletin of Marine Science (66): 535–542.

Ross, S; Moser, M (1995) Life-history of juvenile gag, *Mycteroperca-microlepsis*, in North-Carolina estuaries. Bulletin of Marine Science. 56: 222–237.

Schumacher, J D; Kendall, A W (1991) Some interactions between young walleye Pollock and their environment in the western gulf of Alaska. California Cooperative Oceanic Fisheries Investigations Reports (32): 22–40.

Schwarz, A-M; Morrison, M; Hawes, I; Halliday, J (2006) Physical and biological characteristics of a rare marine habitat: subtidal seagrass beds of offshore islands. Science for Conservation 269. 30 p.

Thrush, S F; Gray, J S; Hewitt, J E; Ugland, K I (2006) Predicting the effects of habitat homogenization on marine biodiversity. Ecological Applications (16): 1636–1642.

Tracey, D M; Rowden, A A; Mackay, K A; Compton, T (2011) Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. Marine Ecology Progress Series 430: 1–22.

Turner, G E; Boesch, D (1987) Aquatic animal production and wetland relationships: insights gleaned following wetland loss or gain.

pp 25–39 In: Hooks, D (Ed.) Ecology and management of wetlands. Croon Helms, Ltd., Beckenham, Kent, U.K.

Turner, S; Schwarz, A-M (2006) Management and conservation of seagrass in New Zealand: an introduction. Science for Conservation 264: 90 p.

Valavanis, V D; Pierce, G J; Zuur, A F; Palialexis, Saveliev, A; Katara, I; Wang, J (2008) Modelling of essential fish habitat based on remote sensing, spatial analysis and GIS. Hydrobiologia 612: 5-20.

Anatoly Saveliev Æ Isidora Katara Æ Jianjun Wang Vooren, C (1975) Nursery grounds of tarakihi (*Teleostei: Cheilodactylidae*) around New Zealand. New Zealand Journal of Marine and Freshwater Research (9): 121–158.

Warner, R R; Swearer, S E; Caselle, J E (2000) Larval accumulation and retention: Implications for the design of marine reserves and essential fish habitat. Bulletin of Marine Science (66): 821–830.

Werner, E E; Hall, D J (1988) Ontogenetic habitat shifts in bluegill: the foraging rate-predation risk trade-off. Ecology 69 (5): 1352–1366.

Western Pacific Regional Fishery Management Council (1998) Magnuson-Stevens Act definitions and required provisions. Western Pacific Regional Fishery Management Council, Hawaii.

13 LAND-BASED EFFECTS ON FISHERIES, AQUACULTURE AND SUPPORTING BIODIVERSITY

Scope of chapter	This chapter outlines the main known threats from land-based activities to fisheries, aquaculture and supporting biodiversity. It also describes the present status and trends in land-based impacts.
Area	All of the New Zealand freshwater, EEZ and territorial sea.
Focal localities	Freshwater habitats and areas closest to the coast are likely to be most impacted; this will be exacerbated in areas with low water movement. Anthropogenically increased sediment run-off is particularly high from the Waiapu and Waipaoa river catchments on the east coast of the North Island. Areas of intense urbanisation or agricultural use of catchments are also likely to be impacted by bacteria, viruses, heavy metals or nutrients, or some combination of these.
Key issues	Habitat modification, sedimentation, aquaculture, shellfish, terrestrial land-use change (particularly for urbanisation, forestry or agriculture) water quality and quantity, contamination, consequences to seafood production of increased pollutants, freshwater management and demand.
Emerging issues	Impacts on habitats of particular significance to fisheries management (HPSFM), linkages through rainfall patterns to climate change, shellfish bed closures, habitat remediation, domestic animal diseases in protected marine species, proposed aquaculture expansion, water abstraction impacts.
MPI Research (current)	Research on Biogenic Habitat-Forming Biota and their functional role in maintaining Biodiversity in the Inshore Region, 5–150m depths (ZBD2008/01 – this is also part-funded by Oceans Survey 2020, NIWA and MBIE).
NZ Government Research (current)	NZ Government Research (current) Ministry of Business, Innovation and Employment (MBIE) funded programmes: After the outfall: recovery from eutrophication in degraded New Zealand estuaries (UOCX0902) and "Management of Cumulative Effects of Stressors in Aquatic Ecosystems" (CO1X1005). NIWA core-funded research on this topic occurs in two areas. Firstly, the "Managing marine ecosystems" programme, specifically the projects "Measuring mapping and conserving", "Ecosystem-based management of coasts and estuaries", "Coastal management" (C01X0907) and "Marine Futures" (C01X0227) (Note that the latter two finish 30 September 2014). Secondly, in the "Fisheries" Centre, the EAFM programme deals with ecosytem-based management approaches in conjunction with the "Coasts and Oceans" centre. Some funding within these areas will be aligned to the Sustainable Seas Science Challenge in the near future in which the focus is on ecosystem based management of the marine environment.
Links to 2030 objectives	Objective 8: Improve Fisheries/RMA interface. Objective 4: Support aquaculture development
Related chapters/issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring.

Note: This chapter has been updated for the AEBAR 2014.

13.1 CONTEXT

Land-based activities that may have impacts on seafood production are primarily regulated under the Resource Management Act 1991 (and subsequent amendments). Fisheries are controlled under the Fisheries Act 1996, this includes marine and freshwater responsibilities regarding aquatic life (under Part 2 of the Fisheries Act). Fisheries 2030 is a long-term policy strategy and direction paper of the Ministry for Primary Industries. It was released in 2009 and states that improving the Fisheries/Resource

Management Act interface is a priority (objective 8). Strategic actions to achieve this priority are listed as:

> 8.1 Improve fisheries sector input to processes that manage RMA-controlled effects on the marine and freshwater environment.
>
> 8.2 Promote the development and use of RMA national policy statements, environmental standards, and regional coastal and freshwater plans.

The Government's 'Fresh Start for Freshwater Programme[73]' (led by MfE and MPI) aims to create a water management system that allows us to make more transparent and better targeted and informed decisions on fresh water. Businesses and water users will have more certainty so that they can plan and invest. All New Zealanders will have a greater say on the water quality they want for their lakes and rivers. The Coastal Policy Statement (2010) also has relevance to matters of fisheries interest, e.g. Policy 20(1) (paraphrased) controls the use of vehicles on beaches where (b) harm to shellfish beds may result. MPI also works with other agencies, principally DOC, MfE and regional councils and through the Natural Resource Cluster to influence these processes to ensure consideration of land-based impacts upon seafood production. The New Zealand aquaculture industry has an objective of developing into a billion dollar industry by 2025[74]. Government supports well-planned and sustainable aquaculture through its *Aquaculture Strategy and Five-year Plan*. One of the desired outcomes of actions by the New Zealand Government is to enable more space to be made available for aquaculture. This outcome is likely to heighten the potential for conflict between aquaculture proponents and those creating negative land-based effects.

A MPI funded survey of scientific experts (MacDiarmid et al 2012) addressed the vulnerability to a number of threats of marine habitat types within the New Zealand's Territorial Sea and Exclusive Economic Zone (EEZ). Each vulnerability score was based on an assessment of five factors including the spatial scale, frequency and functional impact of the threat in the given habitat as well as the susceptibility of the habitat to the threat and the recovery time of the habitat following disturbance from that threat. The study found that the number of threats and their severity were generally considered to decrease with depth, particularly below 50 m. Reef, sand, and mud habitats in harbours and estuaries and along sheltered and exposed coasts were considered to be the most highly threatened habitats. The study also reported that over half of the twenty-six top threats fully, or in part, stemmed from human activities external to the marine environment itself. The top six threats in order were:

1.	ocean acidification,
2.	rising sea temperatures resulting from global climate change,
3rd equal.	bottom trawling fishing,
3rd equal.	increased sediment loadings from river inputs
5th equal.	change in currents from climate change
5th equal.	increased storminess from climate change

The reader is guided to MacDiarmid et al (2012) for more detail including tables of threats-by-habitat and habitats-by-threat. Climate change and ocean acidification, although they can be considered land-based effects, are covered under the Chapters in this document called "New Zealand Regional climate and oceanic setting" and "Biodiversity".

Land-based effects on seafood production and biodiversity in this context are defined as resulting either from the inputs of contaminants from terrestrial sources or through engineering structures (e.g., breakwaters, causeways, bridges), that change the nature and characteristics of coastal habitats and modify hydrodynamics. The major route for entry of land-based contaminants into the marine environment is associated with freshwater flows (rivers, streams, direct runoff and ground water), although contaminants may enter the marine environment via direct inputs (e.g., landslides) or atmospheric transport processes.

The most important land-based effect in New Zealand is arguably increased sediment deposition around our coasts (Morrison et al 2009; MacDiarmid et al 2012). This deposition has been accelerated due to increased erosion from land-use, which causes gully and channel erosion and landslides (Glade 2003). Inputs of sediments to our coastal zone, although naturally high in places due to our high rainfall and rates of tectonic uplift (Carter 1975), have been accelerated by human activities (Goff 1997).

[73] http://www.mfe.govt.nz/issues/water/freshwater/fresh-start-for-fresh-water/
[74] http://aquaculture.org.nz/about-us/strategy/

Sediment inputs are now high by world standards and make up about 1% of the estimated global detrital input to the oceans (Carter et al 1996). By contrast New Zealand represents only about 0.3% of the land area that drains into the oceans (Griffiths & Glasby 1985, Milliman & Syvitski 1992).

Different land use effects act over different scales; for example localised effects act on small streams and adjacent estuarine habitats, large scale effects extend to coastal embayments and shelf ecosystems. Associated risks will vary according to location and depend on the relevant ecosystem services (e.g. high value commercial fishery stocks) and their perceived sensitivities. The risk from stormwater pollutants will be more important near urban areas and the effects of nutrient enrichment will be more important near intensively farmed rural areas.

The risk from land-based impacts for seafood production is that they will limit the productivity of a stock or stocks. For example, the bryozoan beds around Separation Point in Golden Bay, were protected from fishing in 1980, partly because of their perceived role as nursery grounds for a variety of coastal fish species (Grange et al 2003). Recent work has suggested that the main threat to these bryozoans is now sedimentation from the Motueka River, which may inhibit recovery of any damaged bryozoans (Grange et al 2003, Morrison et al 2009). Any declines in this bryozoan bed and associated ecological communities could also affect the productivity of adjacent fishery stocks.

MPI mainly manages in the marine environment, therefore this topic area will be dealt with first. The main freshwater fisheries management MPI is involved in is the freshwater eel fishery; this will be dealt in later sections, as relevant.

13.2 GLOBAL UNDERSTANDING

13.2.1 LAND-BASED INFLUENCES

It has been acknowledged for some time now that land-based activities can have important effects on seafood production. The main threats to the quality and use of the world's oceans are (GESAMP 2001):

- alteration and destruction of habitats and ecosystems;
- effects of sewage on human health;
- widespread and increased eutrophication;
- decline of fish stocks and other renewable resources; and
- changes in sediment flows due to hydrological changes.

Coastal development is projected to impact 91% of all inhabited coasts by 2050 and will contribute to more than 80% of all marine pollution (Nellemann et al 2008). The importance of different land-based influences differ regionally but the South Pacific Regional Environmental Programme (SPREP, which includes New Zealand) defines waste management and pollution control as one of its four strategic priorities for 2011–2015 (SPREP 2010).

Influences, including land-based influences, seldom work in isolation; for example the development of farming and fishing over the last hundred years has meant that increased sediment and nutrient runoff has to some degree occurred simultaneously with increased fishing pressure. However, the impact of these influences has often been studied in isolation. In a review on coastal eutrophication, Cloern (2001) stated that *"Our view of the problem [eutrophication] is narrow because it continues to focus on one signal of change in the coastal zone, as though nutrient enrichment operates as an independent stressor; it does not reflect a broad ecosystem-scale view that considers nutrient enrichment in the context of all the other stressors that cause change in coastal ecosystems"*. These influences (in isolation or combination) can also cause indirect effects, such as decreasing species diversity which then lessens resistance to invasion by non-indigenous species or species with different life-history strategies (Balata et al 2007, Kneitel & Perrault 2006, Piola & Johnston 2008). Studies that research a realistic mix of influences are rare, but valuable.

Sediment deposition can be an important influence, particularly in areas of high rainfall, tectonic uplift, and forest clearances, or areas where these activities coincide. Sediments are known to erode from the land at an increased rate in response to human use, for example, estimates from a largely deforested tropical highland suggest erosion rates 10–100 times faster than pre-clearance rates (Hewawasam et al 2003). Increased sediment either deposited on the seafloor or suspended in the water column can negatively impact upon invertebrates in a number of ways including: burial, scour, inhibiting settlement, decreasing filter-feeding efficiency and decreasing light penetration, generally leading to less diverse communities, with a decrease in suspension feeders (Thrush et al 2004). These impacts can affect the structure, composition and dynamics of benthic communities (Airoldi 2003, Thrush et al 2004). Effects of this increased sediment movement and deposition on finfish are mostly known from freshwater fish and can range from behavioural (such as decreased feeding rates) to sublethal (e.g., gill tissue disruption) and lethal as well as having effects on habitat important to fishes (Morrison et al 2009). These effects differ by species and life-stage and are dependant upon factors that include the duration, frequency and magnitude of exposure, temperature, and other environmental variables (Servizi & Martens 1992).

Increased nutrient addition to the aquatic environment can initially increase production, but with increasing nutrients there is an increasing likelihood of harmful algal blooms and cascades of effects damaging to most communities above the level of the plankton (Kennish 2002; Heisler et al 2008). This excess of nutrients is termed eutrophication. Eutrophication can stimulate phytoplankton growth which can decrease the light availability and subsequently lead to losses in benthic production from seagrass, microalgae or macroalgae and their associated animal communities. Algal blooms then die and their decay depletes oxygen and blankets the seafloor. The lack of oxygen in the bed and water column can lead to losses of finfish and benthic communities. These effects are likely to be location specific and are influenced by a number of factors including: water transparency, distribution of vascular plants and biomass of macroalgae, sediment biogeochemistry and nutrient cycling, nutrient ratios and their regulation of phytoplankton community composition, frequency of toxic/harmful algal blooms, habitat quality for metazoans, reproduction/growth/survival of pelagic and benthic invertebrates, and subtle changes such as shifts in the seasonality of ecosystems (Cloern 2001). The effects of eutrophication abound in the literature, for example, the formation of dead (or anoxic) zones is exacerbated by eutrophication, although oceanographic conditions also play a key role (Diaz & Rosenberg 2008). Dead zones have now been reported from more than 400 systems, affecting a total area of more than 245 000 square kilometres (Diaz & Rosenberg 2008). This includes anoxic events from New Zealand in coastal north-eastern New Zealand and Stewart Island (Taylor et al 1985, Morrissey 2000).

Other pollutants such as heavy metals and organic chemicals can have severe effects, but are more localised in extent than sediment or nutrient pollution (Castro and Huber 2003, Kennish 2002). Fortunately the concentration of these pollutants in most New Zealand aquatic environments is relatively low, with a few known exceptions. Examples of this include naturally elevated levels of arsenic in Northland[75], cadmium levels in Foveaux Strait oysters (Frew et al 1996) and levels of nickel and chromium within the Motueka river plume in Tasman Bay (Forrest et al 2007). The high cadmium levels have caused market access issues for Foveaux Strait oysters. Some anthropogenically generated pollutants such as copper, lead, zinc and PCBs are high in localised hotspots within urban watersheds. In the Auckland region these hotspots tend to be in muddy estuarine sites and tidal creeks that receive runoff from older urban catchments[76]. There is a lack of knowledge on the impacts of these pollutants upon fisheries.

Climate change is likely to interact with the effect of land-based impacts as the main delivery of land-based influences is through rainfall and subsequent freshwater flows. Global climate change projections include changes in the amount and regional distribution of rainfall over New Zealand (IPCC 2007). More regional predictions include increasing frequency of heavy rainfall events over New Zealand (Whetton et al 1996). This is likely to exacerbate the impact of some land-based influences as delivery peaks at times of high rainfall, e.g. sediment delivery (Morrison et al 2009).

Physical alterations of the coast are generally, but not exclusively (e.g. wetland reclamation for agriculture), concentrated around urban areas and can have a number of consequences on the marine environment (Bulleri & Chapman 2010). Changes in diversity, habitat fragmentation or loss and increased invasion susceptibility have all been identified as consequences of physical alteration. The effects of physical alterations upon fisheries remain largely unquantified; however the habitat loss or alteration portion of physical alterations will be

[75] Accessible on the www.os2020.org.nz website.

[76] Available from the State of the Auckland Region report 2010, Chapter 4.4 Marine, at http://www.arc.govt.nz/albany/index.cfm?FD6A3403-145E-173C-986A-A0E3C199B8C5

dealt with under the habitats of particular significance for fisheries management (HPSFM) section.

An area of emerging interest internationally is infectious diseases from land-based animals affecting marine populations. Perhaps the most well-known example of this is the canine distemper outbreak in Caspian seals that caused a mass mortality in the Caspian sea in 2000 (Kennedy et al 2000).

13.2.2 HABITAT RESTORATION

Habitat restoration or rehabilitation has been the subject of much recent research. Habitat restoration or rehabilitation rarely, if ever, replaces what was lost and is most applicable in estuarine or enclosed coastal areas as opposed to exposed coastal or open ocean habitats (Elliott et al 2007). Connectivity of populations is a key consideration when evaluating the effectiveness of any marine restoration or rehabilitation (Lipcius et al 2008). In the marine area, seagrass replanting methodologies are being developed to ensure the best survival success (Bell et al 2008) and artificial reefs can improve fisheries catches, although whether artificial reefs boost population numbers or merely attract fish is unclear (Seaman 2007). In addition, the incorporation of habitat elements in engineering structures, e.g., artificial rockpools in seawalls, shows promise in terms of ameliorating the impacts of physical alterations (Bulleri 2006). Spatial approaches to managing land-use impacts, such as marine reserves, will be covered under the section about HPSFM.

Freshwater rehabilitation has been reviewed by Roni et al (2008). Habitat reconnection, floodplain rehabilitation and instream habitat improvement are all suggested for improving habitat and local fish abundances. Riparian rehabilitation, sediment reduction, dam removal, and restoration of natural flood regimes have shown promise for restoring natural processes that create and maintain habitats, but there is a lack of long-term studies to gauge their success. Wild eel fisheries in America and Europe have declined over time (Allen et al 2006, Atlantic States Marine Fisheries Commission 2000, Haro et al 2000). Declines in wild eel fisheries have been linked to a number of factors including: barriers to migration; hydro turbine mortality; and habitat loss or alteration. Information to quantitatively assess these linkages is however often lacking (Haro et al 2000).

13.3 STATE OF KNOWLEDGE IN NEW ZEALAND

Land-based effects will be most pronounced closest to the land, therefore freshwater, estuarine, coastal, middle depths and deepwater fisheries, will be affected in decreasing order. The scale of land-use effects will, however, differ depending upon the particular influence. The most localised are likely to be direct physical impacts; for example, the replacement of natural shorelines with seawalls; although even direct physical impacts can have larger scale impacts, such as affecting sediment transport and hence beach erosion, or contributing to cumulative effects upon ecosystem responses. Point-source discharges are likely to have a variable scale of influence, and this influence is likely to increase where a number of point-sources discharge, particularly when this occurs into an embayed, low-current environment. An example of this is Waitemata harbour in Auckland where there are multiple stormwater discharges (Hayward et al 2006). The influences on the largest scale can be from diffuse-source discharges such as nutrients or sediment (Kennish 2002). For example, the influence of diffuse-source materials from the Motueka river catchment in Golden Bay on subtidal sediments and assemblages and shellfish quality can extend up to tens of kilometres offshore (Tuckey et al 2006; Forrest et al 2007), with even a moderate storm event extending a plume greater than 6 km offshore (Cornelisen et al 2011). Terrestrial influences on New Zealand's marine environment can, at times, be detected by satellites from differences in ocean colour and turbidity extending many kilometres offshore from river mouths (Gibbs et al 2006).

All coastal areas are unlikely to suffer from land-based impacts in the same way. The quantities of pollutants or structures differ spatially. Stormwater pollutants, seawalls and jetties are more likely to be concentrated around urban areas. Nutrient inputs are likely to be concentrated either around sewage outlets or associated with areas of intensive agriculture or horticulture. Sediment production has been mapped around the country and is greatest around the west coast of the South Island and the East coast of the North Island (Griffiths & Glasby 1985, Hicks & Shankar 2003, Hicks et al 2011). Notably the catchments where improved land management may result in the biggest changes to sediment delivery to coastal environments are likely to be the Waiapu and Waipoa river catchments on the East coast of the North Island. In addition to this, the sensitivity of receiving environments is also likely to differ; this will be covered in subsequent sections.

A MPI funded project (IPA2007/07) reviewed the impacts of land based influences on coastal biodiversity and fisheries (Morrison et al 2009). This review used a number of lines of evidence to conclude that in this context, sedimentation is probably New Zealand's most important pollutant. The negative impacts of sediment include decreasing efficiency of filter-feeding shellfish (such as cockles, pipi, and scallops), reduced settlement success and survival of larval and juvenile phases (e.g., paua, kina), and reductions in the foraging abilities of finfish (e.g., juvenile snapper). Indirect effects include the modification or loss of important nursery habitats, particularly biogenic habitats (green-lipped and horse mussel beds, seagrass meadows, bryozoan and tubeworm mounds, sponge gardens, kelps/seaweeds, and a range of other structurally complex species). Inshore filter-feeding bivalves and biogenic habitats were identified as the most likely to be adversely affected by sedimentation. Eutrophication was also identified as a potential threat from experience overseas. This review identified knowledge gaps and made suggestions for more relevant research on these influences:

- identification of fisheries species/habitat associations for different life stages, including consideration of how changing habitat landscapes may change fisheries production;
- better knowledge of connectivity between habitats and ecosystems at large spatial scales;
- the role of river plumes;
- the effects of land-based influences both directly on fished species, and indirectly through impacts on nursery habitats;
- a better spatially-based understanding, mapping and synthesis of the integrated impacts of land-based and marine-based influences on coastal marine ecosystems.

The locations where addressing land-based impacts is likely to result in a lowering in risk to seafood production or increased seafood production, excluding those already mentioned, are undefined.

A national scale threat analysis has been completed for biogenic habitats, given their likely importance for fisheries management as nursery areas (Morrison et al 2014b). The sparse data available (often anecdotal accounts), shows that strong declines in biogenic habitats have occurred, which appear largely attributable to land-based effects (e.g., sedimentation and elevated nutrient levels), and fishing impacts. Examples include the extensive loss of seagrass meadows (e.g. large areas in Whangarei, Waitemata, Manukau, Tauranga and Avon-Heathcote estuaries), green-lipped mussel beds (about 500 km2 in the Hauraki Gulf), bryozoan beds (about 80 km2 in Torrent Bay, about 800 km2 in Foveaux Strait), and deep-water coral thickets on sea-mounts. Cumulatively, the magnitude and extent of biogenic habitat losses are likely to have been very substantial, but are unknown, and probably will never be able to be calculated. Other biogenic habitat species for which evidence points to historical losses include horse mussels, kelp forests, oyster beds, and sponges, both in assemblages where they tend to dominate, and as part of mixed biogenic habitat assemblages. A better understanding of the threats to these biogenic habitats is recommended.

The Kaipara Harbour has been identified as a system which supports important fisheries functions both for the harbour proper, and for the wider west coast North Island ecosystem (Morrison et al 2014a). This report detailed fish-habitat associations in the harbour and concluded that increased sedimentation, and to a lesser extent the possibility of eutrophication, was probably the greatest threat to these fisheries.

The threat of sedimentation has prompted much concern and action by land managers and local communities (Morrison et al 2014a). For example, in the Kaipara Harbour the southern subtidal seagrass meadows area is especially important as a juvenile nursery for snapper and trevally and based on its high value as a juvenile fish nursery habitat, the Auckland Council has listed this area as an Ecologically Significant Area (ESA) in its draft unitary plan. There are significant collaborative CRI / Northland Regional Council / Auckland Council sediment erosion and transport research programmes currently under way in Kaipara Harbour catchment and the harbour itself. There are also local initiatives around tree planting and the improvement of riparian and other forms of land management. The fish/fisheries habitat work described here engages and collaborates with the IKHMG and

Kaipara Research Advisory Group (KRAG), and this type of collaboration/interaction between fisheries habitat research, other scientific research programmes, and management agencies is one promising way for these issues to be addressed.

Another study investigated correlations between environmental variables and flounder abundance for the Manukau and Mahurangi Harbours (McKenzie et al 2013). Consistent correlations were obtained for a variety of environmental variables for juvenile sand and yellowbelly flounder (YBF) in the Manukau, but not in Mahurangi Harbour. The influence of environmental variables on adult YBF catch in the Manukau Harbour was even more evident. These correlations suggested that decreasing oxygen and increasing ammonia and turbidity may have negatively affected yellowbelly flounder recruitment success. When these results were considered alongside the declining trends in flatfish abundance in the FLA 1 fishery, estuarine water quality may be a significant factor affecting the sustainability of the flatfish fishery.

Marine restoration studies published in New Zealand have focused on the New Zealand cockle Austrovenus stutchburyi. The first of these studies identified a tagging methodology to aid relocation of transplanted individuals (Stewart & Creese 2002). Subsequent studies stressed the use of adults in restoration and the importance of site selection, either from theoretical or modelling viewpoints (Lundquist et al 2009, Marsden & Adkins 2009). Detailed restoration methodology has been investigated in Whangarei Harbour and recommends replanting adults at densities between 222 and 832 m-2 (Cummings et al 2007).

Multiple influences in areas relevant to seafood production in New Zealand have been addressed by three studies. A field experiment near Auckland showed greater effects on infaunal colonisation of intertidal estuarine sediments when three heavy metals (copper, lead and zinc) were in combination compared to each in isolation (Fukunaga et al 2010). A survey approach looking at the interaction of sediment grain size, organic content and heavy metal contamination upon densities of 46 macrofaunal taxa across the Auckland region also showed a predominance of multiplicative effects (Thrush et al 2008). However influences can work in unexpected directions; as in a study on large suspension feeding bivalves off estuary mouths where the anticipated negative impacts from sediment were not observed and these species benefited from food resources generated from the estuaries (Savage et al 2012).

Toheroa populations are currently closed to all but customary harvesting but have failed to recover to former population levels even though periodic (and sometimes substantial) pulses in young recruits have been detected in both Northland and Southland (Beentjes 2010, Morrison & Parkinson 2008). Current thinking suggests that a mix of influences are probably responsible for these declines including over-harvesting, land-use changes leading to changes in freshwater seeps on the beaches, and vehicle traffic (Morrison et al 2009, Williams at al 2013). A number of discrete pieces of research have been completed in this area. A review of the wider impact of vehicles on beaches and sandy dunes has been completed, and suggested that more research was needed on the impacts of vehicle traffic on the intertidal (Stephenson 1999). A four day study over a fishing contest on Ninety Mile Beach showed the potential of traffic to produce immediate mortalities of juvenile toheroa, but the temporal importance of this could not be gauged (Hooker & Redfearn 1998). Mortalities of toheroa from the Burt Munro Classic motorcycle race on Oreti beach have been quantified and recommendations made for how to minimise these, but again the importance of vehicle traffic for toheroa survival over longer time periods was unclear (Moller et al 2009). Notably, similar negative impacts from driving were observed on juvenile tuatua (Paphies donacina) on a Pegasus Bay beach (Marsden & Taylor 2010). The impact of a range of influences upon toheroa at Ninety Mile Beach has been investigated by Williams et al. (2013). The main factors identified that potentially affect toheroa abundance were food availability, climate and weather, sand smothering/sediment instability, toxic algal blooms, predation, harvesting, vehicle impacts, and land use change. To investigate the causal mechanisms operating, a combination of monitoring, experimental, and modelling studies may be necessary.

Rhodolith beds have been surveyed in the Bay of Islands and high diversity was reported even in areas of abundant fine sediments (Nelson et al 2012). It is unclear if the increasing sedimentation occurring in the Te Rawhiti Reach is negatively impacting rhodoliths and whether this atypical rhodolith bed (i.e., with abundant fine sediments) is at risk if current sedimentation and mobilisation rates continue.

The protozoan *Toxoplasma gondii* has been identified as the cause of death for 7 of 28 Hector's and Maui's dolphins examined since 2007 (W. Roe, Massey University, unpubl. data, 31 July 2012). Land-based runoff containing cat faeces is believed to be the means by which *Toxoplasma gondii* enters the marine environment (Hill & Dubey 2002). A Hector's dolphin has also tested positive for Brucella abortus (or a similar organism) a pathogen of terrestrial mammals that can cause late pregnancy abortion, and has been seen in a range of cetacean species elsewhere [77]. This resulted in the Department of Conservations suggested research priorities in the "Review of the Maui's dolphin Threat management plan: Consultation paper" including objectives to determine the presence, pathways and possible mitigation of the threat from *Toxoplasmosis gondii* [78]. The recently established Maui dolphin Research Advisory Group[79] confirmed risk factors to Maui dolphin from *Toxoplasma gondii* as a priority area for future research.

The effects of large-scale habitat loss and modification on eels in New Zealand are clearly significant, but difficult to quantify (Beentjes et al 2005). Significant non-fisheries mortality of New Zealand freshwater longfin and shortfin eels are caused by mechanical clearance of drainage channels, and damage by hydro-electric turbines and flood control pumping. Eels prefer habitat that offers cover and in modified drains aquatic weed provides both daytime cover and nighttime foraging areas. Loss of weed and natural debris can thus result in significant displacement of eels to other areas. In addition, wetlands drainage has resulted in greatly reduced available habitat for eels, particularly shortfins which prefer slower-flowing coastal habitats such as lagoons, estuaries, and lower reaches of rims. Water abstraction is one of a number of information requirements identified in Beentjes et al (2005). to better define the effects on eel populations.

A number of Integrated Catchment Management (ICM) projects are underway in New Zealand. These take a holistic view to land management incorporating aquatic effects; this approach could help restore water quality of both fresh and coastal waters. An overview of these projects is given in a Ministry for the Environment Report on integrated catchment management (Environmental Communications Limited 2010). Many of these projects employ restoration techniques such as riparian planting, but few assessments of the effectiveness of riparian planting exist. One assessment of the effect of nine riparian zone planting schemes in the North Island on water quality, physical and ecological indicators concluded that riparian planting could improve stream quality; in particular rapid improvements were seen in terms of visual clarity and channel stability (Parkyn et al 2003). Nutrient and faecal contamination results were more variable. Improvement in macroinvertebrate communities did not occur in most streams and the three factors needed for these were canopy closure (which decreased stream temperature), long lengths of riparian planting and protection of headwater tributaries. A modelling study also demonstrated the long time lag needed to grow large trees which then provide wood debris to structure channels which achieves the best stream rehabilitation results (Davies-Colley et al 2009). Although some of these studies extend into the marine realm (at least in terms of monitoring) it is difficult to gauge the impact of these activities upon fisheries or aquaculture, particularly on wider scales because ICM studies have been localised at small scales.

13.3.1 CURRENT RESEARCH

A MPI biodiversity project also has components that address land-based effects; the threats to biogenic habitats are addressed in project ZBD2008/01 (for more detail see the Marine Biodiversity chapter).

A Ministry of Business, Innovation and Employment (MBIE) funded project [80] of particular relevance is "Nitrogen reduction and benthic recovery" (UOCX0902, University of Canterbury). This research aims to determine the trajectories and thresholds of coastal ecosystem recovery following removal of excessive nutrient loading (called "eutrophication") and earthquake impacts. This will be achieved by monitoring the effects of diverting all of

[77] http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-tmp-discussion-document-full.pdf

[78] http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-tmp-discussion-document-full.pdf

[79] http://www.doc.govt.nz/conservation/native-animals/marine-mammals/dolphins/mauis-dolphin/docs-work/maui-dolphin-research-advisory-group/

[80] http://www.msi.govt.nz/update-me/who-got-funded/

Christchurch's treated wastewater discharge from the eutrophied Avon-Heathcote (Ihutai) Estuary and the subsequent earthquake induced disturbances to this diversion.

13.4 INDICATORS AND TRENDS

A national view of the impacts of land-based influences upon seafood production does not exist; this could be facilitated by better coordination and planning of the many disparate marine monitoring programmes operating around the country. Monitoring of marine water quality and associated communities is carried out through a variety of organisations, including universities, regional councils and aquaculture or shellfisheries operations. Regional council monitoring of water quality and associated biological communities is often reported through web sites such as the Auckland Regional Council environmental monitoring data which is available on the internet[81], or summary reports such as the Hauraki Gulf state of the Environment 2011 report[82]. Water quality and associated marine communities may also be monitored for a regional council as part of a consent application or as a stipulation for a particular marine development. However the data from aquaculture and shellfisheries water quality monitoring is not generally available.

Improved coordination and planning of marine monitoring has been achieved in some countries, e.g., the United Kingdom [83]. The Marine Environmental Monitoring Programme (ZBD2010-42), is a step towards this goal, more information is available on this project in the Biodiversity chapter of this document. This project identifies remote sensing of sea surface particulate matter in nearshore waters as a possible indicator of changes in sediment inputs in the future, but this requires algorithm validation for New Zealand waters. Possible national scale proxies for coastal faecal contamination may exist after collating information from sanitation area monitoring for shellfish harvesting and/or coastal bathing beaches[84].

High faecal coliform counts (primarily from mammal or bird faeces) can impact upon the value gained from shellfish fisheries and aquaculture. Area closures to commercial harvesting usually depend on an area's rainfall/runoff relationship and areas closer to significant farming areas or urban concentrations are likely to be closed more frequently, due to high faecal coliform counts, than areas where the catchment is unfarmed or not heavily populated. For example, Inner Pelorus sound is likely to be closed more frequently than outer Pelorus Sound (Marlborough Sounds) F For coastal areas of the Marlborough Sounds, the Coromandel Peninsula and Northland closures can range from a few days to over 50 percent of the time in a given year[85]. Certain fisheries may be limited by the amount of time where water quality is sufficient to allow harvesting, e.g. the cockle fishery in COC 1A (Snake bank in Whangarei harbour) was closed for 101, 96, 167, 86, 117 and 118 days for the 2006–07, 2007–08, 2008–09, 2009–10, 2010–11 and 2011–12 fishing years respectively, due to high faecal coliform counts from sewage spills or runoff[86]. Models also now exist that allow real-time prediction of E. coli pulses associated with storm events, e.g. Wilkinson et al (2011), which may help harvesters to better cope with water quality issues.

The Ministry for the Environment (MfE) also reports on freshwater quality. River water quality indicators that have been assessed have direct relevance to the eel, and other freshwater fisheries, and this water will flow through estuaries and enter the marine environment. The National River Water Quality Network (NRWQN) has national coverage, and has been running for over 20 years and has recently reported upon the following eight variables: temperature, dissolved oxygen, visual clarity, dissolved reactive and total phosphorous, and ammoniacal, oxidised and total nitrogen (Ballantine & Davies-Colley 2009).

[81] http://maps.auckland.govt.nz/aucklandregionviewer/?widgets=HYDROTEL
[82] http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Coastal%20and%20marine/hgfstateoftheenvreport2011.pdf
[83] http://www.cefas.co.uk/data/marine-monitoring/national-marine-monitoring-programme-(nmmp).aspx
[84] http://www.mfe.govt.nz/environmental-reporting/fresh-water/suitability-for-swimming-indicator/index
[85] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.
[86] Statistics supplied by New Zealand Food Safety Authority in Whangarei. Notably the fishery has not been operating since November 2012.

Dissolved oxygen showed few meaningful trends and the ammoniacal nitrogen data suffered from a processing artefact. An upward, although not significant trend in temperature and an improvement of water clarity were seen at the national scale. However, a negative correlation was seen between water clarity and percent of catchment in pasture, which suggests that any expansion of pasture lands may have impacts on clarity. Strong increasing trends over time were seen in oxidised nitrogen, total nitrogen, total phosphorous and dissolved reactive phosphorous. These latter trends all signify deteriorating water quality and are mainly attributable to increased diffuse-source pollution from the expansion and intensification of pastoral agriculture.

Total nitrogen and phosphorous loads to the coast in New Zealand have been modelled and were estimated at 167 300 and 63 100 t yr-1, respectively (Elliot et al 2005)[87]. The main sources of nitrogen and phosphorous were from pastoralism (70%) and erosion (53%), respectively. Dairying contributes 37% of the nitrogen load from only 6.8% of the land. The total amount of land used for dairy farms increased by 47% (1.4 to 2.0 million hectares) from 1986 to 2002 [88]. These statistics provide strong circumstantial evidence that the expansion in dairying is primarily responsible for the observed declines in water quality from agricultural sources.

13.5 REFERENCES

Airoldi, L (2003) The effects of sedimentation on rocky coast assemblages. Oceanography and Marine Biology Annual Review 41:. 161–236.

Allen, M; Rosell, R; Evans, D (2006) Predicting catches for the Lough Neagh (Northern Ireland) eel fishery based on stock inputs, effort and environmental variables. Fisheries Management and Ecology (13): 251–260.

Atlantic States Marine Fisheries Commission (2000) Interstate Fishery Management Plan for American Eel. Fishery Management Report No. 36 of the Atlantic States Marine Fisheries Commission. 93 p.

Balata, D; Piazzi, L; Cinelli, F (2007) Increase of sedimentation in a subtidal system: Effects on the structure and diversity of macroalgal assemblages. Journal of Experimental Marine Biology and Ecology (351): 73–82.

Ballantine, D; Davies-Colley, R (2009) Water quality trends at National River Water Quality Network sites for 1989–2007. Prepared for Ministry for the Environment, NIWA Client Report: HAM2009-026. 43 p.

Beentjes, M; Boubée, J; Jellyman, J D; Graynoth, E (2005) Non-fishing mortality of freshwater eels (Anguilla spp.). New Zealand Fisheries Assessment Report 2005/34. 38 p.

Beentjes, M (2010) Toheroa survey of Oreti Beach, 2009, and review of historical surveys. New Zealand Fisheries Assessment Report 2010/06. 40 p.

Bell, S S; Tewfik, A; Hall, M O; Fonseca, M S (2008) Evaluation of seagrass planting and monitoring techniques: Implications for assessing restoration success and habitat equivalency. Restoration Ecology (16): 407–416.

Bulleri, F (2006) Is it time for urban ecology to include the marine realm? Trends in Ecology & Evolution (21): 658–659.

Bulleri, F; Chapman, M (2010) The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology (47): 26–35.

Carter, L (1975) Sedimentation on the continental terrace around New Zealand: A Review. Marine Geology (19): 209–237.

Carter, L; Carter, R; McCave, I; Gamble, J (1996) Regional sediment recycling in the abyssal Southwest Pacific Ocean. Geology (24): 735–738.

Castro, P; Huber, M (2003) Marine Biology. (Vol) 4. New York, McGraw Hill Higher Education.

Cloern, J (2001) Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series (210): 223–253.

Cornelisen, C; Gillespie, P; Kirs, M; Young, R; Forrest, R; Barter, P; Knight, B; Harwood, V (2011) Motueka River plume facilitates transport of ruminant faecal contaminants into shellfish growing waters, Tasman Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research 45, 477–495.

Cummings, V; Hewitt, J; Halliday, J; Mackay, G (2007) Optimizing the success of *Austrovenus stutchburyi* restoration: preliminary investigations in a New Zealand estuary. Journal of Shellfish Research (26): 89–100.

Davies-Colley, R J; Meleason, M A; Hall, G M J; Rutherford, J C (2009) Modelling the time course of shade, temperature, and wood recovery in streams with riparian forest restoration. New Zealand Journal of Marine and Freshwater Research (43): 673–688.

Diaz, R J; Rosenberg, R (2008) Spreading dead zones and consequences for marine ecosystems. Science (321): 926–929.

[87] This is a known underestimate because streams with catchments less than 10 km^2 were excluded from this calculation.

[88] http://www3.stats.govt.nz/environment/Fertiliser_use_and_the_environment_Aug06.pdf

Elliot, A; Alexander, R; Schwarz, G; Shankar, U; Sukias, J; McBride, G (2005) Estimation of nutrient sources and transport for New Zealand using the hybrid mechanistic-statistical model SPARROW. Journal of Hydrology: New Zealand (44): 1–27.

Elliott, M; Burdon, D; Hemingway, K L; Apitz, S E (2007) Estuarine, coastal and marine ecosystem restoration: Confusing management and science - A revision of concepts. Estuarine Coastal and Shelf Science (74): 349–366.

Environmental Communications Limited (2010) Integrated catchment management - a review of literature and practice. A report for the Ministry for the Environment. 158 p.

Forrest, B; Gillespie, P; Cornelisen, C; Rogers, K (2007) Multiple indicators reveal river plume influence on sediments and benthos in a New Zealand coastal embayment. New Zealand Journal of Marine and Freshwater Research (41): 13–24.

Frew, R; Hunter, K; Beyer, R (1996) Cadmium in Oysters and Sediments From Foveaux Strait, New Zealand. Proceedings of the Trace Element Group of New Zealand, 1996. Waikato University.

Fukunaga, A; Anderson, M J; Webster-Brown, J G; Ford, R B (2010) Individual and combined effects of heavy metals on estuarine infaunal communities. Marine Ecology-Progress Series (402): 123–136.

GESAMP (2001) Protecting the oceans from land-based activities. Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment. GESAMP Reports and Studies No. 71. 168 p.

Gibbs, M; Hobday, A; Sanderson, B; Hewitt, C (2006). Defining the seaward extent of New Zealand's coastal zone. Estuarine Coastal and Shelf Science 66: 240-254.

Glade, T (2003) Landslide occurrence as a response to land use change: A review of evidence from New Zealand. Catena (51): 297–314.

Goff, J R (1997) A chronology of natural and anthropogenic influences on coastal sedimentation, New Zealand. Marine Geology (138): 105–117.

Grange, K; Tovey, A; Hill, A F (2003) The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay. Marine Biodiversity Biosecurity Report No. 4. 22 p.

Griffiths, G; Glasby, G (1985) Input of River-derived sediments to the New Zealand Continental Shelf: I. Mass. Estuarine, Coastal and Shelf Science (21): 773–784.

Haro, A; Richkus, W; Whalen, K; Hoar, A; Busch, W D; Lary, S; Brush, T; Dixon, D (2000) Population decline of the American eel: Implications for research and management. Fisheries (25): 7–16.

Hayward, B W; Grenfell, H R; Sabaa, A T; Morley, M S; Horrocks, M (2006) Effect and timing of increased freshwater runoff into sheltered harbor environments around Auckland City, New Zealand. Estuaries and Coasts (29): 165–182.

Heisler, J; Glibert, P; Burkholder, J; Anderson, D; Cochlan, W; Dennison, W; Dortch, Q; Gobler, C; Heil, C; Humphries, E; Lewitus, A; Magnien, R; Marshall, H; Sellner, K; Stockwell, D; Stoecker, D; Suddleson, M (2008) Eutrophication and harmful algal blooms: A scientific consensus. Harmful algae 8: 3-13.

Hewawasam, T; von Blanckenburg, F; Schaller, M; Kubik, P (2003) Increase of human over natural erosion rates in tropical highlands constrained by cosmogenic nuclides. Geology (31): 597–600.

Hicks, D; Shankar, U (2003) Sediment from New Zealand rivers, NIWA Chart, Miscellaneous Series No.79.

Hicks, D; Shankar, U; McKerchar, A.I.; Basher, L; Lynn, I; Page, M; Jessen, M. (2011) Suspended sediment yields from New Zealand rivers. Journal of Hydrology (New Zealand) 50, 81–142.

Hill, D; Dubey, J P (2002) *Toxoplasma gondii*: transmission, diagnosis and prevention. Clinical Microbiology and Infection 8(10): 634–640.

Hooker, S; Redfearn, P (1998) Preliminary survey of toheroa (*Paphies ventricosa*) populations on Ninety Mile Beach and possible impacts of vehicle traffic. NIWA Client Report: AK98042. 34 p.

IPCC (2007) Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri R.andReisinger A.E., eds. Geneva, Switzerland. 104 p.

Kennedy, S; Kuiken, T; Jepson, P; Deaville, R; Forsyth, M; Barrett, T; Wilson, S (2000) Mass Die-Off of Caspian Seals caused by Canine Distemper Virus. Emerging Infectious Diseases, 6(6 November-December 2000), 637-639.

Kennish, M J (2002) Environmental threats and environmental future of estuaries. Environmental Conservation (29): 78–107.

Kneitel, J.M; Perrault, D (2006) Disturbance-induced changes in community composition increase species invasion success. Community Ecology (7): 245–252.

Lipcius, R N; Eggleston, D B; Schreiber, S J; Seitz, R D; Shen, J; Sisson, M; Stockhausen, W T; Wang, H V (2008) Importance of metapopulation connectivity to restocking and restoration of marine species. Reviews in Fisheries Science (16): 101–110.

Lundquist, C J; Oldman, J W; Lewis, M J (2009) Predicting suitability of cockle *Austrovenus stutchburyi* restoration sites using hydrodynamic models of larval dispersal. New Zealand Journal of Marine and Freshwater Research (43): 735–748.

MacDiarmid, A; McKenzie, A; Sturman, J; Beaumont, J; Mikaloff-Fletcher, S; Dunne, J (2012). Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No.93: 255p.

Marsden, I; Adkins, S (2009) Current status of cockle bed restoration in New Zealand. Aquaculture International 18. 83–97.

Marsden, I D; Taylor, G F (2010) Impact of vehicles on juvenile tuatua, *Paphies donacina* on Pegasus Bay surf beaches. Environment Canterbury Estuarine Research Report 38. 23 p.

McKenzie, J.; Parsons, D M; Bian, R (2013) Can juvenile yellowbelly and sand flounder abundance indices and environmental variables predict adult abundance in the Manukau and Mahurangi Harbours? New Zealand Fisheries Assessment Report 2013/10. 31 p.

Milliman, J; Syvitski, J (1992) Geomorphic/Tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers. The Journal of Geology (100): 525–544.

Moller, J; Moller, S; Futter, J; Moller, J; Harvey, J; White, H; Stirling, F; Moller, H (2009) Potential impacts of vehicle traffic on recruitment of Toheroa (*Paphies ventricosa*) on Oreti Beach, Southland, New Zealand. Dunedin, University of Otago. 61 p.

Morrisey, D J (2000) Predicting impacts and recovery of marine farm sites in Stewart Island New Zealand, from the Findlay-Watling model. Aquaculture (185): 257–271.

Morrison, M; Jones, E; Consalvey, M; Berkenbusch, K (2014a) Linking marine fisheries species to biogenic habitats in New Zealand: a review and synthesis of knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 130. 156 p.

Morrison, M; Lowe, M; Jones, E; Makey, L; Shankar, U; Usmar, N; Miller, A; Smith, M; Middleton, C (2014b) Habitats of particular significance for fisheries management: the Kaipara Harbour. New Zealand Aquatic Environment and Biodiversity Report No. 129. 169 p.

Morrison, M; Lowe, M; Parsons, D; Usmar, N; McLeod, I (2009) A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 37. 100 p.

Morrison, M; Parkinson, D (2008) Distribution and abundance of toheroa (*Paphies ventricosa*) on Ninety Mile Beach, March 2006. New Zealand Fisheries Assessment Report 2008/26. 27 p.

Nellemann, C; Hain, S; Alder, J E (2008) In Dead Water - Merging of climate change with pollution, over-harvest, and infestations in the world’s fishing grounds. United Nations Environment Programme, GRID-Arendal. 64 p.

Nelson, W; Neill, K; Farr, T; Barr, N; D’Archino, R; Miller, S; Stewart, R (2012) Rhodolith Beds in Northern New Zealand: Characterisation of Associated Biodiversity and Vulnerability to Environmental Stressors. New Zealand Aquatic Environment and Biodiversity Report No. 99: 102p.

Parkyn, S M; Davies-Colley, R; Halliday, N J; Costley, K J; Croker, G F (2003) Planted Riparian Buffer Zones in New Zealand: Do They Live Up to Expectations? Restoration Ecology (11): 436–447.

Piola, R F; Johnston, E L (2008) Pollution reduces native diversity and increases invader dominance in marine hard-substrate communities. Diversity and Distributions (14): 329–342.

Roni, P; Hanson, K; Beechie, T (2008) Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management (28): 856–890.

Savage, C; Thrush, S; Lohrer, A; Hewitt, J (2012) Ecosystem services transcend boundaries: estuaries provide resource subsidies and influence functional diversity in coastal benthic communities. PLoS ONE: 7:e42708.

Seaman, W (2007) Artificial habitats and the restoration of degraded marine ecosystems and fisheries. Hydrobiologia (580): 143–155.

Servizi, J A; Martens, D W (1992) Sublethal responses of coho salmon, *Oncorhynchus kisutch*, to suspended sediments. Canadian Journal of Fisheries & Aquatic Sciences 49(7): 1389–1395.

SPREP (2010) South Pacific Regional Environment Programme, Strategic Plan 2011–2015. (Draft for comment available at www.sprep.org) 29 p.

Stephenson, G (1999) Vehicle impacts on the biota of sandy beaches and coastal dunes: A review from a New Zealand perspective. Science for Conservation No. 121. 48 p.

Stewart, M J; Creese, R G (2002) Transplants of intertidal shellfish for enhancement of depleted populations: preliminary trials with the New Zealand little neck clam. Journal of Shellfish Research 21 (1): 21-27.

Taylor, F J; Taylor, N J; Walsby, J R (1985) A bloom of planktonic diatom *Ceratulina pelagica* off the coastal northeastern New Zealand in 1983, and its contribution to an associated mortality of fish and benthic fauna. Internationale Revue der gesamten Hydrobiologie und Hydrographie. 70: 773–795.

Thrush, S; Hewitt, J; Cummings, V; Ellis, J; Hatton, C; Lohrer, A; Norkko, A (2004) Muddy waters: elevating sediment input to coastal and estuarine habitats. Frontiers in ecology and the environment (2): 299–306.

Thrush, S F; Hewitt, J E; Hickey, C W; Kelly, S (2008) Multiple stressor effects identified from species abundance distributions: Interactions between urban contaminants and species habitat relationships. Journal of Experimental Marine Biology and Ecology (366): 160–168.

Tuckey, B; Gibbs, M; Knight, B; Gillespie, P (2006) Tidal circulation in Tasman and Golden Bays: implications for river plume behaviour. New Zealand Journal of Marine and Freshwater Research 40: 305-324.

Whetton, P; Mullan, A.B; Pittock, A (1996) Climate change scenarios for Australia and New Zealand, pp. 145–168. In: Bouma, W; Pearman, G; Manning, M. (Eds.) Greenhouse: coping with climate change. CSIRO Publishing, Collingwood, Australia.

Wilkinson, R; McKergow, L; Davies-Colley, R; Ballantine, D; Young, R (2011) Modelling storm-event E. coli pulses from the Motueka and Sherry Rivers in the South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 45: 369–393.

Williams, J; Paterson, C; Sim-Smith, C (2013) Review of factors affecting the abundance of toheroa (*Paphies ventricosa*). New Zealand Aquatic Environment and Biodiversity Report No. 114. 76 p.

14 ECOLOGICAL EFFECTS OF MARINE AQUACULTURE

Scope of chapter	The known effects of current impacts from aquaculture operations in New Zealand.
Area	All of the New Zealand EEZ and territorial sea, although presently aquaculture operations are located coastally.
Focal localities	Northland, Coromandel, Auckland, Marlborough Sounds, Tasman and Golden Bays, Canterbury, Southland.
Key issues	Uncertainty in predictions, cumulative effects, levels of nitrogen loading in coastal areas that will cause adverse effects
Emerging issues	Marine spatial planning, Integration of monitoring datasets.
MPI Research (current)	ENV2012-01 Nitrogen levels and adverse marine ecological effects Aquaculture Planning Fund 12/03 Marine Management Model (Waikato Regional Council) 12/04 Guidance for aquaculture monitoring in the Waikato region 13/01 Marlborough Sounds Hydrodynamic & Ecological Modelling 13/02 Aquaculture Zoning in the Southland Region
NZ Research (current)	C01X0904 NIWA Sustainable Aquaculture
Links to 2030 objectives	Objective 4 Support aquaculture development Objective 6: Manage impacts of fishing and aquaculture
Related issues	Land-based effects, marine biodiversity, habitats of particular significance for fisheries management

Note: This chapter was new for the AEBAR 2013.

14.1 CONTEXT

Aquaculture is the world's fastest growing primary industry and in 2011 supplied 41.2 percent of the supply of seafood globally, including 12.5 percent from marine aquaculture in the same year (FAO 2012). Fish convert a greater proportion of the food they eat into body mass than livestock and therefore the environmental demands per unit biomass or protein produced are lower (Hall et al 2011). The production of 1 kilogram of finfish protein requires less than 14 kilograms of grain compared to 62 kilograms of grain for beef protein and 38 kilograms for pork protein. However, although farmed fish may convert food more efficiently than livestock there are important issues globally with respect to farming carnivorous fish species, which places demands on the use of capture fisheries for animal feeds.

In 2011 the Oceania region (which includes New Zealand and Australia) produced only 0.3 percent of the world's aquaculture production (183 516 t); globally nearly 60 million tonnes were produced (FAO 2012). The average annual value of New Zealand aquaculture exports from 2008 to 2012 has been dominated by green-lipped mussels ($197 million), Salmon ($61 million) and Pacific oysters ($16 million) (Aquaculture New Zealand 2012). As of December 2011, aquaculture activities in New Zealand take place within approximately 19 268 ha of allocated water space (Aquaculture New Zealand 2012). This space can be categorised as below (Aquaculture New Zealand 2012):

- 7743 ha is granted to the aquaculture industry with the right to farm for a defined term, and is in known productive growing areas;
- 8960 ha is in open-ocean sites where productivity is yet to be proven;
- 1195 ha is in near shore sites yet to be developed;
- 1370 ha is undeveloped space in interim Aquaculture Management Areas (AMAs).

In New Zealand, the majority of aquaculture activities are located in the coastal marine environment, and the main current aquaculture locations are shown in Figure 14.1.

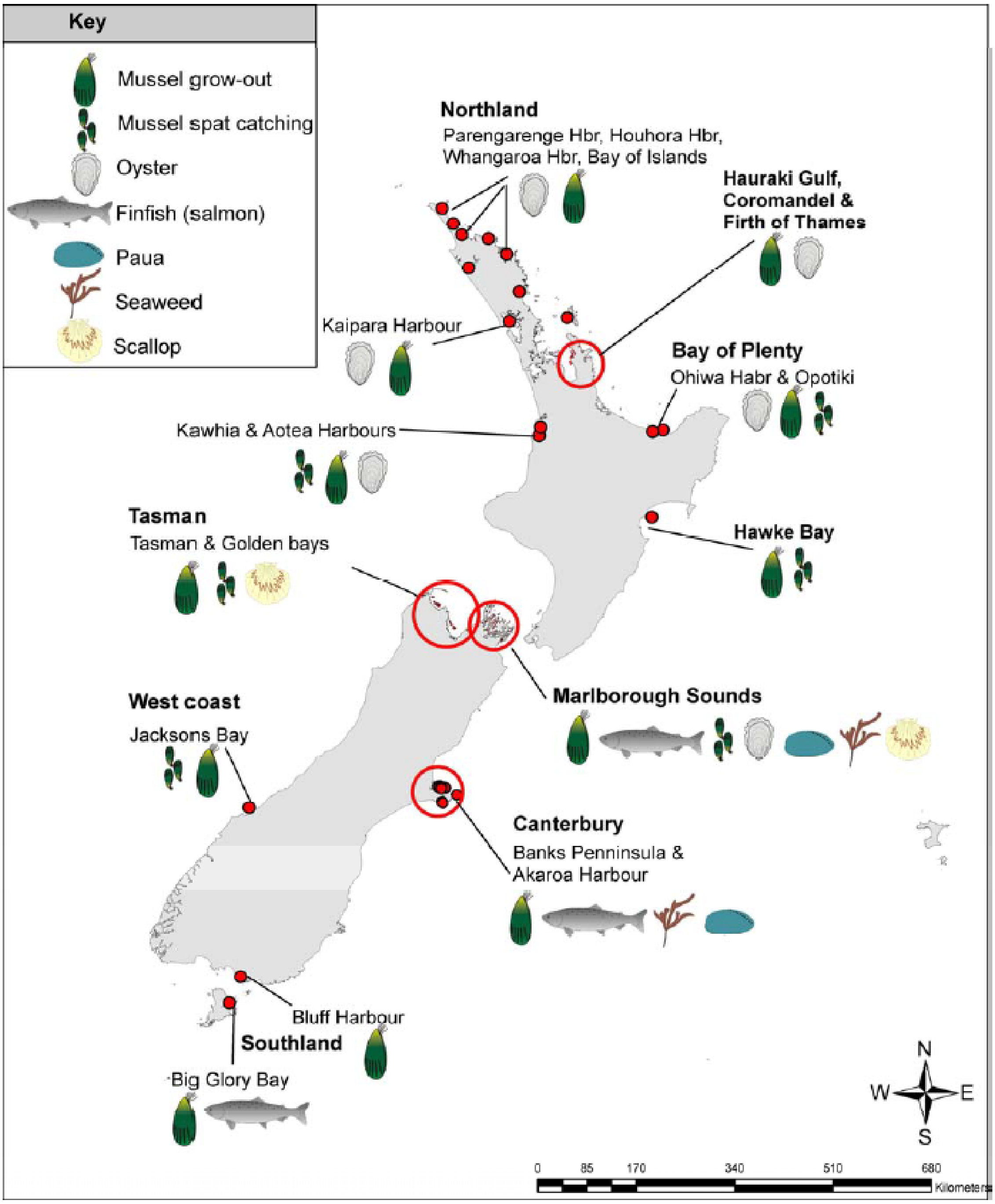


Figure 14.1: Geographic locations of main marine farming areas in New Zealand (Keeley et al 2009).

The New Zealand aquaculture industry has a current estimated value in excess of $400 million and an objective of developing into a billion dollar industry by 2025 (Aquaculture New Zealand 2012). This ambition has been supported by the New Zealand Government through the establishment of the Aquaculture Unit (now within the Ministry for Primary Industries (MPI)), the release of Government's Aquaculture Strategy and 5-Year Action Plan to support aquaculture, the 2011 aquaculture legislation reforms, and ongoing reforms of the Resource Management Act (RMA). One of the desired outcomes of these actions was to improve the consenting process to enable more space to be made available for aquaculture. To this end a number of Aquaculture Planning Fund projects have been initiated to address factors limiting aquaculture growth regionally. It is however recognised that aquaculture development, along with all other activities controlled by the RMA, needs to be ecologically sustainable.

Sustainable development of aquaculture in New Zealand needs to be supported by good quality information on ecological effects to enable appropriate decision making. The aquaculture unit of MPI therefore funded a collaborative project between NIWA and the Cawthron Institute to review the ecological effects of aquaculture (PRM2010-36). This chapter largely summarises the findings of that larger document (MPI 2013) which should be referred to for further details, references or clarification.

14.2 GLOBAL UNDERSTANDING

It is known that the environmental effects of aquaculture vary by country, region, production system and species (Hall et al 2011). Ninety-one percent of the world's aquaculture production comes from Asia and only 0.3 percent from Oceania (Hall et al 2011); therefore global reports on the environmental impacts of aquaculture tend to focus on Asia. The relevant (as judged by the authors of MPI (2013)) references to New Zealand from overseas literature will hence be included in the following Section (14.3).

14.3 STATE OF KNOWLEDGE IN NEW ZEALAND

A 2009 survey of experts assessed the relative importance of 62 threats on 65 of New Zealand's marine habitats (MacDiarmid et al 2012). Threat scores were categorised as extreme if the score was 3 or more, major if the score was 2–2.9, moderate if the score was 1–1.9, minor if the score was 0.5–1.0, and trivial if the score was less than 0.5. For example, the three top threats identified across all habitats were ocean acidification, increased sea temperatures from climate change and bottom trawling which scored mean impacts across all habitats of 2.6 (major), 1.6 (moderate) and 1.5 (moderate) respectively. The study considered three threats posed by aquaculture activities: benthic accumulation of debris (shells, faeces, food material), a decrease in the availability of primary production downstream of the marine farm (particularly mussel farms) and an increase in habitat complexity that may be detrimental to some species. The benthic accumulation of shells, food and faeces from aquaculture ranked 19th equal with a score of 0.7 (minor). The two other aquaculture threats were ranked 36th equal with a score of only 0.4 (trivial). Notably this is an average score across all habitats, however the highest scores attained for any of these aquaculture threats in particular habitats were 2.6 and 2.3 for the benthic accumulation of debris (shells, faeces, food material) in muddy sediment on sheltered coasts (2–9 m) and seagrass meadows in harbours and estuaries, respectively. The benthic accumulation of debris was the fourth most highly scoring threat in sheltered muddy coasts (2–9 m deep) and the third most highly scoring threat in seagrass meadows in harbours and estuaries.

The actual and potential effects of filter feeding and feed added culture are shown diagrammatically in Figure 14.2 and Figure 14.3.

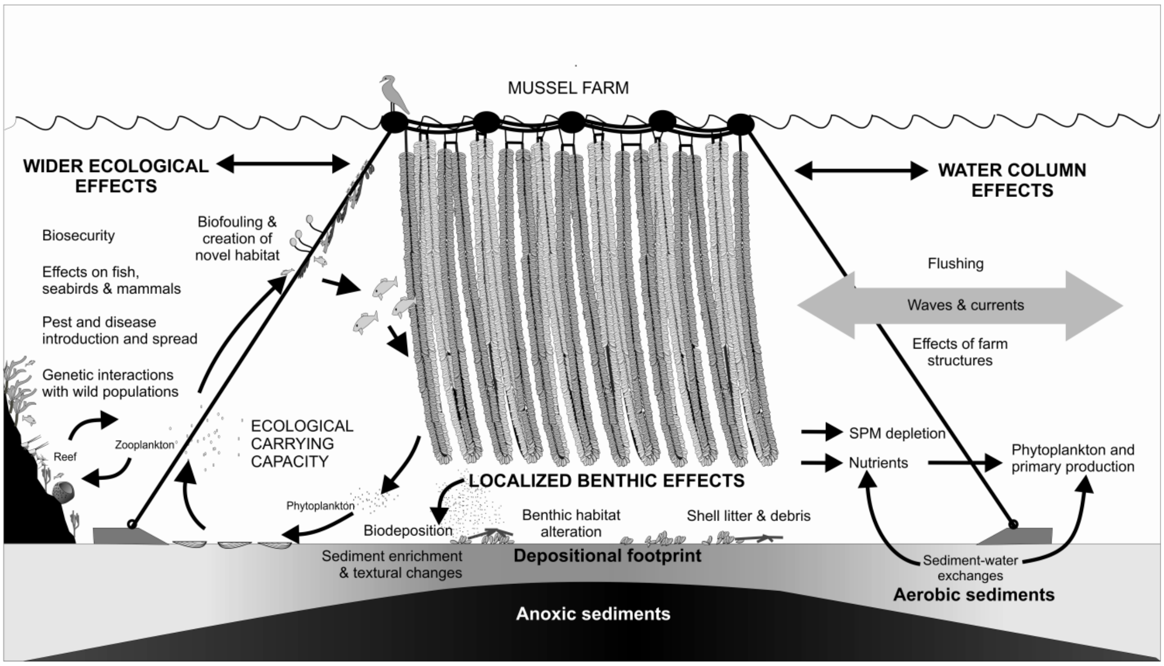


Figure 14.2: Schematic of actual and potential ecological effects from mussel farming (Keeley et al 2009).

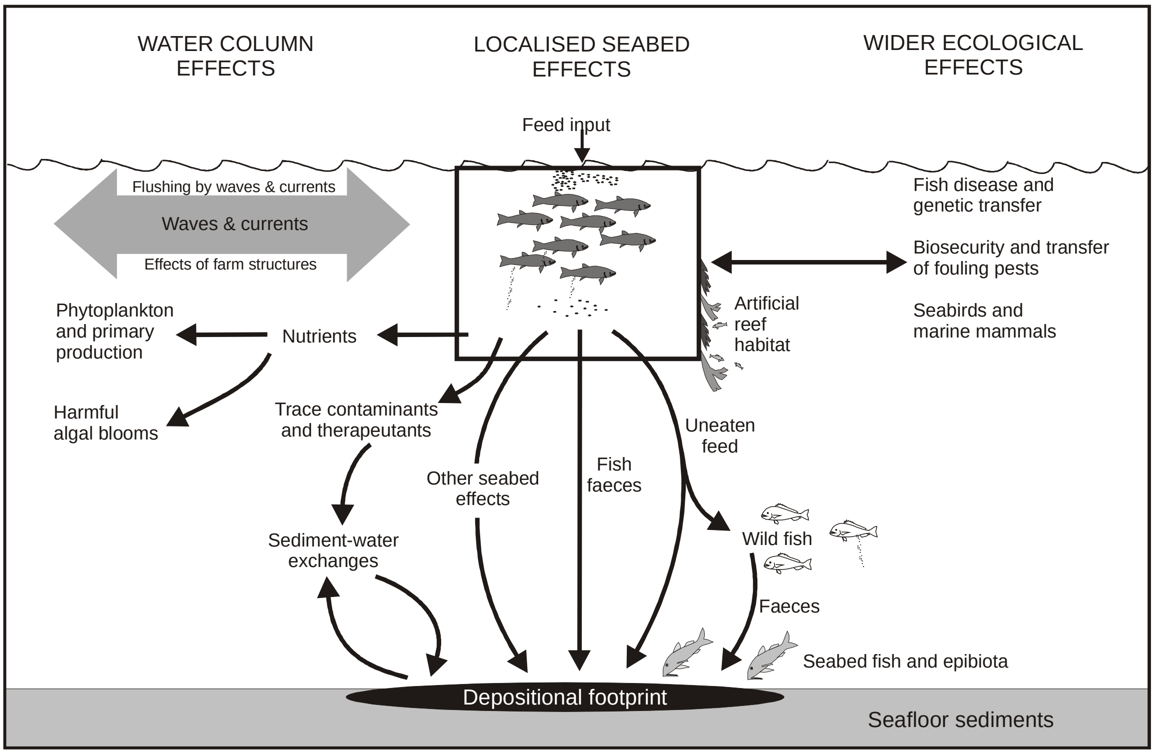


Figure 14.3: Schematic of actual and potential ecological effects from feed-added farming (Forrest et al 2007c).

An expert panel approach was also used to trial a method for prioritising the ecological threats from aquaculture (Stoklosa et al 2012). This process brought together 17 knowledgeable participants from across a range of interested parties (central and local government, aquaculture industry and scientists), to attempt to gain consensus on the relative importance of a range of ecological threats from aquaculture. The results of this process are only indicative but for both feed-added and filter-feeding species the same three issues were identified as most important; these were (in decreasing order of importance): biosecurity threats, pelagic effects and marine mammal interactions (Table 14.1). Notably the score for the threat from biosecurity was more than 50% greater than the next highest score and the threat of pelagic effects was rated as markedly higher for feed-added species than it was for filter-feeders. Other potential ecological threats considered were of lesser importance and are listed bullet pointed below the top three, along with an explanatory sentence about what was considered under each term (in no particular order). Interactions between threats and large scale effects were not covered within this prioritisation exercise.

1. Biosecurity threats – how aquaculture may influence risks associated with pests and diseases.
2. Pelagic effects - aquaculture effects on the water column (excluding those explicitly dealt with by other chapters in the MPI 2013 literature review) at approximately the scale of the farm.
3. Marine mammal interactions - aquaculture effects on marine mammals.

- Benthic effects - aquaculture effects on the seafloor.
- Seabird interactions - aquaculture effects on birds.
- Effects from additives - The effect of chemicals used in aquaculture upon the environment.
- Escapee effects - the effects of escaped farmed species upon the environment.
- Wild fish interactions - aquaculture effects on non-farmed fish populations.
- Hydrodynamic alteration of flows - aquaculture effects on the water movement at scales greater than the farm scale.

Table 14.1: Trial prioritisation of potential classes of aquaculture effects from Stoklosa et al (2012). Results of pair-wise comparisons using the Analytical Hierarchy Process (Saaty 1987) from the phase two workshop of the Aquaculture Ecological Guidance Project. RIW = relative importance weight. Order is decreasing in importance for the feed-added species[89].

	Feed-added species		Filter-feeder species	
Potential ecological effects	RIW	Rank	RIW	Rank
Biosecurity threats	0.360	1	0.373	1
Pelagic effects	0.236	2	0.143	2
Marine mammal interactions	0.118	3	0.135	3
Benthic effects	0.090	4	0.088	5
Seabird interactions	0.079	5	0.092	4
Additive effects	0.042	6	0.019	9
Escapee effects	0.029	7	0.088	5
Wild fish interactions	0.026	8	0.021	8
Hydrodynamic alteration of flows	0.019	9	0.041	7

These topic areas will be discussed further under each of their headings below (in the order above). In addition, note that stressors do not act in isolation, and any aquaculture impacts will occur within the context of (and potentially interacting with) other anthropogenic stressors and natural ongoing natural processes (see Figure 13.4 for an example of this). The interacting and cumulative effects of aquaculture will be discussed in Section 14.3.10 of this chapter.

14.3.1 BIOSECURITY THREATS

Aquaculture biosecurity has recently been covered by the reviews of Forrest et al (2011) for finfish and Keeley et al (2009) for other species, and then compiled and summarised in MPI (2013), this section draws heavily from those sources, and the reader is referred to them for more detail.

[89] Notably there was a chapter in MPI (2013) on the potential effects from genetic manipulation and polyploidy. However, genetic manipulation is controlled by the Environmental Protection Authority (EPA) and is not authorised for use in aquaculture. Polyploidy was also considered by the risk assessment workshop participants to be relatively rare in aquaculture and therefore this topic area was not considered by the prioritisation.

14.3.1.1 INTRODUCTION

The Ministry of Agriculture and Forestry (MAF) Biosecurity Strategy defines biosecurity as “the exclusion, eradication or effective management of risks posed by pests and diseases” (Biosecurity Council 2003). Biosecurity risk organisms include animals, plants and micro-organisms capable of causing diseases (e.g., the ostreid herpes virus in Pacific oysters) or otherwise adversely affecting New Zealand’s natural, traditional or economic values (e.g. the sea squirt *Styela clava*, and the red seaweed *Grataloupia turuturu*). In an aquaculture context, biosecurity also encompasses the protection of hatchery or culture operations from parasites, microscopic pathogens[90] or biotoxin-producing microalgae. These organisms may include indigenous species already present in the environment that become enhanced as a result of culture operations (Forrest et al 2011).

The primary source of entry for biosecurity risk organisms into New Zealand is through international shipping (Cranfield et al 1998, Kospartov et al 2010). However, aquaculture production systems may increase biosecurity risk, through acting as reservoirs or exacerbators (Okamura & Feist 2011, Peeler & Taylor 2011). Reservoirs host risk-organisms that can then spread by either natural or human-mediated mechanisms. Exacerbators create incubators/stepping stones for otherwise benign or low impact pests, pathogens or parasites (both native and exotic species).

Considerable effort is placed on preventing incursions of pests, parasites and diseases into the New Zealand environment. This is because the introduction, proliferation and spread of risk species in New Zealand can have effects on marine and freshwater environments that are often difficult to manage, resulting in permanent and irreversible impacts (Forrest et al 2011). The few successful efforts to eradicate aquatic invasive species (AIS) have several common elements (Locke et al 2009b) which are unlikely to occur in combination:

- early detection and correct identification of the invader,
- pre-existing authority to take action,

[90] Defined here as an agent of disease, e.g. a bacterium or virus.

- the ability to sequester the AIS to prevent dispersal, (or else the AIS had very limited dispersal capabilities),
- political and public support for eradication,
- acceptance of some collateral environmental damage,
- follow-up monitoring to verify the completeness of the eradication.

Environmental factors including depth, wave climate, temperature regime, and currents that influence dispersal of waste, disease agents, and pests play a significant role in determining the potential biosecurity risk for a given site.

The hydrodynamics (water movement patterns which are dependent on depth, wave climate and currents) at a site play an important role on several levels. Hydrodynamics can influence the mineralisation of wastes and nutrient release through oxygen supply to the sediment and also dispersion of pathogens and pests and parasites in the water column (Zeldis et al 2011b). For example, individual farms within any one Aquaculture Management Area (AMA) in Nelson Bays could function as a source of infection to other AMAs in Golden Bay (Zeldis et al 2011b) via the transfer of viral or bacterial pathogens. Dispersion potential (within farms, between farms or between blocks of farms), which is largely controlled by hydrodynamics, will also be influenced by temperature, as temperature can regulate metabolic growth and the proliferation of bacteria/viruses etc. that are shed as free-living single-celled organisms (Zeldis et al 2011b).

Temperature and salinity can also affect the associated biosecurity risks associated with individual species by controlling their range. For example in the case of the proliferation of invasive Pacific oysters, the southern distribution is limited to Nelson/Marlborough, as water temperatures further south are too low for successful reproduction (Quale 1969, Askew 1972, Dinamani 1974). Salinity can vary with season, climatic variation (Scavia et al 2002), and the catchment rainfall, with catchments that are dry in summer producing less runoff, elevating coastal salinities which then affect the distribution of fouling species (Handley unpub. data). Farm stocks that may be susceptible to biosecurity risks are usually at greatest risk in summer. Summer is when temperatures, and hence metabolic rates of farmed animals, are highest, dissolved oxygen levels in the water are lowest (hence the risk of oxygen deprivation is highest), and the proliferation of fouling populations is also greatest (Handley, unpub. data.).

Over the last decade aquaculture space allocation in New Zealand has predominantly been driven by constraint mapping, allocating space in areas that do not conflict with other users and stakeholders (e.g. Handley & Jeffs 2002). This strategy increases potential biosecurity risks by encouraging development of aquaculture at environmentally less favourable sites The use of ecosystem based approaches to aquaculture development that incorporate tools like GIS can incorporate biosecurity risks (if known) to optimise site selection even in cases of data poor environments (Aguilar-Manjarrez et al 2010, Soto et al 2008, Silva et al 2011).

14.3.1.2 SIGNIFICANCE OF EFFECTS

It is generally recognised that adverse ecological effects arising from pests, parasites and pathogenic species associated with aquaculture can result in a range of level of threat including (Molnar et al 2008):

f. disruptions to entire ecosystem processes with wider abiotic influences,
g. disruptions to wider ecosystem function, and/or keystone species or species/assemblages of high conservation value (e.g. threatened species),
h. disruptions to single species with little or no wider ecosystem impact,
i. little or no disruption.

The infection of marine farms by pest organisms can lead to the development of significant infestations on farm structures, which may then:

1. act as a reservoir for subsequent spread to natural ecosystems,
2. increase drag on cages and anchoring systems in high current areas, which in turn increases the chance of escapee effects if stocks are infected with pathogens or parasites (Forrest et al 2011)
3. significantly reduce the flow of water (in areas of lower current velocity), carrying vital food and oxygen to cultured species.

Examples of significant effects from pest fouling organisms on aquaculture activities in New Zealand include documented impacts from infestation of marine farms with *Undaria* and the colonial tunicate *Didemnum vexillum* (e.g. Forrest & Taylor 2002 and L. Fletcher, Cawthron, unpubl. data). As well as attached fouling organisms, aquaculture structures may also act as recruitment substrata for mobile pelagic or benthic species (e.g. jellyfish, ctenophores, sea star *Asterias amurensis*, sea cucumbers, or the crab *Carcinus maenas*, Forrest et al 2009, 2011).

Any attempt to assess the significance of potential effects of invasive pests, pathogens or parasites in terms of their magnitude will be limited by the lack of robust information on the affected environments, inherent difficulties in making reliable predictions regarding the invasiveness of difference species, and hence inferences regarding their direct or indirect effects (Forrest et al 2011). An example of the ecological effects stemming from a pathogen is the outbreak of pilchard herpes virus that was thought to have stemmed from pilchards imported for tuna aquaculture feed in South Australia. This event caused starvation and the recruitment failure of little penguins which prey on pilchards (Dann et al 2000). The potential effects of pests and pathogens are illustrated in Table 14.3 for finfish aquaculture in the Waikato region.

Table 14.2: Matrix illustrating the often unknown effects of pests, pathogens and parasites associated with finfish aquaculture in the Waikato Region. Examples are given of direct interactions (shaded cells) between potential biosecurity hazards and values in the Waikato region, and indirect effects (I). Direct interactions designated as: likely to be new and important (***), may be an important incremental risk above that already occurring (**), and probably a minor incremental risk (*). ? = direct interaction possible but significance unknown. From Forrest et al (2011).

Potentially affected uses and values	Component directly affected	Marine pests			Pathogens or parasites		
		Fouling	Predation	HABS	Virus	Monogenean	Digenean
Ecological							
Habitats and their biodiversity	Unstructured soft-sediment habitats	*	**	?			
	Structured soft-sediment habitats (physical or biogenic)	**	**	?			
	Zostera meadows	*		?			
	Saltmarsh			?			
	Rocky reef	**	**	?			
	Water column (plankton communities)			?			
Wildlife of conservation importance	Wading and seabirds	I	I	I	?+I		?
	Marine mammals	I	I	I	?+I		?
Wild fishery resources and fishing							
Finfish populations of commercial, recreational or customary importance	Conspecific finfish populations (kingfish or hapuku)			?	?	*	*
	Pelagic finfish populations (e.g. snapper, kahawai)			?	?	*	*
	Benthic finfish (e.g. flatfish) or reef-fish populations	I	I	?	?	*	*
Shellfish populations of commercial, recreational or customary importance	Infaunal soft-sediment shellfish (e.g. cockles, tuatua)	*	?	?	?		?
	Epibenthic soft-sediment shellfish (e.g. scallops)	**	?	?	?		?
	Reef-associated non-finfish species (e.g. paua, crayfish)	**	?	?	?		?
Harvesting of fish/shellfish (interference)	Pelagic finfish populations (e.g. snapper, kahawai)						
	Benthic finfish (e.g. flatfish) or reef-fish populations	*	*				
	Infaunal soft-sediment shellfish (e.g. cockles, tuatua)		*				
	Epibenthic soft-sediment shellfish (e.g. scallops)	**	*				
	Reef-associated non-finfish species (e.g. paua, crayfish)	*	*				
Harvesting of fish/shellfish (contamination)	Finfish or shellfish harvestability for human consumption			?	?	?	?

14.3.1.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Biosecurity control of aquaculture activities currently occurs through: resource consent conditions, farm practices and import health standards. The resource consenting process under the Resource Management Act (RMA) considers biosecurity via factors such as farm spacing, zoning [91], staged development and epidemiological units. Best farm practices are often described by industry codes of practice (NZMIC 2001, NZOIA 2007, NZSFA 2007). Import health standards are controlled by the Ministry for Primary Industries (MPI) and include requirements that must be met in the exporting country, during transit and on arrival. For example, existing standards cover:

- import of juvenile yellowtail kingfish (*Seriola lalandi*) from Australia,
- import of fish food and fish bait from all countries.

Possible prevention approaches that could be considered are summarised here as pathway management or on-farm management Forrest et al (2011).

Pathway management should focus on controls and surveillance on pathways from:

i. international source regions or pathways that are novel,
ii. pathways from domestic source regions known to be infected by recognised high-risk pests,
iii. pathways along which the frequency of transfers is considerably greater than that occurring as a result of other human activities.

Broadly there are two approaches to management of pathway risk (Forrest & Blakemore 2002), either a) avoid transfers on high risk pathways, or b) treat pathways to minimise risk. Both pathway management strategies have been used, for example, in relation to the New Zealand mussel industry (Forrest et al 2011). Surveillance strategies for pathways can focus on entry surveillance, routine surveillance or targeted surveillance of high risk areas. Entry surveillance includes activities such as routine screening at airports, ports and mail centres. MPI also commissions routine surveillance in ports and harbours around New Zealand. Targeted surveillance may be undertaken when activities such as harvest, grading or transfer of stock from hatcheries or between sites is undertaken.

Good on-farm management is often guided by industry codes of practice (NZMIC 2001, NZOIA 2007, NZSFA 2007). These should include farm cleaning and surveillance (MPI 2013). Farm cleaning guidelines should deal with factors such as frequency and waste disposal. Routine surveillance, undertaken on and around marine farms is often the first point of detection of pests, pathogens and diseases.

Recent New Zealand experience suggests that even when pest organisms become well-established, the benefits gained from even limited management success have the potential to greatly outweigh the consequences of uncontrolled fouling (Forrest 2007). To be effective, however, management requires buy-in from all marine stakeholders whose activities can spread pest organisms. Aquaculture companies can assist by:

j. identifying existing and future pests that threaten the aquaculture industry,
k. implementing surveillance of farm structures and associated vessels and infrastructure,
l. developing coordinated response plans for high risk species before they become established,
m. preventing incursions of new pests onto aquaculture structures.

For vectors of spread such as service vessels and farm equipment, preventative management options include:

i. maintenance of effective antifouling coatings,
ii. hull inspections and hull cleaning as necessary,
iii. early eradication of pests from farm structures before they become well established.

[91] The World Organisation for Animal Health's (OIE) online aquatic animal health code (http://www.oie.int/en/international-standard-setting/aquatic-code/access-online/) suggests establishing zones and using compartmentalization (through geographical separation) to manage biosecurity and epidemiological risks.

However, once incursions have occurred, the use of eradication treatments is only advised if the risk of re-invasion can be managed. Many eradication treatments have been used in an attempt to control fouling and pests either directly (Carver et al 2003, Coutts & Forrest 2005, Locke et al 2009a, Morrisey et al 2009), indirectly (Handley & Jeffs 2002, Handley 2002, Handley & Bergquist 1997) or via biological control agents (NRC 2010, Hidu et al 1981, Enright et al 1983, 1993, Cigarria et al 1998).

Perhaps the best method for controlling the spread of disease is through the use of management practices that call for the pathological inspection of animals to ensure that infected animals are not moved into areas that do not currently have endemic infections (WWF 2010). In New Zealand, in the absence of enforced stock transfer protocols, management of gear and vessel transfers between geographic zones by voluntary codes of practice developed by industry could be used to minimize risks, e.g., the New Zealand Mussel Industry Council Ltd. code of practice for transfer of mussel seed (NZMIC 2001).

The different prospective farmed groups: feed-added (referred to as finfish), filter-feeders (referred to as shellfish), and lower trophic level species (Undaria and sea cucumbers) and their potential impacts and management measures were covered in the literature review (MPI 2013) and are summarised in Table 14.3.

Table 14.3: Matrix of biosecurity management options and their relevance to key aquaculture groups (MPI 2013).

Management measure	Description	Finfish	Shellfish	Undaria	Sea cucumbers
Import					
Import health standards	For import of seedstock	y	n	n	n
Boarder Surveillance	Prevent import of macroscopic pests	y	y	y	y
Regulations on fouling on vessels/bilge water release	Prevent import of macroscopic pests/ fouling organisms/ harmful algae	y	y	y	y
Planning and development					
Site selection	Sites with appropriate environment for biological requirements of stock	y	y	y	y
Zoning	Sites location in relation to pathogen risks – other farms, processing plants, rivers, sewerage discharge	y	y	y	y
Vessel berthing	Segregate local vessels from vessels that move regionally (commercial or recreational)	y	y	y	y
Targeted surveillance	Routine monitoring for pre-determined range of species	y	y	y	y
Farm practices					
Fouling					
Management of nets, and equipment to minimise fouling	Regularly remove fouling organisms from equipment	y	y	n	n
Anti-fouling	Treat equipment with chemicals to prevent fouling	y	?	n	n
Transfer of equipment between sites/ regions	Prevent transfer of potentially contaminated equipment between sites				
Husbandry					
Appropriate stock husbandry	Minimise stress = reduce risk of disease becoming established	y	y	y	y
Management of feed so as not to attract birds/fish	Limit opportunity for transfer between sites/wild stocks through direct contact	y	n	n	n
Routine environmental monitoring linked to husbandry activities	Manage stock within environmental limits	y	y	y	y
Remove mortalities	Limit opportunity for reservoir of disease to accumulate	y	n	n	n
	Reduce attraction of predators	y	n	n	n
Use of processed feeds	Feeds heat treated to kill pests/pathogens	y	n	n	y
Surveillance	Observe and record mortality causes, unusual fouling etc.	y	y	y	y
Stock transfer		y	y	y	y
Hatchery testing for disease	Prevent diseased stock being sent to sites	y	y	y	y
Single year-class sites	Prevent disease transmission between year classes	y	n	y	y

Table 14.3: Continued … Matrix of biosecutriy management options and their relevance to key aquaculture groups (MPI 2013).

Management measure	Description	Finfish	Shellfish	Undaria	Sea cucumbers
Harvest					
Isolate waste streams from growing areas	Prevent reintroduction of pests/pathogens to harvested sites	y	y	y	y
Fallow Sites	Reduce opportunities for reintroduction of pests/pathogens from intermediate hosts	y	y	y	y
Education					
Codes of practice	Educate and alert staff to biosecurity requirements	y	y	y	y
Public notification	Alert public to biosecurity risks	y	y	y	y
Eradication					
Culling	Cull diseased stock to remove pathogen/ pest	y	y	y	y
Fallowing	Remove stock from an area to allow host mediated pathogen to die out	y	y	y	y
Manual removal of macroscopic organisms	Eradication of individual pest organisms early in the invasion process	y	y	y	y
Treatment technologies	Treatment of whole farms or bays to remove pests	y	y	y	y
Pharmaceutical treatment	Treatment of individual affected stocks to remove pathogen/parasite	y	n	n	n

14.3.2 PELAGIC EFFECTS

There is a large volume of international literature on the effects of shellfish and salmon farming on the pelagic environment and much of this material is referenced in three local reviews: finfish (Forrest et al 2007a), shellfish (Keeley et al 2009) and oysters (Forrest et al 2007b) and summarised in MPI (2013), the reader is referred to these for more detail.

14.3.2.1 INTRODUCTION

This section deals with near-field (approximately at the scale of the farm) pelagic effects (those seen in the water column). This should be read in conjunction with the benthic effects (where wastes from the pelagic zone settle) and the cumulative effects sections (where far-field pelagic effects are seen).

The pelagic zone is the zone where:

- Filter-feeders extract phytoplankton, microzooplankton and organic particulates from the water column, which can reduce food available to other consumers (Zeldis et al 2004).
- Dissolved oxygen (DO) is extracted by respiration of farmed organisms and this can potentially lead to DO depletion when cages are heavily stocked or where they are located in shallow sites with weak flushing (La Rosa et al 2002). Excessive DO depletion in the water column could potentially stress or kill the fish and other animals, with sediment DO depletion resulting in the release of toxic by-products (e.g. hydrogen sulphide) into the water, which can also have adverse effects on fish and other organisms (Forrest et al 2007a).
- Fish pellets and the excretory products and waste products of cultured and fouling organisms are received. Wastes excreted can either be as a particulate "cloud" that disperses rapidly, in the case of fin-fish, or be bound in long strands composed of digested and undigested plankton, in the case of filter-feeders (Reid 2007). The difference in shellfish and finfish faeces can result in different biochemical impacts on the pelagic zone (Reid 2007). Dissolved farm waste has the potential to increase ambient DIN (Dissolved Inorganic Nitrogen), the potential effects of this are usually experienced away from the farm so will be dealt with in the cumulative effects section.

14.3.2.2 SIGNIFICANCE OF EFFECTS

The significance of these key primary impacts depends on the assimilation capacity (or carrying capacity) of the environment. Local hydrodynamics, water depth and ambient oxygen levels are the most critical criteria for determining the pelagic impacts of aquaculture (Zeldis 2008a, Zeldis et al 2010, 2011a). In shallow areas with slow currents, effects will be more pronounced compared to a deep site with strong flow and good flushing. In the New Zealand situation where most shellfish farms are located in well flushed areas, nutrient enrichment beyond the farm boundaries is presently difficult to detect (Zeldis 2008a). In addition there are a number of design and management factors that will greatly influence potential impacts:

- Density of farms in a unit volume of water; more farms will generally have more effect.
- Stocking density; higher stocking densities will generally have more effect, this may differ seasonally.
- Feed conversion ratio (FCR for feed-added species): FCR is a measure of the efficiency of growth relative to feed used, the global range is 1.1 to 1.7 on average (Reid 2007). The lower the FCR the less waste will be produced.
- Cage designs and orientation to prevailing current direction. This will impact on drag on passing water masses, flushing of cages and settlement of biofouling organisms.

Undaria and sea cucumbers have less significant ecological effects on the pelagic environment since seaweeds utilise dissolved nutrients for growth (mainly dissolved inorganic nutrients (DIN)) and sea cucumbers feed on organic material on the surface of the seabed (MPI 2013). The reader is guided to the document MPI (2013) for coverage of the specific threats created via farming *Undaria* and sea cucumbers.

14.3.2.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Pelagic effects can be partially controlled through carefully selecting sites, deep sites (more than 25 m) with high currents are preferable. The farm design, orientation and stocking rates should then be appropriate to that site. Good farm management (e.g. compliance with The New Zealand Finfish Aquaculture Environmental Code of Practice (2007)[92]) should include reducing biofouling on nets by regular cleaning and removal of biofouling waste. Monitoring, adaptive management and the use of Integrated Multi Trophic aquaculture (IMTA) are also potential mitigation measures (see the cumulative effects section for more discussion of these). Notably pelagic effects are reversible upon removal of the farm.

Models are an important component in determining pelagic effects at a site and a number of potential model improvements are identified in MPI (2013), including improved methods for determining ecological carrying capacity.

14.3.3 MARINE MAMMALS

The reader is referred to MPI 2013 (and references therein) for more detail.

14.3.3.1 INTRODUCTION

Several overseas studies (Würsig & Gailey 2002, Kemper et al 2003, Wright 2008) have characterised the possible interactions between marine mammals and aquaculture, which include:

- competition for space (habitat modification or exclusion),
- potential for entanglement,
- underwater noise disturbance,
- attraction to artificial lighting,
- possible flow-on effects due to alterations in trophic pathways.

The physical location of the farm within important habitats or migration routes of New Zealand marine mammal species is the main factor that leads to potentially adverse interactions or avoidance issues. Once a farm is within the habitat or migration route of a species, the types of gear and equipment employed, as well as operational procedures around regular farm activities, influence the probability and scale of the impacts discussed above.

14.3.3.2 SIGNIFICANCE OF EFFECTS

Incidences of marine mammal entanglement with aquaculture operations are very few in New Zealand despite over 25 years of sea-cage salmon farming, due in part to the relatively small scale of this industry and operational procedures that minimise entanglement risk

[92] A copy of these codes can be obtained from Aquaculture New Zealand (www.aquaculture.org.nz)

at New Zealand farms (Forrest et al 2007c). Studies in New Zealand have so far only addressed interactions between mussel farms with Hector's (Slooten et al 2001) and dusky dolphins (Markowitz et al 2004, Vaughn & Würsig 2006, Duprey 2007, Pearson et al 2007). Collectively, these works suggest that while some marine mammal species are not completely displaced from regions as a whole, they do not appear to be utilising habitats occupied by shellfish farms in the same manner as prior to the farms' establishment.

These effects may need to be reconsidered in relation to any larger scale and offshore developments in New Zealand waters (MPI 2013). For instance, as multiple farms or several types of aquaculture begin to overlap or enlarge in their locations, marine mammal populations may be excluded from particular bays or regions depending on the species and its sensitivity to such activities. In the case of depleted populations (e.g., southern right whales), the issues of low population size and a fairly isolated population structure make these species more vulnerable to such impacts than other species. This large variation in the significance of aquaculture impacts (depending on the size of the affected populations) on New Zealand marine mammals makes developing and implementing one set of effective management guidelines or standards extremely difficult.

14.3.3.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Farm locations need to be carefully selected to minimise the likelihood of overlap with marine mammal migration routes and/or known habitats. In Admiralty Bay, where overlap with dusky dolphins was a concern, and distribution patterns were not well known, three years worth of presence monitoring was required prior to commencement of aquaculture development (Mulcahy & Peart 2012). The risks associated with physical interactions can be further minimised by adopting maintenance and operational guidelines and standards for farm structures as well as any noise-generating equipment (BCSGA 2001, SAD 2011). Some examples include enclosing predator nets at the bottom, keeping nets taut, using mesh sizes of less than 6 centimetres (Kemper et al 2003), keeping nets well maintained (e.g., repairing holes), and reducing feed waste. In Admiralty Bay surface lines were removed from the water over winter to minimise interactions when dolphins are more active foragers (Mulcahy & Peart 2012). Unfortunately, detailed information on abundance, distribution and critical habitats is available for only a handful of New Zealand's marine mammals. Monitoring records of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site along with any detailed observations of their time spent under or around the farm structure should be compiled when possible. Future research needs to focus on those species most likely to come in contact with aquaculture in the future. In addition, ongoing research into the types of design and maintenance features and operational procedures that minimise entanglement risk should be supported. For example, cage technology in South Australia has developed and improved to the point where predators are excluded by the cage structures themselves (Taylor et al 2010).

14.3.4 BENTHIC EFFECTS

This area is covered by the review of Forrest et al (2007c) and summarised in MPI (2013), the reader is referred there for more detail.

14.3.4.1 INTRODUCTION

The benthic effects of aquaculture can be classified as:

- Organic enrichment and smothering which can lead to (Forrest et al 2007c):
  - localised biodeposition leading to enrichment of the seabed and associated microbial processes, and chemical and biological changes (including to infauna and epifauna, e.g. Christensen et al 2003, Keeley et al 2009);
  - in the case of intensive filter-feeder cultivation widespread biodeposition can potentially lead to a reduction in natural deposition rates;
  - smothering of benthic organisms and changes in sediment physical composition;
  - widespread biodeposition leading to mild enrichment in naturally depositional areas which has the potential for effects on reefs, inshore habitats and sensitive taxa;
  - sediment contamination (copper and zinc, covered in the additives section).
- Biofouling and drop-off of debris which can lead to:

  - smothering and changes to physical composition of sediments (Keeley et al 2009);
  - creation of habitat structure (Davidson & Brown 1999) and aggregations of predators and scavengers (Inglis & Gust 2003).
- Seabed shading by structures which can change localised productivity under the farm (Huxham et al 2006).

The magnitude and spatial extent of seabed effects from finfish farms are a function of a number of inter-related factors, which can be broadly considered as farm attributes and physical environment attributes.

Farm attributes that can affect the mass load of organic material deposited to the seabed include the following:

- fish stocking density and settling velocities of fish faeces (Magill et al 2006);
- the type of feed and feeding systems, the feeding efficiency of the fish stock and the settling velocities of waste feed pellets;
- the type of cage structure can also influence depositional effects through differences in fish holding capacity, which affects feed loadings and may affect feeding efficiencies. Furthermore, cage design and position may affect the site's hydrodynamics; any reductions in flow will reduce waste dispersal and flushing, potentially resulting in depositional effects that are more localised but also more pronounced.

The capacity of the environment to disperse and assimilate farm wastes is a function of the attributes of the site (primarily water depth and current speeds), although assimilative capacity may also vary seasonally in relation to factors such as water temperature. Consequently, sites located in deep water (more than 30 m) and exposed to strong water currents (more than 15 cm s-1 on average) will have more widely dispersed depositional footprints with less intense enrichment than shallow, less well-flushed sites (e.g. Molina Dominguez et al 2001, Pearson & Black 2001, Aguado-Gimenez & Garcia-Garcia 2004).

14.3.4.2 SIGNIFICANCE OF EFFECTS

In general, benthic effects from feed-added and filter-feeder aquaculture are similar as they are caused by debris and waste falling to the seafloor generally in close proximity to the farm. However the higher volume of waste and the uneaten food involved in feed-added farming and its more particulate nature generally means that effects from feed-added aquaculture are greater than those seen from filter-feeder aquaculture, and can be seen further away (within 1 km for feed-added species as opposed to within 100 m for filter-feeders (Forrest et al 2007c)). In extreme cases this can lead to anoxia and outgassing of hydrogen sulphide and methane. At low flow sites very little resuspension occurs and effects are largely constrained to the local environment (Forrest et al 2007). At high flow sites, however, the majority of the biodeposits are resuspended, exported and eventually deposited in a very diffuse form in neighbouring low flow areas (e.g. in blind bays). If depositional inputs are sufficiently elevated then there is potential for effects in the form of increased far-field deposition. This may result in very mild, but potentially spatially extensive organic enrichment. The ecological effects of farming Undaria and sea cucumbers are likely to be less severe on the benthos then those from feed-added or filter-feeding species (Keeley et al 2009).

Fish farm and mussel farm studies in New Zealand and overseas indicate timescales of recovery ranging from a few months in well-flushed areas where effects are minor, to a few years in poorly flushed areas where moderate/strong enrichment has occurred (references within MPI 2013).

14.3.4.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Management measures for mitigating benthic impacts for aquaculture are similar to those for mitigating pelagic impacts (Section 14.3.2.3). Site selection is important for the same reasons, to maximise the dispersive properties of the site, but should also try to avoid potentially sensitive/valuable benthic habitats (conservation areas, reefs etc.). The fine scale positioning of the cages should optimise the dispersal of wastes and minimise impacts on potentially sensitive habitats. Depositional modelling should be used to predict benthic effects from a range of farming scenarios to inform decisions regarding optimum (sustainable) site-specific feed capacities. The use of Environmental Quality standards (EQS), staged development and a Modelling-Ongrowing-Monitoring (MOM) approach are also potentially beneficial (MPI 2013).

14.3.5 SEABIRD INTERACTIONS

The reader is referred to MPI 2013 (and references therein) for more detail.

14.3.5.1 INTRODUCTION

In New Zealand, the generally perceived negative effects of both feed-added aquaculture and filter feeder aquaculture have centred on entanglement (resulting in birds drowning) and habitat exclusion and displacement from feeding grounds. The location of the farm within the range of seabirds and the conservation status (which is a measure of the risk of extinction) of these seabird species are the main factors that may lead to issues of sustainability and conservation concern. Of particular concern are the location of farms in relation to breeding and feeding sites and the operational procedures of regular farm activities (which can affect things like likelihood of entanglement).

Potential negative effects may include disturbance of breeding colonies and birds feeding, blockage of the digestive tract following ingestion of foreign objects, injury or death following collision with farm structures and the spread of pathogens or pest species. In contrast, a potential beneficial effect includes the provision of roost sites closer to foraging areas (Lalas 2001), saving energy and enabling more efficient foraging; this is most likely to benefit shags, gulls and terns (MPI 2013). Likewise, the attraction and aggregation of small fish around marine farm structures (Grange 2002) may provide enhanced feeding opportunities for piscivorous seabirds.

14.3.5.2 SIGNIFICANCE OF EFFECTS

Siting of a farm close to a seabird breeding colony is very likely to have an immediate adverse effect that will continue as long as the duration of the farm. However, there are no reports of seabird deaths as a result of entanglement in aquaculture facilities in New Zealand (Butler 2003, Lloyd 2003) as the use of top-nets over sea cages in New Zealand appears to effectively exclude seabirds (MPI 2013). The potential effects of habitat exclusion by feed-added farms in New Zealand are considered to be insignificant given the small area occupied in relation to the large total area of suitable habitat available for foraging seabirds (MPI 2013).

14.3.5.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

At present, potential risks are identified on a case-by-case basis. The most obvious is the choice of site for a farm to avoid disturbance to sensitive breeding colonies of seabirds. Good operating practices (for feed-added farms) such as enclosing predator nets above and below cages, controlling litter, minimising the use of lights at night, keeping nets taut and using mesh sizes less than 6 centimetres, all minimise the chances of negative seabird interactions. Given the current relatively small size of the aquaculture industry in New Zealand, the overlap of farming activities with the feeding areas of seabirds is unlikely to present significant issues (MPI 2013).

There are significant knowledge gaps concerning almost all seabird species in New Zealand. Detailed information on the time-specific distribution, abundance and critical habitats is lacking. Also missing is information on key prey species of seabirds, particularly those that may be affected by aquaculture. In addition, there should be ongoing monitoring (where an issue is identified) and research into the operation, design and maintenance of farm structures that minimise disturbance and entanglement risks. Little is known about the exclusion distance needed from different species of foraging and feeding seabirds, for example, proposed exclusion distances for king shags in the Marlborough Sounds range from 100 to 1000 m (Davidson et al 1995, Taylor 2000), but more recently, Lalas (2001) noted that king shags resting ashore or on emergent objects only flew off when approached to within 30 metres.

14.3.6 EFFECTS FROM ADDITIVES

Background data on the use and impact of chemicals locally are from research on salmon aquaculture and have been reviewed previously (Forrest et al 2007c, Wilson et al 2009, Burridge et al 2010, Clement et al 2010, Forrest et al 2011, MPI 2013), the reader is referred there for more detail.

14.3.6.1 INTRODUCTION

The main intentional use of additives is as antibiotics, antibacterials and other therapeutants (MPI 2013). The concern with therapeutants is their potential to affect non-target organisms (phyto- and zooplankton, sediment bacteria) and the rise of resistant bacteria and/or parasites (GESAMP 1997, Forrest et al 2007c, Forrest et al 2011). The main unintentional additions are from zinc in fish feed and copper when used as an antifouling agent on structures (MPI 2013). The main concern with metals is their toxicity to animals (Forrest et al 2007c, Clement et al 2010, Forrest et al 2010).

14.3.6.2 SIGNIFICANCE OF EFFECTS

Currently, there is minimal use of chemicals such as antibiotics, antibacterials and other therapeutants intentionally added to the marine environment by the New Zealand aquaculture industry; however, culture of native species may lead to the emergence of diseases that may require new treatments.

Recent assessments at salmon farming sites in the Marlborough Sounds revealed locally elevated copper and zinc levels (with maxima exceeding ANZECC (2000) sediment quality guideline values between 2005 and 2010 (Hopkins et al 2006)). Potential adverse effects from high zinc exposures range from interference with growth at low concentrations to behavioural abnormalities at high concentrations (Eisler 1993, Burridge et al 2010); but elevated metal concentrations do not necessarily indicate adverse ecological effects as they may not be bioavailable (Forrest et al 2007c).

14.3.6.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

All species cultured for human consumption from aquaculture have to meet strict food safety standards, which regulate the acceptable concentrations of metals, chemicals and additives in food products. New Zealand salmon farmers must also comply with the New Zealand Salmon Farmers Association’s Finfish Aquaculture Environmental Code of Practice, with harvesting and processing in accordance with New Zealand food safety standards.

No chemical/additives are known to be used in the farming of bivalves and lower trophic level species. If these are used in the future ‘best management practice’, should minimise food wastage and the use of therapeutants, and hence help mitigate potential effects. The most important means to reduce and manage the overall antibiotic usage would be to support development of targeted disease management strategies and alternative therapies, in particular vaccines, which are not presently licensed for use, nor used, in New Zealand.

The potential for environmental issues from therapeutant use in the future will need to be assessed on a case-by-case basis. Use of therapeutants in New Zealand is low, but their persistence in the environment, the induction of resistance of targeted organisms and the effects on non-target organisms are the main knowledge gaps. Studies on the bioavailability and forms of the metals will give better understanding of their toxicity; a focus is needed on sub-lethal effects on individual species and the broader effects on benthic communities.

14.3.7 ESCAPEE EFFECTS

The subject of escapee effects from aquaculture is well covered for finfish by the reviews of Forrest et al (2007c) for New Zealand and Jensen et al (2010) for Norway, and for shellfish by Keeley et al (2009) and summarised in MPI (2013). The reader is referred to these sources for more detail.

14.3.7.1 INTRODUCTION

It is useful to recognise that the human-mediated transfer of numerous marine organisms to New Zealand and around the coastline is an issue with a long history that continues today. Historically, this reflects deliberate transplants of marine organisms (including salmon), and more recently the inadvertent transfer of a range of native and non-indigenous marine species (including fish), especially via vessel movements (e.g., Hayward 1997, Cranfield et al 1998). The alteration to marine ecosystems and transfer of fish diseases via these unmanaged mechanisms is well recognised (Ruiz et al 2000, Hilliard 2004), and hence any incremental risk from finfish culture should be considered within this broader context.

The effects of escapees from aquaculture vary considerably in relation to the following factors (Forrest et al 2007c):

- the numbers involved in the escape episode,
- the location of the farm in relation to wild populations and its size, distribution and health,
- whether the species is native (hapuku, kingfish) or introduced (salmon),

- whether the brood stock is hatchery bred or wild sourced,
- the fish harvest size in relation to reproductive maturity and the ability of gametes to survive and develop in the wild,
- the ability of escapees to survive and reproduce in the wild, as determined by their ability to feed successfully and interbreed with wild stocks.

The main effects of escapees (Forrest et al 2007c) for feed-added species are in terms of:

- competition for resources with wild fish and related ecosystem effects from escapee fish (e.g., through predation),
- alteration of the genetic structure of wild fish populations by escapee fish and potential loss of genetic integrity in the wild populations,
- transmission of pathogens from farmed stocks to wild fish populations.

The main factors controlling the number of fish escaping, and their subsequent effects are the integrity of the nets used to contain the fish and the amount of difference between the wild fish and farmed fish in terms of their genetics and their pests and diseases.

14.3.7.2 SIGNIFICANCE OF EFFECTS

The likelihood of escapee effects in New Zealand is low, based on the current small size of the industry, limited overlap of wild and farmed populations (in terms of salmon, Deans et al 2004) and the broad home range (in terms of kingfish and hapuku) and likelihood of high genetic diversity in these native species (Paul 2002, Forrest et al 2007c). If escapee effects are seen on wild populations they are, however, likely to be irreversible and could potentially be at a national scale.

14.3.7.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Management strategies to minimise escapees are usually based upon maintaining net integrity. In Norway reporting of escapes, and estimation of numbers escaped is mandatory and therefore provides a baseline to improve upon (Jensen et al 2010). In New Zealand escapee events are not reported to any central authority. At this time no knowledge is available on the potential effect that escaped farmed kingfish or hapuku could have upon the wild populations.

14.3.8 EFFECTS ON WILD FISH

The reader is referred to MPI 2013 (and references therein) for more detail.

14.3.8.1 INTRODUCTION

A potential immediate effect on wild fish populations from the development of a finfish farm is the degradation or loss of habitat beneath or within close proximity to new farm structures (e.g., spatial overlap with species' critical spawning grounds and/or migration routes). By adding three-dimensional structures to the marine environment, finfish farms provide habitat for colonisation by fouling organisms and associated biota (Glasby 1999, Connell 2000, Dealteris et al 2004). These newly colonised structures and the habitat they create tend to attract wild fish species seeking foraging habitat, detrital food sources and/or refuge from predators (e.g., Dealteris et al 2004). Submerged artificial lighting at night is frequently used on finfish farms to control maturation and increase productivity (e.g., Porter et al 1999). The lighting can enhance the attraction of wild fish to farm structures (Cornelisen & Quarterman 2010).

The main effects associated with the creation of artificial habitats, and attraction of wild fish species to aquaculture structures, include the following:

- enhanced predation on wild fish by higher trophic level predators (e.g., seals) and predation by cultured fish on wild fish trapped within cage structures,
- consumption of waste feed by wild fish (Felsing et al 2004, Dempster et al 2005),
- changes in recreational fishing patterns and pressure (N. Keeley, pers. obs.) which could affect wild fish populations differently than in the absence of the structures,
- larval fish depletion by filter-feeders (as observed by Davenport et al (2000) and Lehane & Davenport (2002)) and/or potential trophic interactions (e.g., alteration of plankton composition and food availability).

14.3.8.2 SIGNIFICANCE OF EFFECTS

In general, the effects of aquaculture on wild fish populations are likely to be small in comparison with the effects on other aspects of the marine ecosystem, such as effects on the seabed. The effects of farming hapuku or kingfish on wild fish are expected to be generally similar to those from farming of king salmon already in New Zealand. Modelling of larval egg depletion (Broekhuizen et al 2002) and other work suggest that while the feeding of fish in farms could have an impact on recruitment to fisheries; the scale of this effect will largely be governed by the extent of the culture, the behaviour and characteristics of larvae and the flow dynamics of the regions in question (MPI 2013).

The effects of farming filter-feeders are likely to be less than those of farming feed-added species (due to the lack of food added as an attractant), but shell-drop is likely to create a (lesser) attraction. The extent of impacts from the farming of Undaria and sea cucumbers is likely to have a lesser impact than feed-added or filter-feeding aquaculture, as they neither require feed nor exhibit shell drop (MPI 2013).

14.3.8.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Management options identified in MPI (2013) for minimising effects on wild fish include proper site selection, which requires assessment of potential impacts of farm developments on wild fish stocks. Assessments should identify proximity and impact to critical, sensitive or protected habitats and species, with particular reference to potential impacts on spawning grounds or juvenile habitats. Careful management of feed quality and feeding practices should minimise waste feed inputs to the surrounding environment and minimise effects on wild fish populations. The effects of finfish farms on wild fish populations in New Zealand are not well documented and knowledge gaps exist, particularly with regard to the effects of finfish farms on fish movements and various reproductive stages (e.g., larval settlement).

14.3.9 HYDRODYNAMIC EFFECTS

The reader is referred to MPI 2013 (and references therein) for more detail.

14.3.9.1 INTRODUCTION

Hydrodynamic conditions are an important determinant of the suitability of a site for aquaculture, as well as the spatial size and magnitude of the environmental effects. Here, hydrodynamics refers to the physical attributes of the water including:

- currents,
- stratification, and
- waves.

Current speed is a key factor determining the exchange of water through the cage, areas over which deposition occurs, where the dissolved material is transported and how it is dispersed and the re-suspension of material. Stratification refers to the layering of water caused by differences in temperature and salinity. Stratification can play a strong role in oxygen depletion by restricting vertical transport of oxygen from the surface to deeper waters. Waves can break-up stratification, play a key role in determining which species can inhabit an area and can re-suspend material.

14.3.9.2 SIGNIFICANCE OF EFFECTS

Aquaculture operations can have a number of effects on hydrodynamics. The drag from cages can affect currents, causing wakes, turbulence and flow diversion (Helsley & Kim 2005, Venayagamoorthy et al 2011). Low velocity areas have a higher probability of issues of deposition, oxygen depletion and ammonium build-up. There are likely to be interactions between stratification and fish cages in the form of selective blocking, restricted underflow, generation of internal waves and vertical mixing (Plew et al 2006). Fish swimming may also play a role in enhancing mixing and causing upwelling within cages (Chacon-Torres et al 1988). Wave energy is attenuated by fish cages, and this will result in a shadow of reduced wave activity behind the farmed areas (Chan & Lee 2001, Lader et al 2007).

While some physical effects may affect other physical processes directly, for example attenuation of wave energy affecting surf or coastal sediment transport; it is generally more important to consider how physical effects influence ecological processes. For example, the physical effect of reduced current speeds caused by drag from aquaculture structures (Helsley & Kim 2005, Venayagamoorthy et al 2011) may result in an increase in the flushing time of a bay (Plew 2011). This in turn may lead to increased nutrient concentrations. Reductions in wave energy near the coast may change the mix of species inhabiting an area.

14.3.9.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

The physical hydrodynamic effects will interact strongly with pelagic and benthic processes. Selection of suitable indicators for physical changes should ideally be based on their relative importance in determining the habitat for ecological communities in an area. However, it is this link between the physical and ecological changes that is often the least understood area of hydrodynamic impacts.

14.3.10 CUMULATIVE IMPACTS

The following section draws heavily on previous reviews of the environmental effects of finfish (Forrest et al 2007c) and non-finfish aquaculture (Keeley et al 2009). Complementary information on the wider ecosystem effects of aquaculture in relation to the water column is provided in Section 14.3.2: Pelagic Effects. The reader is referred to MPI 2013 (and references therein) for more detail.

14.3.10.1 INTRODUCTION

The previous sections (14.3.1–14.3.9) have focused on issue-specific ecological effects of aquaculture developments on the marine environment. Our understanding of these effects is largely based on farm-scale assessments and monitoring; the potential for wider-ecosystem effects (e.g. far-field benthic enrichment, effects on fish populations, migrating mammals, etc) is acknowledged but is far less well understood. As aquaculture develops and the number of farms in coastal waters increases, wider-ecosystem issues become more important to consider due to the cumulative environmental effects that could arise from multiple farms combined with additional anthropogenic stressors affecting, and possibly interacting with natural marine processes (see Figure 14.4 for an example of multiple stressors interacting with natural processes).

Within the context of aquaculture development in the marine environment, cumulative effects are defined here as:

> *Ecological effects in the marine environment that result from the incremental, accumulating and interacting effects of an aquaculture development when added to other stressors from anthropogenic activities affecting the marine environment (past, present and future activities) and foreseeable changes in ocean conditions (i.e. in response to climate change).*

A number of examples of potential cumulative impacts of aquaculture exist, three of these will be given here to illustrate the definition above:

- Drop off of mussels, shells and biofouling organisms onto the seabed beneath mussel farms, can lead to the creation of reef-like habitat, and alter the composition and abundance of benthic organisms beneath farms (see Section 14.3.4). Where this occurs in high densities such as the ribbon-like developments in the Marlborough Sounds, this could lead to additive (cumulative) effects on the wider ecosystem due to alteration of a larger proportion of the benthos.
- In the case of farm structures, aquaculture involving numerous farms situated along the coast could also have cumulative effects on nearshore currents and waves, which in turn could affect important processes (e.g. larval transport, nutrient exchange) along the shoreline (see Section 14.3.9). As aquaculture development intensifies, there is likely to be an increase in man-made structures and boat traffic, increasing the risk of invasion and establishment of pests. Cumulative degradation of the marine environment from multiple stressors compromises habitat quality and could enhance biosecurity risks by increasing productivity and proliferation of pest species such as invasive macroalage (e.g. *Undaria*) and invertebrates (e.g. the bivalve *Theora lubrica* and tunicate *Styela clava*) that thrive on the benthos under conditions of high organic enrichment (Section 14.3.1 provides comprehensive information on methods for minimising biosecurity risk that are applicable to wider, regional scales).

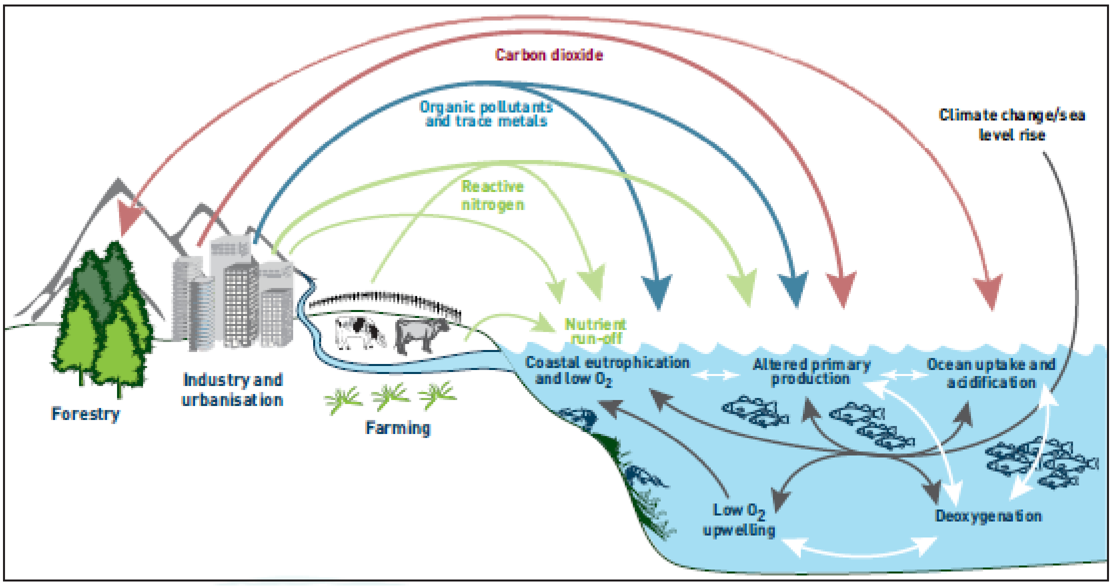


Figure 14.4: Conceptual diagram of anthropogenic influence in marine ecosystems.

Limited resources and uncertainty in understanding all of the potentially complex interactions between aquaculture, other stressors and the environment necessitates the need to focus on those aspects of aquaculture most likely to contribute to cumulative environmental change. Hence, increasing emphasis has been placed on assessing the contribution of aquaculture to cumulative changes in nutrient conditions and primary production, and in turn the knock-on effects on the wider ecosystem (see Hargrave et al 2005, Volkman et al 2009 and chapters therein). All forms of aquaculture addressed in this report contribute to these nutrient effects, whether through nutrient emissions to the water column and seabed, or the net extraction of plankton (filter-feeding bivalves) and nutrients (nutrient uptake by macroalgae) from the water column. The following sections focus on the potential far-field nutrient implications of aquaculture.

14.3.10.2 SIGNIFICANCE OF EFFECTS

The particular concern with the potential expansion of fish farms is the potential risk of eutrophication (SEPA 2000, Hargrave et al 2005, Diaz et al 2012). Eutrophication is the process where excessive nutrient inputs to a water body result in accelerated primary production (phytoplankton and macroalgae growth) and flow-on effects to the wider environment such as reduced water clarity, physical smothering of biota, or extreme reductions in DO because of microbial decay (Degobbis 1989, Cloern 2001, Paerl 2006). On a global scale, runoff from land-based agriculture has been identified as the primary driver of intense eutrophication of coastal environments, however, feed-added forms of aquaculture have been singled out as an important emerging contributor to nutrient enrichment (Diaz et al 2012).

Nutrients of varying particulate and dissolved organic and inorganic forms are added to the environment as a result of feed-added aquaculture. Particulate organic nitrogen (PON) and phosphorus (POP) are primarily deposited onto the seabed as fish faeces but also as waste feed pellets and particles. Farmed fish also excrete dissolved inorganic nutrients such as ammonium (NH4). Smaller particles of feed in the water column (through the addition of feed and/or via resuspension) can be consumed by other organisms such as zooplankton and shellfish, which, through subsequent excretion, in turn contribute to the dissolved nutrient pool. The dissolved inorganic nutrients from feed-added aquaculture combined with other sources of nutrient inputs can fuel the growth of phytoplankton (Wu et al 1994) and at high concentrations can cause harmful phytoplankton blooms (Sorokin et al 1996). In New Zealand's temperate waters, nitrogen may be the nutrient limiting phytoplankton growth under certain conditions e.g. when concentrations are generally low and light is plentiful (MacKenzie 2004, Howarth & Marino 2006). Complicating matters is the fact that nutrients from finfish farms are only one source of nutrients in the marine environment, and, like other sources, their inputs vary over time, e.g. salmon farms in the Marlborough Sounds increase feed levels by about 50% during summer months, which is also the period of greatest light availability for primary production. Internationally there have been experiences of blooms of species that produce biotoxins, some of which can be directly toxic to fish, and others which can accumulate in shellfish and affect consumers. As far as is known to date salmon farming in New Zealand has not given rise to any harmful phytoplankton blooms and such effects are unlikely in the near future unless considerable new development occurs (Forrest et al 2007c).

The risk of exceeding the assimilative capacity and accelerating eutrophication will be dictated by the physical characteristics of a region, such as retention time, water depth and ambient nutrient concentrations, combined with the intensity and types of existing and planned aquaculture and upstream land-based developments. There is compelling evidence that bivalve aquaculture can affect nutrient cycling and the quantity and quality of food (plankton) across a range of spatial scales from local to system-wide (Prins et al 1998, Cerco & Noel 2007, Coen et al 2007). In turn, the quantity and quality of food available to other consumers could be affected (Prins et al 1998, Dupuy et al 2000, Pietros & Rice 2003, Leguerrier et al 2004), with consequences for local populations of higher trophic level organisms such as fish.

In some regions where numerous farms with high-density cultures occur, there is the potential risk of exceeding the region's capacity to sustain high shellfish production and the wider ecosystem itself. An example is Pelorus Sound, where questions around the concept of carrying capacity arose following observed decreases of about 25% in Greenshell mussel yields between 1999 and 2002 (Zeldis et al 2008). These reductions were attributed to climatic forcing conditions and inter-annual variability in phytoplankton biomass over multi-year time scales (Zeldis et al 2008). This suggests that this region is close to sustainable production limits during years of naturally low primary production.

14.3.10.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

The management of cumulative effects in the marine environment can be addressed using a two-tiered approach that not only considers the contribution of effects from individual developments, but also an overall regional assessment of wider environmental change in response to the many stressors impacting on the marine environment (e.g. Dubé 2003). Critical to regional assessments of cumulative effects in the marine environment is accessibility and coordination of datasets, including those derived from consent monitoring at individual farms, and long-term State of the Environment (SoE) monitoring programmes. Standardised monitoring requirements for aquaculture is an important step in ensuring the usefulness of consent monitoring datasets within broader-scale assessments. The requirements for assessing and managing cumulative effects fall beyond the scope of a single consent applicant or industry and are best dealt with through regional councils (e.g. Dubé 2003, Hargrave et al 2005, Zeldis 2008a,b) or central government departments (Morrisey et al 2009, Zeldis et al 2011a,b).

Two ongoing projects will help address monitoring requirements for aquaculture. An ongoing MPI Biodiversity project "Marine Environmental Monitoring Programme" (ZBD2010-42) is seeking to address the following two objectives:

4. prepare an online inventory of repeated biological and abiotic marine observations/datasets in New Zealand,
5. review, evaluate fitness for purpose, and identify gaps in the utility and interoperability of these datasets for inclusion in a Marine Environmental Monitoring Programme (MEMP) from both science and policy perspectives.

Therefore any attempts to standardise monitoring datasets for aquaculture should try to learn from the experience or recommendations of this project. In addition the Aquaculture Planning Fund project 12/04 "Guidance for aquaculture monitoring in the Waikato Region" will develop an environmental monitoring framework to manage environmental change from aquaculture growth that will incorporate SOE monitoring, consent monitoring and predictive monitoring and have application to other regions.

Spatial modelling tools offer a way of estimating the extent to which the cumulative effects of aquaculture may be approaching ecological carrying capacity on "bay-wide" and "regional" scales. However, knowledge gaps are still evident in these models; particularly in the biological aspects (e.g. feeding behaviour and growth of the shellfish) which are still areas of active research (particularly within the Sustainable Aquaculture MBIE funded programme CO10X0904).

Some generalisations have been proposed in terms of carrying capacity, but these are not always in agreement. Using 'sustainability performance indicators', Gibbs (2007) suggests that the retention (flushing) time for a water body should not exceed 5% of the clearance time of farmed mussels in order to minimise cumulative effects on the wider ecosystem. Whilst recently proposed bivalve aquaculture standards suggest that if the clearance time for the farmed bivalves divided by the retention time of the water body is less than 1 and the area occupied by the farms is less than 10 percent of the total area of the water body then ecological impacts are likely to be acceptable (Bivalve Aquaculture Dialogue 2010).

ECOPATH modelling (Christensen et al 2000) was applied to assess the potential of Tasman Bay for mussel aquaculture development. This indicated that significant ecosystem energy flow changes occurred at mussel biomass levels less than 20% of a mussel dominated ecosystem, thus implying that ecological carrying capacity limits may be much lower than production carrying capacity limits (Jiang & Gibbs 2005). Typically modelling is therefore used to determine the ecological carrying capacity of each system. An ongoing MPI project "Nitrogen levels and adverse marine ecological effects" (ENV2012-01) is seeking to determine to what extent knowledge from overseas about the adverse effects of nitrogen on the marine environment can be applied here.

In the case of cumulative effects related to eutrophication, there is currently a very limited scientific understanding of the transport, fate and ecological consequences of nutrient loading from different sources and, in turn, how they cumulatively affect marine ecosystems (Olsen et al 2008). Managing cumulative effects to achieve sustainability ultimately requires regional approaches to managing developments and activities in a holistic, ecosystem-based management (EBM) framework which utilises spatial planning (Crain et al 2008).

In the absence of over-arching EBM programmes and a robust scientific base for adaptive management in response to cumulative effects, a precautionary approach is warranted in future developments of feed-added aquaculture. Using a precautionary approach, development should be conducted in a staged manner based on conservative limits of expansion. Important tools and components of a precautionary approach include:

6. The use of models and existing data to gauge limits to development[93] within the context of a region's assimilation capacity (i.e. ecological carrying capacity).
7. Establishment of wider-ecosystem, long-term monitoring programmes that include establishment of baseline conditions of a region and adoption of limits of acceptable change.
8. Mitigation of effects through continual improvement of on-farm practices, potentially including improved feed technologies and the use of Integrated Multitrophic Aquaculture (IMTA, Figure 14.5). IMTA combines farming of different species to potentially ameliorate environmental effects.
9. Targeted monitoring and research for validating and improving accuracy of predictive models and understanding the role of feed-added aquaculture in driving cumulative effects.

In New Zealand the Limits of Acceptable Change (LAC) adaptive framework has been applied in the 3000 ha Wilson Bay Aquaculture Management Area (AMA), in the eastern Firth of Thame[94]. This involved stakeholders agreeing both to levels of acceptable change in indicators, and to management responses to apply if monitoring showed that these changes have been exceeded. An overseas example of the precautionary approach is the M-O-M system (Modelling–Ongrowing fish farms–Monitoring), which has been undertaken in Norway to provide information for adaptive management of salmon farming (Ervick et al 1997, Hansen et al 2001).

[93] In some cases, areas may not be suitable for any development of aquaculture.

[94] http://www.niwa.co.nz/publications/wa/vol14-no2-june-2006/limits-of-acceptable-change-a-framework-for-managing-marine-farming

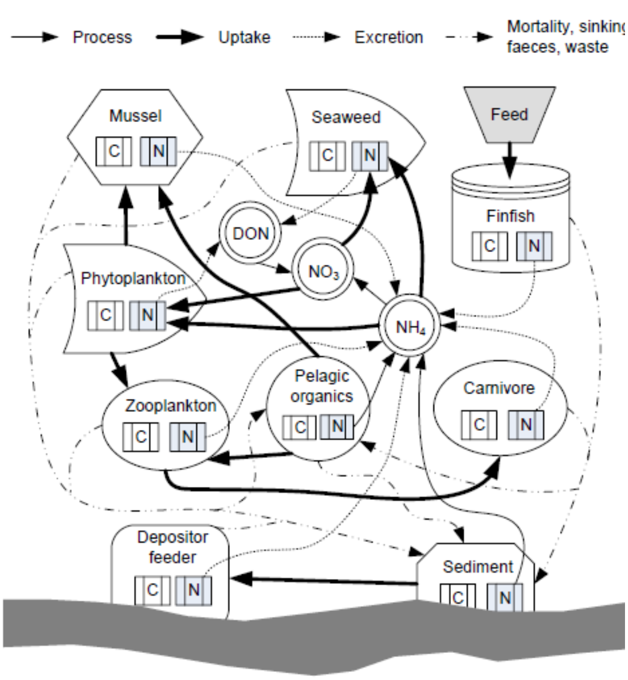


Figure 14.5: Conceptual diagram of IMTA model in terms of carbon (C) and nitrogen (N) biomass (from Ren pers. comm.).

A precautionary approach necessitates establishment of conservative thresholds or limits to minimise risks and the extent of cumulative effects. Minimising risk of eutrophication by setting a limit (or cap) on nutrient loads in a coastal receiving environment would be similar to the approach taken in restoring the Rotorua Lakes. Nutrient mass-balance models can provide guidance on nutrient loading rates in a region under various scenarios, and on gauging proximity to conservative critical nutrient loading rates or CNLRs (Olsen et al 2008). The mass-balance approach has facilitated the development of system-wide nutrient budgets and estimates of carrying capacity for feed-added aquaculture in Golden and Tasman Bays (Zeldis 2008b, Zeldis et al 2011a, b) and the Firth of Thames (Zeldis 2008a, Zeldis et al 2010).

Internationally, there is a very limited understanding of the cumulative effects of multiple stressors on marine ecosystems in the long-term. A critical requirement for understanding these effects is having good information on existing environmental conditions, and continued monitoring to provide long time-series datasets from which to validate models and quantify and forecast changes occurring in the wider environment.

Modelling has an important role to play in understanding, predicting and managing cumulative effects and New Zealand has access to extensive modelling capability; yet in most cases the uncertainty in model accuracy remains high due to insufficient field data for their calibration and validation. For example, underlying hydrodynamic models require sufficient time-series data on currents and water column stratification, while more advanced biogeochemical models require validated estimates of inputs (e.g. surface water, groundwater, marine) and losses (denitrification, burial rates) of nutrients specific to New Zealand's coastal waters.

14.4 REFERENCES

Aguado-Gimenez, F; Garcia-Garcia, B (2004) Assessment of some chemical parameters in marine sediments exposed to offshore cage fish farming influence: a pilot study. Aquaculture 242: 283–296.

Aguilar-Manjarrez, J; Kapetsky, J M; Soto, D (2010) The potential of spatial planning tools to support the ecosystem approach to aquaculture. FAO/Rome. Expert Workshop. 19–21 November 2008, Rome, Italy. FAO Fisheries and Aquaculture Proceedings., No.17. FAO, Rome. 176 p.

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. Volume 2. Aquatic Ecosystems - Rationale and Background Information.

Aquaculture New Zealand (2012) New Zealand Seafood Exports: Calendar Year to December 2012- Report 10B Seafood Exports Country by Species, 251 p.

Askew, C G (1972) The growth of the oysters *Ostrea edulis* and *Crossostrea gigas* in Emsworth Harbour. Aquaculture 1(2):237–259.

BCSGA (British Columbia Shellfish Growers Association) (2001) Environmental management system code of practice. British Columbia Shellfish Growers Association. http://bcsga.netfirms.com/wp-content/uploads/2007/08/enviro-mgmt-code-of-practice_02feb7.pdf. Accessed March 2012.

Biosecurity Council (2003) Tiakina Aotearoa Protect New Zealand – The Biosecurity Strategy for New Zealand. http://www.biosecurity.govt.nz/files/biosec/sys/strategy/biosecurity-strategy.pdf 67 p.

Bivalve Aquaculture Dialogue (2010) Bivalve Aquaculture Dialogue Standards, 50 p.

Broekhuizen, N; Zeldis, J; Stephens, S; Oldman, J; Ross, A; Ren, J; James, M (2002) Factors related to the sustainability of shellfish aquaculture operations in the Firth of Thames: A preliminary analysis. Prepared for Environment Waikato and Auckland Regional Council. NIWA Client Report EVW02243. Environment Waikato Technical Report 02/09 and Auckland Regional Council Technical Publication TP 182.

Burridge, L; Weis, J S; Cabello, F; Pizarro, J; Bostick, K (2010) Chemical use in salmon aquaculture: a review of current practices and possible environmental effects. Aquaculture 306: 7–23.

Butler, D (2003) Possible impacts of marine farming of mussels (*Perna canaliculus*) on king shag (*Leucocarbo carunculatus*). DoC Science Internal Series 111. Department of Conservation, Wellington, New Zealand.

Carver, C E; Chisholm, A; Mallet, A L (2003) Strategies to mitigate the impact of *Ciona intestinalis* (L.) biofouling on shellfish production. Journal of Shellfish Research 22: 621–631.

Cerco, C F; Noel, M R (2007) Can oyster restoration reverse cultural eutrophication in Chesapeake Bay? Estuaries and Coasts 30: 331–343.

Chacon-Torres, A; Ross, L G; Beveridge, M C M (1988) The effects of fish behaviour on dye dispersion and water exchange in small net cages. Aquaculture 73: 283–293.

Chan, A T; Lee, S W C (2001) Wave characteristics past a flexible fishnet. Ocean Engineering 28: 1517–1529.

Christensen, P B; Glud, R N; Dalsgaard, T; Gillespie, P (2003) Impacts of long-line mussel farming on oxygen and nitrogen dynamics and biological communities of coastal sediments. Aquaculture 218: 567–588.

Christensen, V; Walters, C J; Pauly, D (2000) Ecopath with EcoSim: a User's Guide, October 2000 Edition. Fisheries Centre, University of British Columbia. Vancouver, Canada.

Cigarria, J; Fernandez, J; Magadan, L P (1998) Feasibility of biological control of algal fouling in intertidal oyster culture using periwinkles. Journal of Shellfish Research 17(4): 1167–1169.

Clement, D; Keeley, N; Sneddon, R (2010) Ecological Relevance of Copper (Cu) and Zinc (Zn) in Sediments Beneath Fish Farms in New Zealand. Prepared for Marlborough District Council. Report No. 1805. 48 p. http://www.envirolink.govt.nz/PageFiles/584/877-MLDC48%20Ecological%20relevance%20of%20Cu%20and%20Zn%20in%20sediments%20beneath%20fish%20farms%20in%20NZ.pdf.

Cloern, J E (2001) Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 210: 223–253.

Coen, L D; Brumbaugh, R D; Busek, D; Grizzle, R; Luckenbach, M W; Posey, M H; Powers, S P; Tolley, S G (2007) Ecosystem services related to oyster restoration. Marine Ecology Progress Series 341: 303–307.

Connell, S D (2000) Floating pontoons create novel habitats for subtidal epibiota. Journal of Experimental Marine Biology and Ecology 247: 183–194.

Cornelisen, C; Quarterman, A (2010) Effects of artificial lighting on the marine environment at the Clay Point and Te Pangu Bay salmon farms. Prepared for New Zealand King Salmon Company Limited. Cawthron Report No. 1851. Cawthron Institute, Nelson, New Zealand.

Coutts, A D M; Forrest, B M (2005) Evaluation of eradication tools for the clubbed tunicate *Styela clava*. Cawthron Report No.1110. 48 p.

Crain, C M; Kroeker, K; Halpern, B S (2008) Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters 11:1304–1315.

Cranfield, H J; Gordon, D P; Willan, R C; Marshall, B A; Battershill, C N; Francis, M P; Nelson, W A; Glasby, C J; Read, G B (1998) Adventive marine species in New Zealand. NIWA Technical Report 34.

Dann, P; Norman, F I; Cullen, J M; Neira, F J; Chiaradia, A (2000) Mortality and breeding failure of little penguins, Eudyptual minor, in Victoria, 1995–96, following a widespread mortality of pilchard, *Sarinops sagax*. Marine Freshwater Research 51: 355–362.

Dealteris, J T; Kilpatrick, B D; Rheault, R B (2004) A comparative evaluation of the habitat value of shellfish aquaculture gear, submerged aquatic vegetation and a non-vegetated seabed. Journal of Shellfish Research 23: 867–874.

Davenport, J; Smith, R W; Packer, M (2000) Mussels Mytilus edulis: Significant consumers and destroyers of mesozooplankton. Marine Ecology Progress Series 198: 131–137.

Davidson, R J; Brown, D A (1999) Ecological report of potential marine farm areas located offshore of the west coast of Coromandel Peninsula. Prepared by Davidson Environmental Ltd for Environment Waikato. Survey and Monitoring Report No. 177. 39 p.

Davidson, R J; Courtney, S P; Millar, I R; Brown, D A; Deans, N A; Clerke, P R; Dix, J C; Lawless, P F; Mavor, S J; McRae, S M (1995) Ecologically important marine, freshwater, island and mainland areas from Cape Soucis to the Ure River, Marlborough, New Zealand: Recommendations for protection. Occasional Publication 16. Nelson/Marlborough Conservancy, Department of Conservation, Nelson, New Zealand.

Deans, N; Unwin, M; Rodway, M (2004) Sports fishery management Chapter 41. In: Freshwaters of New Zealand. Harding, J; Mosley, P; Pearson, C; Sorrell, B (Eds.). NZ Hydrological Society.

Degobbis, D (1989) Increased eutrophication of the northern Adriatic Sea: second act. Marine Pollution Bulletin 20: 452–457.

Dempster, T; Fernandez-Jover, D; Sanchez-Jerez, P; Tuya, F; Bayle-Sempere, J; Boyra, A; Haroun, R (2005) Vertical variability of wild fish assemblages around sea-cage fish farms: Implications for management. Marine Ecology Progress Series 304: 15–29.

Díaz, R; Rabalais, N N; Breitburg, D L (2012) Agriculture's Impact on Aquaculture: Hypoxia and Eutrophication in Marine Waters.

Report under Directorate for Trade and Agriculture for the OECD (Organisation for Economic Co-operation and Development). 45 p.

Dinamani, P (1974) Pacific oyster may pose threat to rock oyster. Catch 74:5–9.

Dubé, M (2003) Cumulative effect assessment in Canada: a regional framework for aquatic ecosystems. Environmental Impact Assessment Review 23:723–245.

Duprey, N M T (2007) Dusky dolphin (*Lagenorhynchus obscurus*) behaviour and human interactions: Implications for tourism and aquaculture. MSc thesis, Texas A&M University Department of Wildlife and Fisheries Science, Texas, United States of America.

Dupuy, C; Vaquer, A; Lam-Höai, T; Rougier, C; Mazouni, N; Lautier, J; Collos, Y; Gall, S L (2000) Feeding rate of the oyster *Crassostrea gigas* in a natural planktonic community of the Mediterranean Thau lagoon. Marine Ecology Progress Series 205: 171–184.

Eisler, R (1993) Zinc hazards to fish, wildlife and invertebrates: a synoptic review. US Department of the Interior Fish and Wildlife Service. Biological Report No. 10. Contaminant Hazard Reviews 26. 126 p.

Enright, C T; Elner, R W; Griswold, A; Borgese, E M (1993) Evaluation of crabs as control agents for biofouling in suspended culture of European oysters. World Aquaculture 24:49–51.

Enright, C; Krailo, D; Staples, L; Smith, M; Vaughan, C; Ward, D; Gaul, P; Borgese, E (1983) Biological control of fouling algae in oyster aquaculture. Journal of Shellfish Research 3: 41–44.

Ervik, A; Hansen, P K; Aure, J; Stigebrandt, A; Johannessen, P; Jahnsen, T (1997) Regulating the local environmental impact of intensive marine fish farming I. the concept of the MOM system (modelling - ongrowing fish farms - monitoring). Aquaculture 158: 85–94.

FAO (2012) The State of World Fisheries and Aquaculture 2012, Fisheries and Aquaculture Department, Rome, 230 p.

Felsing, M; Glencross, B; Telfer, T (2004) Preliminary study on the effects of exclusion of wild fauna from aquaculture cages in a shallow marine environment. Aquaculture 243: 159–174.

Forrest, B M; Blakemore, K (2002) Inter-regional marine farming pathways for the Asian kelp *Undaria pinnatifida*. Cawthron Report No. 726. 27 p. plus appendices.

Forrest, B; Dunmore, R; Keeley, N (2010) Seabed impacts of the Te Pangu Bay salmon farm: Annual monitoring 2009. Prepared for New Zealand King Salmon Company Limited. Cawthron Report No. 1733. 32 p.

Forrest, B; Elmetri, I; Clark, K (2007a). Review of the ecological effects of intertidal oyster aquaculture. Prepared for Northland Regional Council. Cawthron Report No. 1275. 25 p. http://www.nrc.govt.nz/upload/1742/Oyster%20Effects_Final%20 %28web%29.pdf

Forrest, B M; Hopkins, G A; Dodgshun, T J; Gardner, J P A (2007b) Efficacy of acetic acid treatments in the management of marine biofouling. Aquaculture 262: 319–332.

Forrest, B; Hopkins, G; Webb, S; Tremblay, L (2011) Overview of marine biosecurity risks from finfish aquaculture development in the Waikato region. Prepared for Waikato Regional Council. Cawthron Report No. 1871. 78 p.

Forrest, B; Keeley, N; Gillespie, P; Hopkins, G; Knight, B; Govier, D (2007c) Review of the Ecological Effects of Marine Finfish Aquaculture: Final Report, Cawthron Report for the Ministry of Fisheries, 80 p. (Unpublished report held by the Ministry for Primary Industries.)

Forrest, B; Keeley, N; Hopkins, G; Webb, S; Clement, D (2009) Bivalve aquaculture in estuaries: Review and synthesis of oyster cultivation effects. Aquaculture 298: 1–15.

Forrest, B M; Taylor, M D (2002). Assessing Invasion Impact: Survey Design Considerations and Implications for Management of An Invasive Marine Plant. Biological Invasions 4:375–386.

GESAMP (1997) Towards safe and effective use of chemicals in coastal aquaculture. (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/ UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) Reports and Studies No. 65. 40 p.

Gibbs, M T (2007) Sustainability performance indicators for suspended bivalve aquaculture activities. Ecological indicators 7 (1): 94–107.

Glasby, T M (1999) Differences between subtidal epibiota on pier pilings and rocky reefs at marinas in Sydney, Australia. Estuarine, Coastal and Shelf Science 48: 281–290.

Grange, K R (2002) The effects of mussel farms on benthic habitats and fisheries resources within and outside marine farms, Pelorus Sound. Prepared for Mussel Industry Council. Unpublished NIWA Client Report NEL2002-003.

Hall, S; Delaporte, A; Phillips, M; Beveridge, M; O'Keefe, M (2011) Blue Frontiers: Managing the Environmental Costs of Aquaculture. The WorldFish Center, Penang, Malaysia., 103 p.

Handley, S J (2002) Optimizing intertidal Pacific oyster (Thunberg) culture, Houhora Harbour, northern New Zealand. Aquaculture Research 33: 1019–1030.

Handley, S J; Bergquist, P R (1997) Spionid polychaete infestations of intertidal pacific oysters *Crassostrea gigas* (Thunberg), Mahurangi Harbour, northern New Zealand. Aquaculture 153: 191–205.

Handley, S; Jeffs, A (2002) Assessment for Future Expansion of Pacific Oyster Farming in Northland. NIWA Client Report: AL2003-027. Prepared for Enterprise Northland – Aquaculture Development Group. 36 p. s.handley@niwa.co.nz

Hansen, P K; Ervik, A; Schaanning, M; Johannessen, P; Aure, J; Jahnsen, T; Stigebrandt, A (2001) Regulating the local environmental impact of intensive, marine fish farming: II. The monitoring programme of the MOM system (Modelling-Ongrowing fish farms-Monitoring). Aquaculture 194 (1–2): 75–92.

Hargrave, B T; Silvert, W; Keizer, P D (2005) Assessing and managing environmental risks associated with marine finfish aquaculture. Environmental Effects of Marine Finfish Aquaculture 5: 433–461.

Hayward, B (1997) Introduced marine organisms in New Zealand and their impact in the Waitemata Harbour, Auckland. Tane 36: 197–223.

Helsley, C E; Kim, J W (2005) Mixing downstream of a submerged fish cage: a numerical study. IEEE Journal of Oceanic Engineering 30: 12–19.

Hidu, H; Conary, C; Chapman, S R (1981) Suspended culture of oysters: Biological fouling control. Aquaculture 22:189–192.

Hilliard, R (2004) Best practice for the management of introduced marine pests: a review. GISP: the Global Invasive Species Program, GISP Secretariat. 173 p.

Hopkins, G A; Butcher, R; Clarke, M (2006) Fisheries Resource Impact Assessments (FRIAs) for three proposed marine farm extensions in East Bay Queen Charlotte Sound. Cawthron Report No. 1125. 51 p.

Howarth, R W; Marino, R (2006) Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over three decades. Limnology and Oceanography 51 (1): 364–376.

Huxham, M; Gilpin, L; Mocogni, M; Harper, S (2006) Microalgae, macrofauna and sediment stability: an experimental test of a reciprocal relationship. Marine Ecology Progress Series 310: 55–63.

Inglis, G T; Gust, N (2003) Potential Indirect Effects of Shellfish Culture on the Reproductive Success of Benthic Predators. Journal of Applied Ecology 40: 1077–1089.

Jensen, Ø; Dempster, T; Thorstad, E; Uglem, I; Fredheim, A (2010) Escapes of fish from Norwegian sea-cage aquaculture: causes, consequences and methods to prevent escape. Aquaculture and Environmental Interactions 1: 71–83.

Jiang, W M; Gibbs, M T (2005) Predicting the carrying capacity of bivalve shellfish culture using a steady, linear food web model. Aquaculture 244: 171–185.

Keeley, N; Forrest, B; Hopkins, G; Gillespie, P; Knight, B; Webb, S; Clement, D; Gardener, J (2009) Sustainable aquaculture in New Zealand: Review of the Ecological Effects of farming shellfish and other Non-finfish species Cawthron Report No. 1476, prepared for the Ministry of Fisheries, 150 p. plus appendices. (Unpublished report held by Ministry for Primary Industries.)

Kemper, C M; Pemberton, D; Cawthorn, M; Heinrich, S; Mann, J; Würsig, B; Shaughnessy, P; Gales, R (2003) Aquaculture and marine mammals: Co-existence or conflict? In: Marine mammals: Fisheries, tourism and management issues, pp 208–224. Gales, N; Hindell, M; Kirkwood, R (Eds.). CSIRO Publishing, Collingwood, Victoria, Australia.

Kospartov, K; Inglis, G; Seaward, K; Brink, A; D'Archino, R; Ahyong, S (2010) Non-indigenous and cryptogenic marine species in New Zealand. Current state of knowledge – Interim report prepared for MAFBNZ Post Border Directorate. MAF Biosecurity New Zealand. Wellington, New Zealand.

Lader, P F; Olsen, A; Jensen, A; Sveen, J K; Fredheim, A; Enerhaug, B (2007) Experimental investigation of the interaction between waves and net structures--Damping mechanism. Aquacultural Engineering 37: 100–114.

Lalas, C (2001) Evidence presented for Kuku Mara Partnership, Forsyth Bay. Environment Court Hearing, Blenheim. Statements of evidence Volume 1. October.

La Rosa, T; Mirto, S; Favaloro, E; Savona, B; Sarà, G; Danovaro, R; Mazzola, A (2002) Impact on the water column biogeochemistry of a Mediterranean mussel and fish farm. Water Research. 36: 713–721.

Leguerrier, D; Niquil, N; Petiau, A; Bodoy, A (2004) Modeling the impact of oyster culture on a mudflat food web in Marennes-Oléron Bay (France). Marine Ecology Progress Series 273: 147–162.

Lehane, C; Davenport, J (2002) Ingestion of mesozooplankton by three species of bivalve: *Mytilus edulis*, *Cerastoderma edule* and *Aequipecten opercularis*. Journal of the Marine Biological Association of the United Kingdom 82: 3999/1–6.

Lloyd, B D (2003) Potential effects of mussel farming on New Zealand's marine mammals and seabirds: A discussion paper. Department of Conservation, Wellington, New Zealand.

Locke, A; Doe, K G; Fairchild, W L; Jackman, P M; Reese, E J (2009a) Preliminary evaluation of effects of invasive tunicate management with acetic acid and calcium hydroxide on non-target marine organisms in Prince Edward Island, Canada. Aquatic Invasions 4(1): 221–236.

Locke, A; Hanson, J M; MacNair, N G; Smith, A H (2009b) Rapid response to non-indigenous species. 2. Case studies of non-indigenous tunicates in Prince Edward Island. Aquatic Invasions 4: 249–258.

MacDiarmid, A; McKenzie, A; Sturman, J; Beaumont, J; Mikaloff-Fletcher, S; Dunne, J (2012) Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93, 255 p.

MacKenzie, L (2004) River inputs, re-mineralisation and the spatial and temporal distribution of inorganic nutrients in Tasman Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research 38: 681–704.

Magill, S H; Thetmeyer, H; Cromey, C J (2006) Settling velocity of faecal pellets of gilthead sea bream (*Sparus aurata* L.) and sea bass (*Dicentrarchus labrax* L.) and sensitivity analysis using measured data in a deposition model. Aquaculture 251: 295–305.

Markowitz, T M; Harlin, A D; Würsig, B; Mcfadden, C J (2004) Dusky dolphin foraging habitat: Overlap with aquaculture in New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems 14: 133–149.

Molina Dominguez, L; Lopez Calero, G; Vergara-Martin, J M; Robaina, L (2001) A comparative study of sediments under a marine cage farm at Gran Canaria Island (Spain): Preliminary results. Aquaculture 192: 225–231.

Molnar, J L; Gamboa, R L; Revenga, C; Spalding, M D (2008) Assessing the global threat of invasive species to marine biodiversity. Frontiers in Ecology and the Environment 6(9): 485–492.

Morrisey, D; Page, M; Handley, S; Middleton, C; Schick, R (2009) Biology and ecology of the introduced ascidian *Eudistoma elongatum*, and trials of potential methods for its control, MAF Biosecurity New Zealand Technical Paper.

MPI (2013) Literature Review of Ecological Effects of Aquaculture. A collaboration between Ministry for Primary Industries, Cawthron Institute & National Institute for Water and Atmospheric Research Ltd. Ministry for Primary Industries, Wellington, New Zealand. 260 pages. ISBN number 978-0-478-38817-6.

Mulcahy, K; Peart, R (2012) Wonders of the Sea: The protection of New Zealand's marine mammals, 334 p.

NRC (2010) Ecosystem Concepts for Sustainable Bivalve Mariculture. By Committee on Best Practices for Shellfish Mariculture and the Effects of Commercial Activities in Drakes Estero, Pt. Reyes National Seashore, California. 191 p.

NZMIC (2001) New Zealand Mussel Industry Council Ltd. code of practice for transfer of mussel seed. Aquaculture New Zealand. 3 p.

NZOIA (2007) New Zealand Oyster Industry Code of Practice. Aquaculture New Zealand. 51 p.

NZSFA (2007) New Zealand Salmon Farmers Association Inc. Finfish Aquaculture Code of Practice. Aquaculture New Zealand. 27 p.

Okamura, B; Feist, S W (2011) Emerging diseases in freshwater systems. Freshwater Ecosystem 56: 627–637.

Olsen, L M; Holmer, M; Olsen, Y (2008) Perspectives of nutrient emission from fish aquaculture in coastal waters: Literature review with evaluated state of knowledge. Final report for The Fishery and Aquaculture Industry Research Fund. 87 p.

Paerl, H W (2006) Assessing and managing nutrient-enhanced eutrophication in estuarine and coastal waters: Interactive effects of human and climatic perturbations. Ecological Engineering 26 (1): 40–54.

Paul, L (2002) Can existing data describe the stock structure of the two New Zealand groper species hapuku (*Poliprion oxygeneios*) and bass (*P. ainericanus*)? New Zealand Fisheries Assessment Report 2002/14. 24 p.

Pearson, T H; Black, K D (2001) The environmental impact of marine fish cage culture. Pp. 1–31. In: Environmental impacts of aquaculture. Black, K D (Ed.). Academic Press, Sheffield.

Pearson, H; Srivivasan, M; Vaughn, R; Würsig, B (2007) Cetacean abundance, habitat use, and behaviour in winter and spring 2006, Admiralty Bay, New Zealand, with comparisons to 2005. Report to Marlborough District Council and Department of Conservation.

Peeler, E J; Taylor, N G (2011) The application of epidemiology in aquatic animal health – opportunities and challenges. Veterinary Research 42(1):94.

Pietros, J M; Rice, M A (2003) The impacts of aquacultured oysters, *Crassostrea virginica* (Gmelin, 1791) on water column nitrogen and sedimentation: results of as mesocosm study. Aquaculture 220: 407–422.

Plew, D R (2011) Shellfish farm-induced changes to tidal circulation in an embayment, and implications for seston depletion. Aquaculture Environment Interactions 1: 201–214.

Plew, D R; Spigel, R H; Stevens, C L; Nokes, R I; Davidson, M J (2006) Stratified flow interactions with a suspended canopy. Environmental Fluid Mechanics 6: 519–539.

Porter, M J R; Duncan, N J; Mitchell, D; Bromagea, N R (1999) The use of cage lighting to reduce plasma melatonin in Atlantic salmon (*Salmo salar*) and its effects on the inhibition of grilsing. Aquaculture 176(3–4): 237–244.

Prins, T C; Smaal, A C; Dame, R F (1998) A review of the feedbacks between bivalve grazing and ecosystem processes. Aquatic Ecology 31: 349–359.

Quale, D B (1969) Pacific oyster culture in British Columbia. Fisheries Research Board of Canada Bulletin 169.

Reid, G (2007) Nutrient releases from Salmon Aquaculture (Chapter 1). In: Buschmann, A; Costa-Pierce, A; Cross, S; Iriarte, L; Olsen, Y; Reid, G (committee members). Nutrient impacts of farmed Atlantic salmon (*Salmo salar*) on pelagic ecosystems and implications for carrying capacity. Report of the Technical Working group (TWG) on nutrients and carrying capacity of the salmon aquaculture dialogue, pp 7–23.

Ruiz, G M; Rawlings, T K; Dobbs, F C; Drake, L A; Mullady, T; Huq, A; Colwell, R R (2000) Global spread of microorganisms by ships. Nature 408: 49–50.

Saaty, T (1987) Risk, its priority and probability: the analytic hierarchy process. Risk Analysis 7 (2): 159–172.

SAD (Salmon Aquaculture Dialogue) (2011) Second draft standards for responsible salmon aquaculture: Revised draft standards for public comment, 16 May 2011.

www.worldwildlife.org/salmondialogue. Accessed March 2012.

Scavia, D; Field, J; Boesch, D; Buddemeier, R; Burkett, V; Cayan, D; Fogarty, M; Harwell, M; Howarth, R; Mason, C; Reed, D; Royer, T; Sallenger, A; Titus, J (2002) Climate change impacts on U.S. Coastal and Marine Ecosystems. Estuaries and Coasts 25(2): 149–164.

SEPA (2000) Policy on regulation and expansion of caged fish farming of salmon in Scotland. Policy No 40, Scottish Environmental Protection Agency.

Silva, C; Ferreira, J G; Bricker, S B; DelValls, T A; Martín-Díaz, M L; Yáñez, E (2011) Site selection for shellfish aquaculture by means of GIS and farm-scale models, with an emphasis on data-poor environments. Aquaculture 318(3–4): 444–457.

Slooten, E; Dawson, S M; DuFresne, S (2001) Report on interactions between Hector's dolphins (*Cephalorynchus hectori*) and a Golden Bay mussel farm. Unpublished report for Environment Canterbury.

Sorokin, Y I; Sorokin, P Y; Ravagnan, G (1996) On an extremely dense bloom of the dinoflagellate *Alexandrium tamarense* in lagoons of the Po river delta: impact on the environment. Journal Sea Research 35:251–255.

Soto, D; Aguilar-Manjarrez, J; Brugère, C; Angel, D; Bailey, C; Black, K; Edwards, P; Costa-Pierce, B; Chopin, T; Deudero, S; Freeman, S; Hambrey, J; Hishamunda, N; Knowler, D; Silvert, W; Marba, N; Mathe, S; Norambuena, R; Simard, F; Tett, P; Troell, M; Wainberg, A (2008) Applying an ecosystem based approach to aquaculture: principles, scales and some management measures. In: Soto, D; Aguilar-Manjarrez, J; Hishamunda, N (Eds.), Building an Ecosystem Approach to Aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings, No. 14. FAO, Rome, pp. 15–35.

Stoklosa, R; Ford, R; Pawson, M; Nielsen, M (2012) Phase Two Report of the MAF Aquaculture Ecological Guidance Project-Risk-based ecological assessment of New Zealand aquaculture, Workshop Report 21–22 February 2012, Nelson. Prepared for the Aquaculture Unit of the New Zealand Ministry of Agriculture and Forestry (E-Systems Pty Limited, Hobart Tasmania, Australia). 95 p. (Unpublished report held by Ministry for Primary Industries.)

Taylor, D I; Keeley, N B; Heasman, K; Clement, D; Knight, B (2010) AEE for offshore finfish farming within the four Kahungunu blocks of the Napier AMA. Cawthron Client Report. Cawthron Institute, Nelson, New Zealand

Taylor, G A (2000) Action plan for seabird conservation in New Zealand. Part A: Threatened seabirds. Threatened Species Occasional Publication 16. Department of Conservation, Wellington, New Zealand.

Vaughn, R; Würsig, B (2006) Dusky dolphin distribution, behaviour and predator associations in spring 2005, Admiralty Bay, New Zealand. A report to Marlborough District Council and New Zealand Department of Conservation.

Venayagamoorthy, S K; Ku, H; Fringer, O B; Chiu, A; Naylor, R L; Koseff, J R (2011) Numerical modeling of aquaculture dissolved waste transport in a coastal embayment. Environmental Fluid Mechanics. DOI 10.1007/s10652-011-9209-0.

Volkman, J; Thompson, P; Herzfeld, M; Wild-Allen, K; Blackburn, S; MacLeod, C; Swadling, K M; Foster, S; Bonham, P; Holdsworth, D (2009) A whole-of-ecosystem assessment of environmental issues for salmonid aquaculture. Aquafin CRC Final Report (CRC Project 4.2 (2)/FRDC Project 2004/074).

Wilson, A; Magill, S; Black, K D (2009) Review of environmental impact assessment and monitoring in salmon aquaculture. Environmental impact assessment and monitoring in aquaculture. FAO Fisheries and Aquaculture Technical Paper 527, pp 455–535.

Wright, A (2008) What's all the noise about? A call for lowering underwater noise from ships. Marine Technology Reporter 51(5): 22–25.

Wu, R S S; Lam, K S; MacKay, D W; Lau, T C; Yam, V (1994) Impact of marine fish farming on water quality and bottom sediment: a case study in the sub-tropical environment. Marine Environmental Research 38: 115–145.

Würsig, B; Gailey, G A (2002) Marine mammals and aquaculture: Conflicts and potential resolutions, pp. 45–59. In: Responsible marine aquaculture. Stickney, R R; McVay, J P (Eds.). CAP International Press, New York, United States of America.

WWF (2010) Bivalve Aquaculture Dialogue Standards Environmental and Social Standards for Bivalve Aquaculture 23 p. http://www.worldwildlife.org/what/globalmarkets/aquaculture/WWFBinaryitem13945.pdf

Zeldis, J (2008a) Wilson Bay marine farm monitoring bi-annual report for 2006 and 2007. NIWA Client Report: CHC2008-086, July 2008. NIWA Project: WBC08501 Prepared for Wilson Bay Group A Consortium.

Zeldis, J R (2008b) Origin and processing of nutrients in Golden and Tasman Bays. Envirolink Advice Grant and Client Report May 2008 CHC 2008 052 (Client Tasman District Council).

Zeldis, J; Broekhuizen, N; Forsythe, A; Morrisey D, Stenton- Dozey, J M E (2010). Waikato Marine Finfish Farming: Production and Ecological Guidance. NIWA Client Report: CHC2010-147. December 2010. NIWA Project: PRM 201016.

Zeldis, J; Broekhuizen, N; Forsythe, A; Morrissey, D; Stenton-Dozey, J (2011a) Waikato marine finfish farming: Production and ecological guidance. NIWA Client Report CHC2010-147, National Institute of Water and Atmospheric Research Ltd. 112 p.

Zeldis, J; Hadfield, M; Broekhuizen, N; Morrisey, D; Stenton-Dozey, J (2011b) Tasman Aquaculture – Guidance on farming additive species (Stage 1). NIWA Report CHC 2011-005. February

2011. Client: Ministry of Fisheries Aquaculture Unit.72 p. (Unpublished report held by Ministry for Primary Industries.)

Zeldis, J R; Howard-Williams, C; Carter, C M; Schiel, D R (2008) ENSO and riverine control of nutrient loading, phytoplankton biomass and mussel aquaculture yield in Pelorus Sound, New Zealand. Marine Ecology Progress Series 371: 131–142.

Zeldis, J; Robinson, K; Ross, A; Hayden, B (2004) First observations of predation by New Zealand Greenshell mussels *Perna canaliculus* on zooplankton. Journal of Experimental Marine Biology and Ecology 311(2): 287–299.

THEME 5: MARINE BIODIVERSITY

15 BIODIVERSITY

Scope of chapter	Provides an overview of the MPI Biodiversity Programme and describes the National and global context for marine biodiversity research in New Zealand; summarises the research findings and progress of the MPI Biodiversity Research Programme from 2000–2014; including one-off, whole-of-government research initiatives administered under this programme (e.g. Ocean Survey 20/20 Biodiversity and Fisheries projects; International Polar Year Census of Antarctic Marine Life project).
Area	New Zealand Territorial Seas, EEZ and Continental shelf extension (BioInfo); South-west Pacific Region associated with South Pacific Regional Fisheries Management Organisation (SPRFMO);Southern Ocean and Ross Sea region (BioRoss)
Focal issues	• New Zealand seas have globally significant levels of endemic marine biodiversity, particularly in coastal habitats, offshore island habitats and on underwater topographical features such as seamounts, and canyons. • Mapping and documenting the identity, abundance and distribution patterns of New Zealand's marine biodiversity in our extremely large area of responsibility (~5.8 million km2) is far from complete. Identifying biodiversity hotspots remains a challenge, particularly for environmental impact assessment or assessing response to climate change scenarios. • The state of marine biodiversity in New Zealand (and whether or not it is declining) is not reported nationally. • Selecting suitable ecosystem indicators and monitoring of marine biodiversity remains challenging globally and in New Zealand. In addition to extinctions or reduction in species richness and abundance, proxies such as environmental degradation such as species invasion and hybridisations, habitats that have been diminished or removed, and the disruption of ecosystem structure and function, as well as ecological processes (e.g. biological cycling of water, nutrients and energy) could be used as indicators • The efficacy of current spatial measures and management actions to protect sea life in "halting the decline of biodiversity" in New Zealand seas is not known. • Climate change effects on the ocean are occurring in New Zealand, and as these continue, the likely consequences for marine biodiversity and productivity are significant. • Marine biodiversity has not become an integral part of business or strategic planning across relevant government agencies. The functional role of marine biodiversity and ecosystem services in providing a healthy ecosystem, maintaining environmental limits and maintaining sustainability are not well recognised.
Key progress 2013–14	• A voyage to determine the distribution of VMEs on the Louisville Ridge (in the SPRFMO area) provided an interesting test on the utility of predictive habitat modelling for management purposes (Follows on from ZBD2010-40). It also collected samples for an MPI project on genetic connectivity (ZBD2013-02) • Deep sea cold water corals have been kept alive for over 2 years now under laboratory conditions and are enabling a world-first experimental project to examine their response to projected acidification conditions in the deep (ZBD2013-05). • Ocean acidification issues have been picked up by MPI managers and resulted in an industry-science workshop with the US to "Future proof New Zealand's aquaculture and shellfish industry" (Capson and Guinnotte, 2014). • Biodiversity survey results from the Chatham Rise area have contributed significant evidence about the environment for the Chatham Rock Phosphate development and deepwater fisheries (ZBD2012-03). • Marine Environmental Monitoring: metadata on marine environmental monitoring programmes (bio-physical) throughout New Zealand is now publicly available; we are one step closer to developing Tier 1 Statistics for marine biodiversity and for ocean

	related climate change. The results from the study are being used to feed into New Zealand's environmental reporting bill (ZBD2010-41, ZBD2012-01, ZBD2012-02) • The landmark "Taking Stock" project has been completed with the first multidisciplinary investigation of change in New Zealand's marine ecosystem over the last 1000 years (ZBD2005-05). The results are of particular interest to the Hauraki Gulf Forum. • Modelling seabed disturbance effects on marine biodiversity provides new insight into how benthic ecosystems tolerate direct and indirect stresses that we place on them through fishing and other resource activities. • ID Guides continue to be generated by MPI and DOC, for example DOC's Coral Identification Guide – 2nd version 2014 was published as part of DOC14305 Project for Government. (Tracey et al. 2014)
Emerging issues and gaps	• The combined effects of multiple stressors arising from climate change and a range of other anthropogenic activities on biodiversity and marine ecosystems (structure and function) are likely to be large and complex. • Ecosystem approaches to marine resource management are urgently needed, particularly with the renewed interest in developing the marine economy through marine mining and extraction activities. • The nature and functional role of marine microbial biodiversity in large scale biogeochemical and ecosystem processes may be crucial to productivity in our seas, but are not well understood. • Genetic and life-history stage connectivity between and within large scale habitats are likely to be important to the size and placement of marine protection zones and to their success. • Long-term observations (e.g. decadal to millennia timeframes) of variability and change in the marine environment (including biodiversity) are not yet generally available at geographic scales appropriate for national reporting. • Metrics for assessing the effectiveness of current protection measures in safeguarding marine biodiversity and aquatic ecosystem health in New Zealand and the Ross Sea region are inadequate. • Economic value of ecosystem goods and services provided by marine biodiversity to current and future generations are not yet addressed in extractive business models. • Conservation of marine biodiversity, monitoring, reduction of loss and enhancement are emerging requirements for signatories (including New Zealand) to the CBD Aichi-Nagoya Agreement 2010. • Geo-engineering methods including ocean fertilisation continues to be advocated in some areas of international climate change mitigation • Meeting New Zealand international responsibilities includes participation in international data collection programmes and long-term commitment, e.g.,SAHFOS, IMOS, SOCPR ARGO, BIO-ARGO. • Biodiversity indicators that can be used to evaluate the health of the marine ecosystem and biodiversity loss need to be consolidated. • Marine debris and pollution are increasing in NZ waters, particularly in the coastal zone • The effects of land-use practices on coastal ecosystems are still not fully addressed by management agencies (see Chapter 13)
MPI Research (current)	64 biodiversity projects have been commissioned over the period 2000-14; A new 5 year programme is underway to address seven science objectives in the Biodiversity Programme: 1 characterisation and description; 2 ecosystem scale biodiversity; 3 functional role of biodiversity; 4 genetics; 5 ocean climate effects; 6 indicators; 7 threats to biodiversity. MPI biodiversity research has strong synergies with marine research funded by MPI Aquatic and Environment Working Group (AEWG), Ministry of Business Innovation and Employment (MBIE), Department of Conservation (DOC), Land Information New Zealand (LINZ), other sections within the Ministry for Primary Industries (MPI), Ministry for the Environment (MfE),Statistics New Zealand (Stats NZ), Te Papa and

	Crown Research Institutes
NZ Government Research (current)	Research programmes and database initiatives on Marine Biodiversity are run at University of Auckland (World Register of Marine Species (WoRMS), marine reserves, rocky reef ecology, Ross Sea meroplankton, genetics); Auckland University of Technology, University of Waikato (soft sediment functional ecology and biodiversity), Victoria University of Wellington (monitoring marine reserves, population genetics), University of Canterbury (intertidal and subtidal ecology, kelp forests and biodiversity), University of Otago (land-use effects, bryozoans, inshore ecology, ocean acidification), National Institute of Water and Atmospheric Research (NIWA) and Cawthron Institute. Relevant Core NIWA programmes include: Programme 1 - Marine physical processes and resources; Programme 2 - Marine biological resources; Programme 3 - Ocean flows and productivity; Programme 4 - Marine ecosystem structure and function; Programme 5 - Our changing ocean; Programme 6 - Marine biosecurity. The NIWA Fisheries Centre has 4 core-funded programmes: 1. Stock monitoring assessment and methodologies; 2.International fisheries; 3. Ecosystem approaches to fisheries management; 4.Enhance the value of wild fisheries. Bycatch mitigation and minimisation; DOC, MPI, NIWA and Landcare Research - NZ Organisms Register. MBIE Science Challenges "Deep South" and "Sustainable Seas" and the 2014 Request for Proposals http://www.msi.govt.nz/get-funded/research-organisations/2015-science-investment-round/.
Links to 2030 objectives	Fisheries 2030 Environmental Outcome Objective 1; environmental principles of Fisheries 2030 include: Ecosystem-based approach, Conserve biodiversity: Environmental bottom lines, Precautionary approach, Responsible international citizen, Inter-generational equity, Best available information, Respect rights and interests (MPI 2009). MPI's Strategy "Our Strategy 2030": two key stated focuses are to maximise export opportunities and improve sector productivity; increase sustainable resource use, and protect from biological risk.
Links across Government	The Biodiversity programme engages in Natural Resource Sector discussions (MfE, DOC, MBIE, LINZ, EPA, MOT, Maritime NZ, Antarctica NZ, NZ Statistics, MFAT) and whole of government projects such as Ocean Survey 20/20, International Polar Year, identification of strategic research needs in marine research, the National Science Challenges and the refresh of the NZ Biodiversity Strategy.
Related chapters/issues	Multiple use of marine resources, land-based effects, variability and change, marine monitoring, cumulative effects of use and extraction in the marine environment, protected areas; benthic impacts, ecosystem approaches to fisheries and marine resource management.

Note: This chapter has been updated for the AEBAR 2014.

15.1 INTRODUCTION

This chapter summarises the development and progress of the MPI Marine Biodiversity Research Programme 2000–2014 and reviews the work commissioned in the context of national and global concerns about biodiversity and the maintenance of the marine ecosystem in a healthy functioning state, as identified by the New Zealand Biodiversity Strategy (NZBS, Anon 2000).

15.1.1 HALTING THE DECLINE IN BIODIVERSITY

In June 2000, the 'New Zealand Biodiversity Strategy– Our Chance to Turn the Tide' (NZBS) with the over-arching objectives "to halt the decline of biodiversity in New Zealand and protect and enhance the environment" was launched as part of New Zealand's commitment to the international Convention on Biological Diversity 1993 (Anon 2000). To meet long-term goals of the NZBS, a comprehensive plan, with stated objectives and actions, was developed to address biodiversity issues in terrestrial, freshwater and marine systems. The Desired Outcomes by 2020 for the marine environment (Coasts and Oceans, Theme 3) in the NZBS were stated as:

- "New Zealand's natural marine habitats and ecosystems are maintained in a healthy functioning state and degraded marine habitats are recovering.

- A full range of marine habitats and ecosystems representative of New Zealand's indigenous marine biodiversity is protected.
- No human-induced extinctions of marine species within New Zealand's marine environment have occurred.
- Rare or threatened marine species are adequately protected from harvesting and other human threats, enabling them to recover.
- Marine biodiversity is appreciated, and any harvesting or marine development is done in an informed, controlled and ecologically sustainable manner."

In the marine environment, biodiversity decline is characterised not only by extinctions or reduction in species richness and abundance, but also by environmental degradation such as species invasion and hybridisations, habitats that have been diminished or removed, and the disruption of ecosystem structure and function, as well as ecological processes (e.g. biological cycling of water, nutrients and energy). Measuring the decline of marine biodiversity is complicated by the 'shifting baseline syndrome', a common obstacle to useful biodiversity assessment and monitoring[95]. Furthermore the size range of organisms sampled is often limited to macroscopic. Changes (declines) in biodiversity metrics at a macroscopic level may not detect potentially large changes in biodiversity in smaller sized organisms below our sampling threshold that may also be critical to marine ecosystem health and well-being.

Responsibility for implementing New Zealand's Biodiversity Strategy is led by the Department of Conservation (DOC), with significant input from the Ministry for Environment (MfE), and the Ministry of Fisheries (now part of MPI)[96] DOC is currently leading a process to refresh the Biodiversity Strategy to better meet the Aichi Agreement.

15.1.1.1 DEFINING BIODIVERSITY

New Zealand's Biodiversity Strategy defines biodiversity as:

"The variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part [as defined by the CBD]; this includes diversity within species, between species and of ecosystems [as further disaggregated for New Zealand purposes]. Components include:

- *Genetic diversity: the variability in the genetic make-up among individuals within a single species. In more technical terms, it is the genetic differences among populations of a single species and those among individuals within a population.*
- *Species diversity – the variety of species—whether wild or domesticated— within a particular geographic area.*
- *Ecological diversity – the variety of ecosystem types (such as forests, deserts, grasslands, streams, lakes wetlands and oceans) and their biological communities that interact with one another and their non-living environments."*

MPI's Biodiversity programme is concerned primarily with research to underpin NZBS Theme 3: Biodiversity in Coastal and Marine Ecosystems:

"Coastal and marine ecosystems include estuaries, inshore coastal areas and offshore areas, and all the resident and migratory marine species that live in them."

New Zealand's ocean territory (including territorial sea and the recent continental shelf extension[97]) is very large relative to the area of land[98] and includes some 15–18 000 kilometres of coastline extending from the sub-tropical north to the cool Sub-Antarctic waters to the south. New Zealand also has a rich marine biodiversity that has been recognised as being globally significant with up to 44% estimated as endemic and comprising up to 10% of global marine biodiversity (Gordon et al 2010).

[95] A National Approach to Addressing Marine Biodiversity Decline (Australian Government-available on line at www.environment.gov.au/coasts/publications/marine-diversity-decline/index.html

[96] https://www.biodiversity.govt.nz/picture/doing/programmes/index.html

[97] http://www.mfat.govt.nz/Treaties-and-International-Law/04-Law-of-the-Sea-and-Fisheries/NZ-Continental-Shelf-and-Maritime-Boundaries.php

[98] NZ sea area is about 5.8 million km^2 including TS, EEZ and continental shelf extension; the fourth largest in the world; www.linz.govt.nz

An estimated 34 400 marine species and associated ecosystems around New Zealand deliver a wide range of environmental goods and services that sustain considerable fishing, aquaculture and tourism industries as well as drive major biogeochemical and ecological processes. Several factors would suggest that this estimate of marine species number is conservative. Such factors include the region's size, the depth range, geomorphological and hydrological complexity as well as limited water column sampling and limited benthic sampling, especially below 1500 metres. If recent indications of massive oceanic microbial diversity are taken into account (e.g. Sogin et al 2006) then the number above is certainly conservative.

New Zealand's marine biodiversity is affected by many uses of the marine environment, particularly fishing, aquaculture, shipping, petroleum and mineral extraction, renewable energy, tourism and recreation[99]. Impacts from changing land use, including agricultural, urban run-off and coastal development can also affect marine biodiversity (Morrison et al 2009). The potential loss of marine biodiversity and possible functionality caused by climate change and ocean acidification are of increasing concern worldwide (e.g., Guinotte et al 2006; Ramirez-Llodra et al 2011; as well as in New Zealand–see New Zealand Royal Society Workshop papers[100]). The growing arrival of non-indigenous (sometimes invasive) marine species is also a threat to local biodiversity (e.g., Coutts & Dodgshun 2007, Cranfield et al 2003, Gould & Ahyong 2008, Russell et al 2008, Williams et al 2008).

Understanding about New Zealand's coastal marine environment and its land-sea interactions has progressed, although knowledge about the state of the marine environment and marine biodiversity at a national scale remains limited. Current knowledge about New Zealand's and the Ross Sea's marine biodiversity suggests that it may generally be in better shape than that of many other countries (Costello et al 2010, Gordon et al 2010). However, New Zealand is less well placed when it comes to understanding the threats to marine biodiversity (Costello et al 2010, MacDiarmid et al 2012) and the nature of their impacts. Marine invasion and the effects of climate change and acidification of the ocean are key threats, and anthropogenic threats from increasing resource use, high levels of agricultural runoff and sedimentation as well as marine debris are causing localised degradation of marine habitats.

There are ongoing concerns about the decline of some key species (MfE 2007), localised impacts on habitats and conditions (Thrush & Dayton 2002, Cryer et al 2002, Clark et al 2010a, b, Gordon et al 2010,) and emerging threats to the marine environment (MacDiarmid et al 2012) despite the combined efforts of New Zealand's government and stakeholders. Global scale threats associated with the potential effects of ocean acidification on microbial diversity and their roles in biogeochemical processes have yet to be quantified but could have EEZ wide implications (Bostock et al 2012).

New Zealanders increasingly value environmental, economic and social aspects of marine biodiversity and the ecosystem services that a healthy marine environment provides. They also value the need to sustainably manage the use of coastal and marine environments and maintain biological diversity as reflected by recent policy statements by the New Zealand Government[101][102]. A broad range of legislation, regulations and policies are in place to manage and regulate uses of the marine environment, to protect marine biodiversity, to improve management of the coastal and marine environment and to meet world-wide consumer demands for improved sustainability.

The government's Business Growth Agenda acknowledges the lack of progress in halting the decline in biodiversity in New Zealand, and indicates that development of the marine economy requires a careful approach to the environment. However, despite many documents having been written about the lack of basic ecological

[99] http://www.royalsociety.org.nz/media/Future-Marine-Resource-Use-web.pdf
http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/fish.aspx

[100] http://www.royalsociety.org.nz/publications/policy/yr2009/ocean-acidification-workshop/

[101] MfE Proposed National Policy Statement on Indigenous Biological Diversity (biodiversity) under the Resource Management Act 1991 www.mfe.govt.nz/publications/biodiversity/indigenous-biodiversity/proposed-national-policy-statement/statement.pdf

[102] New Zealand Coastal Policy Statement 2010 www.doc.govt.nz/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement/

characterisation throughout the Territorial sea and EEZ, no priority or action point has been included to rectify the shortfall.

The most recent introduction of new legislation is the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. However, progress on an integrated oceans policy and strategic direction for implementation of New Zealand's Biodiversity Strategy has not progressed as rapidly here compared with other countries such as Canada, the UK, the USA and Australia (Peart et al 2011).

15.1.2 IMPLEMENTATION OF NEW ZEALAND'S BIODIVERSITY STRATEGY

A number of initiatives have been supported by MPI to meet the goals of the NZBS. Commitments include the creation of NABIS (the National Aquatic Biodiversity Information System)[103], the administration of the MPI Biodiversity Research Programme, convening and chairing the Biodiversity Research Advisory Group[104], and developing a Marine Protected Area policy with DOC. DOC also surveys and monitors aspects of marine biodiversity, particularly in marine reserves[105]. MfE has encouraged Regional Councils to develop coastal monitoring programmes and with MPI and DOC, initiated an approach to Marine Environmental Classification[106]. Biodiversity related research has also been carried out through MPI's Biosecurity Science Strategy. One result includes mapping and valuation of marine biodiversity around New Zealand's coastline[107].

Marine biodiversity research is largely supported through public good funding and is conducted mainly by Universities and CRIs. Both have contributed to New Zealand's high profile for marine biodiversity on the international scientific network through participation in global initiatives such as the Census of Marine Life as well as to local programmes that have improved understanding of the role of biodiversity in the marine ecosystem. The Museums of Auckland, Canterbury, Otago and the Museum of New Zealand (Te Papa) also conduct biodiversity sampling expeditions and national collections of specimens have been set up within Museums and at NIWA. Regional Councils give effect to NZBS; Coastal Biodiversity Policy Statement 2011, protected areas and spatial planning.

15.1.3 CURRENT CHALLENGES AND AGENDAS

Since the launch of the Biodiversity Strategy, there have been substantial changes in Government goals for New Zealand. In July 2009, the Minister of Science set an overarching goal for research science and technology[108]:

"to improve New Zealand's economic performance while continuing to strengthen our society and protect our environment".

This goal is reflected in the first progress report on "Building Natural Resources" as part of the Business Growth Agenda[109] released December 2012. The Business Growth Agenda sets an ambitious goal of increasing the ratio of exports to GDP to 40% by 2025. Meeting the target will require the value of our exports to double in real terms by 2025. The report states that one of the goals is to "Make the most of the considerable opportunities for New Zealand to gain much greater value from its extensive marine and aquaculture resources". More recently, the Business Growth Agenda states its goal for Natural Resources as "The quality of our natural resource base increases over time while sustaining the growth needed from key sectors while meeting our 40% export to GDP target"[110]

The economy of the sea is a significant part of the overall economy in New Zealand and has potential for growth,

[103] NABIS is an interactive database accessible at www.nabis.govt.nz

[104] www.fish.govt.nz/en-nz/Research+Services/Background+Information/Biodiversity+background.htm

[105] www.doc.govt.nz

[106] www.mfe.govt.nz/issues/biodiversity/initiatives/marine.html#regional

[107] www.biosecurity.govt.nz/biosec/research

[108] MoRST feedback document on New Zealand's research science and technology: www.morst.govt.nz/Documents/publications/policy

[109] https://www.mbie.govt.nz/what-we-do/business-growth-agenda/pdf-folder/BGA-Natural-Resources-report-December-2012.pdf

[110] http://www.mbie.govt.nz/pdf-library/what-we-do/business-growth-agenda/bga-reports/future-direction-2014.pdf

particularly in aquaculture, oil and gas, minerals (Business Growth Agenda 2014). It is important that the aquatic environment and biodiversity are not adversely affected by new or increasing activities, be they in the seafood sector or other natural resource industries (Fisheries Act 1996; Exclusive Economic Zone and Continental Shelf (Environment Effects) Act 2012).

Most of New Zealand's commercial fisheries are wild-caught, and retention of their productivity is therefore dependent on the retention of a healthy functioning marine ecosystem. The "licence to operate" is mandated by the Fisheries Act 1996 that requires strict compliance with sustainable and environmentally responsible use of fishstocks. Compliance is also required with other legislation such as the Marine Mammals Protection Act 1978 and a range of international obligations such as the United Nations Convention on the Law of the Sea (UNCLOS). Under the Quota Management System, considerable monitoring of fishing activity and the environmental footprint of commercial operators is required.

The marketplace is continually evolving and as social awareness of commercial activity in the sea has increased across the globe, the "social licence" or "acceptance" of commercial fishing activities has come under higher scrutiny in New Zealand. Industry and government have gone beyond legislative requirements to maintain stocks at healthy levels and to demonstrate stewardship of the natural environment as well as the fishstocks; eco-labelling certification such as the Marine Stewardship Council (MSC) of some key fisheries is just one manifestation of this. It will become increasingly important to seek a social licence to operate and to demonstrate responsible environmental stewardship in other industries as New Zealand stretches towards broader goals of growing the marine economy.

The large scale threats to the marine environment and biodiversity posed by increasing global impacts of stressors such as climate change and ocean acidification, increasing exploitation of resources (living or non-living) and the cumulative effect of multiple uses of the marine environment (e.g., renewable energy, commercial fisheries, recreational fisheries, aquaculture, hydrocarbon and mineral extraction) are increasingly being recognised in policy and government circles (e.g, Office of the Prime Minister's Science Advisory Committee 2013[111], NZ Royal Society 2012[112], Statistics New Zealand 2013, Statistics New Zealand 2012[113], see Royal Society 2009[114], Capson and Guinotte 2014; MBIE[115]). Progress on tackling the issues and investment in long-term monitoring of the marine environment and data access remains slow. Long-term monitoring and environmental reporting has however been recognised as a major gap by the government and a draft Environmental Reporting Bill is now available online[116].

Scientific research has provided information about the predicted distribution and abundance of marine biodiversity in some areas of New Zealand's coasts and oceans, but progress on validation in areas that remain unsampled has been slow. The structure and function of biodiversity of macrofauna within some marine ecosystems in the New Zealand and Ross Sea Region is well understood and the available information has been used to assess habitat types at greatest risk from disturbance, particularly fishing. Many ecosystems remain poorly sampled however, and the efficacy of current spatial protection measures for biodiversity in New Zealand is unknown. However, the proportion of different marine habitat types that should be or can be protected to maintain a healthy aquatic environment is also unknown.

Progress has been made on evaluating threats and risks to the marine environment and components within it (e.g. Currey et al 2012, MacDiarmid et al 2011, 2012, 2014, http://www.fish.govt.nz/NR/rdonlyres/9516E99B-6F52-4BB9-9C2D-CC47C1939A07/0/2013NationalPlanofActionSeabirdsincludingcover.pdf, http://www.fish.govt.nz/NR/rdonlyres/94D86BF9-CF41-4BA5-9BCC-CA65DF7A7560/0/NZ_draft_NPOAsharks.pdf).

[111] http://www.pmcsa.org.nz/wp-content/uploads/New-Zealands-Changing-Climate-and-Oceans-report.pdf

[112] http://assets.royalsociety.org.nz/media/Future-Marine-Resource-Use-web.pdf

[113] http://www.statisphere.govt.nz/tier1-statistics.aspx

[114] http://www.royalsociety.org.nz/expert-advice/information-papers/yr2009/ocean-acidification-workshop/

[115] http://www.msi.govt.nz/update-me/major-projects/national-science-challenges/

[116] http://www.legislation.govt.nz/bill/government/2014/0189/latest/whole.html

There is growing awareness of the likely importance of the diversity, biomass and species mix of micro-organisms, nano- and pico-plankton, and it is a fast developing field of research. The rate of change and the resilience of biodiversity to the cumulative effect of multiple stressors across large spatial scales (e.g. ocean acidification, temperature increase and oxygen depletion), particularly as utilisation of marine resources increases, remain semi-quantified (Ramirez-Llodra et al 2011). Understanding the dynamics of climate change and predicting the impacts on food webs and fisheries are only just being investigated (e.g., Fulton 2004, Brown et al 2010, Garcia & Rosenberg 2010).

15.2 GLOBAL UNDERSTANDING AND DEVELOPMENTS

Worldwide, there is concern about biodiversity and the current rate of decline. The current doctrine states that

- Greater species diversity ensures natural sustainability for all life forms
- Healthy ecosystems can better withstand and recover from impacts

In addition, the premise that healthy biodiversity provides a number of natural services for everyone, such as ecosystem services, biological resources and social benefits as slowly reaching to politicians and industry as people ask ."Why is biodiversity important? Does it really matter if there aren't so many species?[117]". It has now been shown that biodiversity boosts ecosystem productivity where each species, no matter how small, has an important role to play. It has also been shown that greater species diversity underpins natural sustainability for all life forms; and healthy ecosystems can better withstand and recover from a variety of disasters.

In April 2002, the Parties to the Convention on Biological Diversity (CBD), including New Zealand, committed to achieve by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth. This target was subsequently endorsed by the World Summit on Sustainable Development and the United Nations General Assembly and was incorporated as a target under the Millennium Development Goals[118].

The third edition of the Global Biodiversity Outlook confirmed that the 2010 biodiversity target had not been met, and the CBD 2010 Strategic Plan notes that "actions [to achieve the 2010 target] have not been on a scale sufficient to address the pressures on biodiversity[119]. Moreover there has been insufficient integration of biodiversity issues into broader policies, strategies, programmes and actions, and therefore the underlying drivers of biodiversity loss have not been significantly reduced". The Strategic Plan includes a new series of targets for 2020 under the heading "Taking action now to decrease the direct pressures on biodiversity". The Strategic Plan for 2011–2020 was updated, revised and adopted by over 200 countries, including New Zealand[120].

The eleventh meeting of the Conference of the Parties to the Convention on Biological Diversity (held 8–19 Oct 2012)[121] generated some agreed outcomes of relevance for New Zealand, in particular:

- There was confirmation that the application of the scientific criteria for EBSAs and the selection of conservation and management measures is a matter for states and relevant inter-governmental bodies but that it is an open and evolving process that should continue to allow ongoing improvement and updating as new information comes to hand.

[117] http://www.globalissues.org/article/170/why-is-biodiversity-important-who-cares

[118] UNEP's work to promote environmental sustainability, the object of Millenium Development Goal 7, underpins global efforts to achieve all of the Goals agreed by world leaders at the Millennium Summit http://www.unep.org/MDGs/

[119] www.cbd.int/2010-target

[120] Draft updated and revised Strategic Plan for the Convention on Biological Diversity for the post-2010 period (UNEP/CBD/WG-RI/3/3) http://www.cbd.int/nagoya/outcomes/

[121] http://www.cbd.int/doc/?meeting=cop-11 UNEP/CBD/COP/11/23 Marine and Coastal Biodiversity: Revised Voluntary Guidelines for the Consideration of Biodiversity in Environmental Impact Assessments and Strategic Environmental Assessments in Marine and Coastal Areas.

- It was recognised that there was a need to promote additional research and monitoring in accordance with national and international laws, to improve the ecological or biological information in each region with a view to facilitating the further description of the areas described.
- There is a tentative schedule of further regional workshops to facilitate the description of areas meeting the criteria for EBSAs.

New Zealand government agencies are currently updating the NZBS to better align with the Aichi Biodiversity targets.

15.2.1 THE DECADE OF BIODIVERSITY 2011–2020

At its 65th session, The United Nations General Assembly declared the period 2011–2020 to be "*the United Nations Decade on Biodiversity, with a view to contributing to the implementation of the Strategic Plan for Biodiversity for the period 2011–2020*" (Resolution 65/161). The decade will serve to support and promote implementation of the objectives of the Strategic Plan for Biodiversity and the Aichi-Nagoya Biodiversity Targets. The principal instruments for implementation are to be National Biodiversity Strategies and Action Plans or equivalent instruments (NBSAPs). CBD signatory nations are expected to revise their NBSAPs and to "ensure that this strategy is mainstreamed into the planning and activities of all those sectors whose activities can have an impact (positive and negative) on biodiversity" (http://www.cbd.int/nbsap/). Throughout the United Nations Decade on Biodiversity, governments are encouraged to develop, implement and communicate the results of progress on their NBSAPs as they implement the CBD Strategic Plan for Biodiversity.

There are five strategic goals and 20 ambitious yet achievable targets. Collectively known as the Aichi Targets, they are part the Strategic Plan for Biodiversity. The five Strategic Goals are:

- Goal A - Address the underlying causes of biodiversity loss by mainstreaming biodiversity (NBSAPs) across government and society.
- Goal B - Reduce the direct pressures on biodiversity and promote sustainable use.
- Goal C - Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.
- Goal D - Enhance the benefits to all from biodiversity and ecosystem services.
- Goal E - Enhance implementation through participatory planning, knowledge management and capacity building.

Targets 6–11 specifically refer to fisheries and marine ecosystems and are provided in section 15.7 of this Chapter.

The CBD also calls for renewed efforts specifically on coastal and marine biodiversity: "The road ahead for coastal areas lies in better and more effective implementation of integrated marine and coastal area management in the context of the Convention's ecosystem approach. This includes putting in place marine and coastal protected areas to promote the recovery of biodiversity and fisheries resources and controlling land-based sources of pollution. For open ocean and deep sea areas, sustainability can only be achieved through increased international cooperation to protect vulnerable habitats and species."[122] The CBD held regional workshops during 2011 to identify information sources that might inform the location of Ecologically or Biologically Sensitive Areas (EBSAs). New Zealand participated in the SW Pacific workshop, and candidate EBSAs were identified[123]. The criteria used for identifying EBSAs and Vulnerable Marine Ecosystems were those recommended through UNGA and managed by Regional Fisheries Management Organisations[124]. The 2012 SPRFMO Science Working Group noted that there are differing approaches to identifying VMEs and EBSAs that may need to be resolved.

15.2.2 GLOBAL MARINE ASSESSMENT

The biological diversity of the marine environment is a crucial component of global resource security, ecosystem function and climate dynamics. The Marine Biodiversity Outlook Reports and Summaries prepared by UNEP's Regional Seas Programme for the 10th Conference of Parties of the Convention on Biological Diversity (CBD) held in 2010 provide the first systematic overview at a sub-global scale of the state of knowledge of marine

[122] www.cbd.int/marine/done.shtml
[123] www.cbd.int/doc/meetings/cop/cop-11/official/cop-11-03-en
[124] http://www.un.org/Depts/los/consultative_process/documents/no4_spc2.pdf

biodiversity, the pressures it faces currently and the management frameworks in place for addressing those pressures[125].

The regional reports reflect a poor outlook for the continuing well-being of marine biodiversity, which faces increasing pressures in all regions from land sourced pollution, ship sourced pollution and the impacts of fishing. These pressures are serious and are generally increasing, despite measures in place to address them. They are amplified by predicted impacts of ocean warming, acidification and habitat change arising from climate and atmospheric change. Without significant management intervention marine biological diversity is likely to deteriorate substantially in the next 20 years with growing consequences for resource and physical security of coastal nations.

With respect to fisheries, the main findings of the reports are that in most regions fisheries peaked at some point between the mid-1980s and mid-2000s that catch expansion is not possible in many cases and that increased exploitation levels would lead to lower catch levels.

All regions report increases in shipping at levels which generally reflect annual economic growth. 3.4% of the global ocean area, 8.4% of all marine areas within national jurisdiction, and 10.9% of all coastal waters are covered by protected areas. Only 0.25% of marine areas beyond national jurisdiction are within protected areas. To meet the 10% target in areas within national jurisdiction, a further 2.2 million square kilometres of marine areas will need to be designated as marine protected areas. In addition, 21.5 million square kilometres in Areas Beyond National Jurisdiction (ABNJ) would need to be protected for the target of 10% to be attained (Juffe-Bignoli et al 2014).

It is likely to be many years before this target is reached. The figures do not include some managed fishery areas that have objectives consistent with multiple sustainable use and overall objectives for conservation but even if these are taken into account the proportion managed with objectives that explicitly address sustainability of biodiversity or ecosystem processes is inadequate.

After many years of international negotiations on the need to strengthen the science-policy interface on biodiversity and ecosystem services at all levels, more than 90 governments (including New Zealand) agreed in April 2012 to officially establish the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[126]. It will be a leading global body providing scientifically sound and relevant information to support more informed decisions on how biodiversity and ecosystem services are conserved and used around the world.

The United Nations Conference on Sustainable Development (UNCSD), also known as the Rio+20 Conference (June 2011)[127] had a strong sustainability focus and generated an outcome document entitled "*the future we want*" which had a section on oceans (para 158–177) including:

- Support for the Regular Process of Global Reporting and Assessment of the State of the Marine Environment established under the General Assembly and looked forward to the completion of the first global integrated assessment of the state of the marine environment by 2014[128].
- The ongoing work of the Ad Hoc Open-ended Informal Working Group on Study Issues Relating to the Conservation and Sustainable Use of Marine Biodiversity Beyond Areas of National Jurisdiction and the wish to, by the end of the 69th session (2014) make a decision about the development of an international instrument under UNCLOS.
- A concern about the health of oceans and marine biodiversity and the work of the IMO and relevant conventions including initiatives like the London Protocol on ocean fertilisation and the global

[125] UNEP (2003) Global Marine Assessments: a survey of global and regional marine environmental assessments and related scientific activities. UNEP-WCMC/UNEP/UNESCO-IOC. 132 p available online at www.unep-wcmc.org/resources/publications/ss1/GMA_Review.pdf

[126] http://www.iucn.org/what/

[127] http://sustainabledevelopment.un.org/futurewewant.html Rio +20 outcome document

[128] Integrated assessment of the state of the marine environment by 2014. http://www.un.org/depts/los/global_reporting/Santiago_Regular_Proceess_Workshop_Presentations/GRAME_Outline_of_the_First_Integrated_Assessment_Report.pdf

programme of action for the protection of the marine environment from land based activities.

- The Rio+20 outcome also endorsed a process to develop sustainable development goals (to apply to all countries) which will include oceans issues. (This is still in its nascent stage and a clear work programme will be finalised by September 2013).

15.2.3 CLIMATE CHANGE MEANS OCEAN CHANGE

"*Rapidly rising greenhouse gas concentrations are driving ocean systems toward conditions not seen for millions of years, with an associated risk of fundamental and irreversible ecological transformation. Changes in biological function in the ocean caused by anthropogenic climate change go far beyond death, extinctions and habitat loss: fundamental processes are being altered, community assemblages are being reorganized and ecological surprises are likely*." (quote from http://www.globalissues.org/article/172/climate-change-affects-biodiversity).

Public discussion about the impacts of climate change tend to focus on changes to land and the planet's surface or atmosphere. However, most of the excess heat is going into the oceans and changes in water chemistry are underway (see Chapter 10).

Climate change can have an adverse impact on the spatial patterns of marine biodiversity and ecosystem function through changes in species distributions, species mix and habitat availability, particularly at critical stages of species life histories. A study of the global patterns of climate change impacts on ocean biodiversity projected the distributional ranges of a sample of 1066 exploited marine fish and invertebrates for 2050 using a newly developed dynamic bioclimate envelope model which showed that climate change may lead to numerous local extinctions in the sub-polar regions, the tropics and semi-enclosed seas (Cheung et al 2009). Simultaneously, species invasion is projected to be most intense in the Arctic and the Southern Ocean. With these elements taken together, the model predicted dramatic species turnovers of over 60% of the present biodiversity, implying ecological disturbances that potentially disrupt ecosystem services (Cheung et al 2009).

The Intergovernmental Panel on Climate Change (IPCC) 5th Report[129] (2014) includes chapters to explicitly address ocean climate change issues for the first time. The Working Group I and Working Group II Contributions to the Fifth Assessment Report include chapters on the ocean (WG I) and Climate Change 2014: Impacts, Adaptation, and Vulnerability including Chapters on Coastal and Oceans ecosystems, and sections on biodiversity(WGII). Working Group I consider ocean biogeochemical changes, including ocean acidification in their Chapter 3 (Observations - Ocean), and in Chapter 6 on carbon and other biogeochemical cycles. Working Group II considered water property changes, including temperature and ocean acidification in Chapter 6, "*Ocean Systems*". In addition, "*Carbon Cycle including Ocean Acidification*" were identified as cross-cutting themes across (predominantly) WG1 and WG2.

The 5th IPCC report identifies that the effects of increasing greenhouse emissions — in particular carbon dioxide — on the oceans is likely to be significant. The basic chemistry of ocean acidification is well understood. These are the 3 main concepts:

1. More CO2 in the atmosphere means more CO2in the ocean;
2. Atmospheric CO2 is dissolved in the ocean, which becomes more acidic; and
3. The resulting changes in the chemistry of the ocean disrupts the ability of plants and animals in the sea to make shells and skeletons of calcium carbonate, while dissolving shells already formed.

The Summary for Policymakers (IPPC AR5, 2014) warns that ocean related climate change at the global scale overshadows the existing challenges of managing local impacts causing declines in marine biodiversity in the face of current levels of human use and impact. "*Due to projected climate change by the mid 21st century and beyond, global marine-species redistribution and marine-biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services (high confidence). Spatial shifts of marine species due to projected warming will cause high-latitude invasions and high local-extinction rates in the tropics and semi-enclosed seas (medium confidence)*".

[129] http://www.global-greenhouse-warming.com/IPCC-5th-Report.html

(Quote from IPCC https://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf)

As the Global Biodiversity Outlook 3 report[130] summarizes, despite numerous successful conservations measures supporting biodiversity, none of the specific targets 2000 to 2010 were met, and biodiversity losses continue throughout most of the world.

In addition, "despite an increase in conservation efforts, the state of biodiversity continues to decline, according to most indicators, largely because the pressures on biodiversity continue to increase. There is no indication of a significant reduction in the rate of decline in biodiversity, nor of a significant reduction in pressures upon it."

The Outlook Report provides a reasonable understanding of the nature and extent of the problems facing marine biodiversity and marine resources. There are examples of effective actions to address some of these problems but management performance is generally insufficient and inadequately coordinated to address the growing problems of marine biodiversity decline and ecosystem change.

The World Bank, together with IUCN and Environmental Services Association released a brief for decision-makers entitled, "Capturing and Conserving Natural Coastal Carbon – Building Mitigation, Advancing Adaptation"[131]. This brief highlights the crucial importance of carbon sequestered in coastal wetlands and in submerged vegetated habitats such as seagrass beds, for climate change mitigation.

Hobday et al (2006) reported on the relative risks and likely impacts of ocean climate change and ocean acidification to marine life in Australian waters (Figure 15.1). This approach was extremely useful for summarising risks and threats of climate change on marine systems to policy makers and the subsequent development of the Commonwealth Environment Research Facilities (CERF) Marine Biodiversity Hub in Australia[132].

[130] http://www.cbd.int/doc/publications/gbo/gbo3-final-en.pdf

[131] UNFCCC COP-16 event. Cancun Messe, Jaguar. 'Blue Carbon: Valuing CO_2 Mitigation by Coastal Marine Systems. Sequestration of Carbon Along Our Coasts: Are We Missing Major Sinks and Sources?'

[132] www.marinehub.org/

Groups	Distribution/ Abundance	Phenology	Physiology/ Morphology/ Behaviour	Impacts on biological communities	Examples of impacts
Phytoplankton	High	High	Medium	High	Temperate phytoplankton province will shrink considerably
Zooplankton	High	High	Medium	High	Acidification will dissolve planktonic molluscs
Seagrasses	Medium	Low	High	Medium	Increased dissolved carbon dioxide may increase productivity
Mangroves	Medium	Low	Medium	High	Sea level rise will destroy mangrove habitat
Kelp	High	Medium	High	High	Ranges will shift southwards as SST warms
Rocky reefs	High	Medium	High	Low	Ranges will shift southwards as temperature warms
Coral reefs	High	Medium	High	High	Acidification and warming will cause calcification problems and coral bleaching
Cold water corals	High	Low	Low	High	Ocean acidification will dissolve reefs
Soft bottom dwelling fauna	Medium	Medium	Medium	Medium	Modified plankton communities or productivity will reduce benthic secondary production
Seafloor dwelling and demersal fishes	High	Medium	Medium	High	Southward movement of species along the east and west coast of Australia
Pelagic fishes	Medium	Low	Medium	Low	Pelagic tunas will move south with warming
Turtles	High	Medium	High	Low	Warming will skew turtle sex ratios
Seabirds	Medium	Medium	Low	Low	Shift in timing of peak breeding season as temperatures warm
Total number of high impact habitats or species groups	8	2	5	7	High impacts are expected for distribution, physiology and community processes

Figure 15.1: Potential biological impacts of climate change on Australian marine life. The ratings in this table are based on the expected responses to predicted changes in Sea Surface Temperature (SST), salinity, wind, pH, mixed layer depth and sea level, and from literature reviews for each species group. The implicit assumption underlying this table is that Australian marine species will respond in similar ways to their counterparts throughout the world (Hobday et al 2006.) Note: phenology means life cycle.

The Hub analysed patterns and dynamics of marine biodiversity through four research programmes to determine the appropriate units and models for effectively predicting Australia's marine biodiversity. These programmes were designed to develop and deliver tools needed to manage Australia's marine biodiversity in a changing ocean climate. The final report from three years intense research is available at the website[133]. Australia also has The Marine Adaptation Network that comprises a framework of five connecting marine themes (integration; biodiversity and resources; communities; markets and policy) that cut across climate change risk, marine biodiversity and resources, socio-economics, policy and governance, and includes ecosystems and species from the tropics to Australian Antarctic waters[134].

In late June 2011, two science-based reports heightened concerns about the critical state of the world's oceans in response to ocean climate change. One focuses on the potential impacts of ocean acidification on fisheries and higher trophic level ecology and takes a modelling approach to scaling from physiology to ecology (Le Quesne & Pinnegar 2011) and the other assesses the critical state of the world's oceans in relation to climate change and other stressors (Rogers & Laffoley (2011). MacDiarmid et al (2012) undertook an expert assessment of the impact of sixty-five potentially hazardous human activities on sixty-two identifiable marine habitats in New Zealand's territorial seas and 200 nautical mile exclusive economic

133 www.marinehub.org/

134 arnmbr.org/content/index.php/site/aboutus/

zone (EEZ). They found that many of the biggest threats stemmed from human activities outside the marine environment itself. The two biggest threats were ocean acidification and ocean warming. Seven other threats deriving from global climate change all ranked in the top 20 threats indicating the importance of global climate change to New Zealand's marine ecosystems.

15.2.4 CENSUS OF MARINE LIFE 2000–2010

In 2010, the international initiative to conduct a Census of Marine Life (CoML)[135] was concluded after ten years of accessing and databasing existing records, sampling and exploration around the globe. The Census was an unprecedented collaboration among researchers from more than 80 nations to assess and explain the diversity, distribution, and abundance of life in the oceans. During the last decade, the 2700 scientists involved in the Census have mounted 540 expeditions, identified more than 6000 potentially new species, catalogued upward of 31 million distribution records, and generated 2600 scientific publications. NIWA scientists were part of the team that led CenSeam[136], the seamount component of the Census of Marine Life, and scientists from NIWA and the University of Auckland played significant roles in a number of other programmes. The New Zealand International Polar Year-Census of Antarctic Marine Life (IPY-CAML) voyage to the Ross Sea in 2008 was a major contribution to CoML.

The Census increased the total number of known marine species by about 20 000, from 230 000 in 2000 to about 250 000 in 2010. Among the millions of specimens collected in both familiar and seldom-explored waters, the Census found more than 6000 potentially new species and completed formal descriptions of more than 1200 of them. It also found that some species considered to be rare are more common than previously thought (Ausubel et al 2010). The digital archive (the Ocean Biogeographic Information System OBIS (Uhttp://www.iobis.org/U) has now grown to 31 million observations, and the Census compiled the first regional and global comparisons of marine species diversity. It helped to create the first comprehensive list of the known marine species, and also helped to compose web pages for more than 80 000 species in the Encyclopaedia of Life[137].

Applying genetic analysis on an unprecedented scale to a dataset of 35 000 species from widely differing major groupings of marine life, the Census graphed the proximity and distance of relations among distinct species, providing new insight into the genetic structure of marine diversity. With the genetic analysis often called barcoding, the Census sometimes decreased diversity but generally its analyses expanded the number of species, especially the number of different microbes, including bacteria and archaea.

The Census has overwhelmingly demonstrated that the total number of species in the ocean remain largely unknown. The Census also demonstrated that evidence of human impacts on the oceans extends to all depths and habitats and that we still have much to learn to integrate use of resources with stewardship of a healthy marine ecosystem. The Census results could logically extrapolate to at least a million kinds of eukaryotic marine life that earn the rank of species and to tens or even hundreds of millions of kinds of microbes.

A summary of the overall state of knowledge about marine biodiversity after the Census by Costello et al (2010) places New Zealand sixth out of 18 national regions based on the collective knowledge assembled by the Census National and Regional Implementation Committees (NRIC) and comparing the Spearman rank correlation coefficients between known diversity (total species richness, alien species, and endemics) and available resources, such as numbers of taxonomic guides and experts. (Figure 15.2).

All NRICs reported what they considered the main threats to marine biodiversity in their region, citing published data and expert opinions. Although the reports were not standardised, the threats identified were grouped into several overarching issues. The data on biodiversity threats were integrated so as to rank each threat from 1 (very low) to 5 (very high threat) in each region. New Zealand was placed 12th out of 18 regions in terms of overall threat levels to biodiversity, overfishing and alien species invasion. Habitat loss and ocean acidification were identified as the biggest threats to marine biodiversity and marine habitats in New Zealand (Costello et al 2010, MacDiarmid et al 2012).

[135] www.coml.org/results-publications

[136] www.coml.org/global-census-marine-life-seamounts-censeam

[137] www.eol.org/

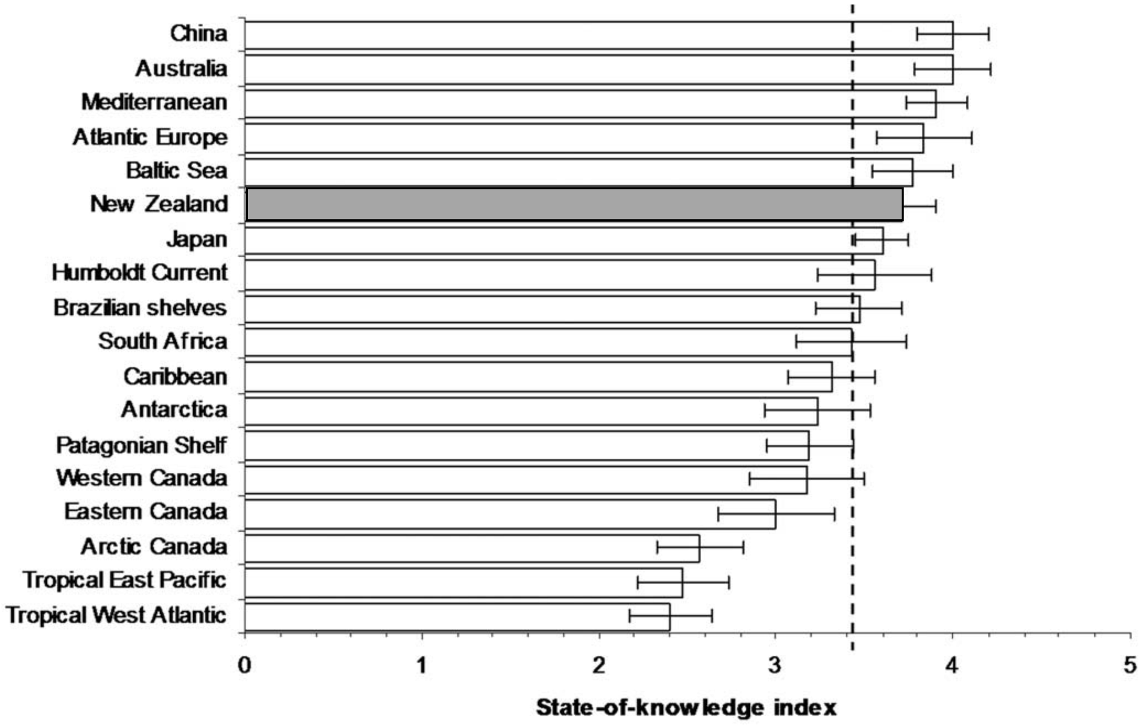


Figure 15.2: The regions are ranked by their state-of-knowledge index (mean ± standard error) across taxa. Dashed line represents the overall mean. (Image Source Costello et al 2010).

15.2.5 GLOBAL MONITORING AND INDICATORS FOR MARINE BIODIVERSITY

There are numerous schemes within and between nations to monitor the marine environment, including physical, chemical and biological components. Marine biodiversity indicators have been developed for the UK and the EU[138]. Marine environmental monitoring networks have been developed in the USA, Canada, Australia and South Africa. Global networks include the Global Ocean Observing System (GOOS) which is a permanent global system for observations, modelling and analysis of marine and ocean variables; Global Climate Observing System (GCOS[139]) which stimulates, encourages, coordinates and otherwise facilitates observations by national or international organizations. A Southern Ocean Observing System (SOOS[140]) is up and running. The SOOS International Project Office was officially opened in August 2011, hosted by the Institute for Marine and Antarctic Studies (IMAS) at the University of Tasmania, Australia[141].

Others include:

- ARGO, an international deepwater monitoring system of free floating buoys that are part of the integrated global observation strategy[142].
- The Ocean Observation Systems (OOS) in Canada have demonstrated many positive benefits.
- The Continuous Plankton Recorder (CPR) Surveys have been collecting data from the North Atlantic and the North Sea on the ecology and biogeography of plankton since 1931[143]. Sister CPR surveys around the globe include the SCAR SO-CPR Survey established in 1991 by the Australian Antarctic Division to map the spatial-temporal patterns of zooplankton and then to use the sensitivity of plankton to environmental change as early warning indicators of the health of the Southern Ocean. It also serves as reference for

138 http://jncc.defra.gov.uk/page-4233
139 www.ioc-goos.org/index.php?option=com_content&view=article&id=12&Itemid=26&lang=en
140 http://www.soos.aq/
141 http://www.scar.org/soos/
142 http://www.qc.dfo-mpo.gc.ca/publications/science/evaluation-assessment-eng.asp
143 www.sahfos.ac.uk/

other monitoring programs such as CCAMLR's Ecosystem Monitoring Program C- EMP and the developing Southern Ocean Observing System[144].

- The Marine Environmental Change Network (MECN) is a collaboration between organisations in England, Scotland, Wales, Isle of Man and Northern Ireland collecting long-term time series information for marine waters[145].
- The MECN has developed links with other networks coordinating long-term data collection and time series. These networks include the Marine Biodiversity and Ecosystem Functioning European Union Network of Excellence (MarBEF[146]) which coordinates long-term marine biodiversity monitoring at a European level.
- New Zealand has now formed a partnership with Australia's Integrated Marine Observing System (IMOS[147]) which was established in 2007. IMOS is designed to be a fully integrated national array of observing equipment to monitor the open oceans and coastal marine environment around Australasia, covering physical, chemical and biological variables. All IMOS data is freely and openly available through the IMOS Ocean Portal for the benefit of Australian and New Zealand marine and climate science as a whole.
- Oceans 2025[148] is an initiative of the Natural Environment Research Council (NERC) funded Marine Research Centres. This addresses environmental issues that require sustained long-term observations.
- The Global Ocean Acidification Observing Network (GOA-ON) is an existing global ocean carbon observatory network of repeat hydrographic surveys, time-series stations, floats and glider observations, and volunteer observing ships. The interactive map below offers the best information available on the current inventory of global OA observing platforms. With participation from scientists from over 30 countries (http://www.goa-on.org/NetworkMembers.html), GOA-ON is a strong foundation of observations of the carbonate chemistry targeted to understand chemical and ecological changes resulting from ocean acidification from regions throughout the world.

A challenge for MPI and New Zealand is how to assimilate any or all of the above monitoring approaches as a means of measuring biodiversity baseline levels and the nature and extent of biodiversity changes, especially as a means of assessing the effectiveness of management measures to protect or enhance biodiversity or halt its decline.

15.2.6 VALUATION OF BIODIVERSITY AND ECOSYSTEM MATERIAL

The national and global responsibility for New Zealand to maintain a strong environmental record in fisheries and other marine-based industries is increasing. There is growing awareness of international treaties and agreements that New Zealand is party to. Global markets are becoming increasingly sensitive to our national environmental record. Fishing companies who meet rigorous standards receive Marine Stewardship Council Certification for certain fisheries (currently, hoki trawl, southern blue whiting pelagic trawl and albacore tuna troll fisheries). Proposals to exploit other living marine resources or extract non-living marine resources are increasingly under scrutiny to ensure that such activities do not adversely degrade the marine environment or impact on marine living resource industries such as fishing and aquaculture.

The invisibility of biodiversity values has often encouraged inefficient use or even destruction of the natural capital that is the foundation of our economies. A recent international initiative "The Economics of Ecosystems and Biodiversity" (TEEB)[149] demonstrates the application of economic thinking to the use of biodiversity and ecosystem services. This can help clarify why prosperity and poverty reduction depend on maintaining the flow of benefits from ecosystems; and why successful environmental protection needs to be grounded in sound

[144] www.sahfos.ac.uk/sister-survey/sister-surveys/-southern-ocean-continuous-plankton-recorder-survey-(scar).aspx
[145] http://www.mba.ac.uk/MECN/
[146] http://www.marbef.org/
[147] http://imos.org.au/
[148] http://www.oceans2025.org/

[149] TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB. www.teebweb.org/

economics, including explicit recognition, efficient allocation, and fair distribution of the costs and benefits of conservation and sustainable use of natural resources. Valuation is seen as a tool to help recalibrate the faulty economic compass that has led to decisions about the environment (and biodiversity) that are prejudicial to both current well-being and that of future generations.

The idea of putting monetary values on natural capital is not without controversy; many underpinning life-supporting services such as nutrient recycling are difficult to quantify at scale, and assigning dollar values to many types of ecosystem services is fraught with difficulty.

A new United Nations platform, the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), was established in 2012, and provides a mechanism to assess the state of the planet's biodiversity, its ecosystems and the essential services they provide to society. This new international platform is similar in function to the IPCC in terms of bringing together international expertise, and will review information on the provisioning of biodiversity for ecosystem services, stimulate science and innovation on this research topic, and interact with national and international management agencies to integrate IPBES results into policy and management.

15.3 STATE OF KNOWLEDGE IN NEW ZEALAND

The past 750 years of human activity have impacted on marine environments. For example, depletion of fur seals and sea lions occurred from the earliest days of human settlement, not just with European arrival (Smith 2005, 2011). There was also a pulse of sedimentation coinciding with the initial clearance of 40% of New Zealand forests within 200 years of Polynesian settlement (McWethy et al 2010). Impacts have occurred near population centres, as well as in more remote areas and to depths in excess of 1000 metres (MacDiarmid et al 2012, Ministry for Primary Industries 2012). In some cases by looking back over historical records it becomes apparent how much biodiversity loss has occurred. Over long time spans incremental impacts can lead to major shifts in biodiversity composition. An analysis of marine biodiversity decline over a couple of decades could miss the major changes that can occur incrementally over long periods.

While New Zealand has reasonable archaeological, historical and contemporary data on the decline in abundance of individual marine species, in some cases over a period of 750 years (e.g., MacDiarmid et al in prep), current trends in the status of New Zealand's marine biodiversity are difficult to determine for several reasons. These include a lack of both pre-disturbance baseline and recent information, and a lack of a nationally coordinated approach to assessing and monitoring marine biodiversity.

A re-evaluation of the threat status of New Zealand's marine invertebrates was undertaken by the Department of Conservation in 2009, and identified no taxa that had improved in threat status as a result of past or ongoing conservation management action, nor any taxa that had worsened in threat status because of known changes in their distribution, abundance or rate of population decline (Freeman et al 2010). The authors cautioned however that only a small fraction of New Zealand's marine invertebrate fauna had been evaluated for their threat status and that many taxa remain 'data deficient' or unlisted. In June 2013, the Department of Conservation held an expert workshop to assess New Zealand's marine invertebrates using the New Zealand Threat Classification System (NZTCS) criteria, updating a previous listing process from 2009 (Freeman et al. 2009). A number of changes were made to the list, including those resulting from taxonomic name changes (Table 15.1). A total of 415 taxa were assessed, with a number of changes made to threat categories to reflect changes in certainty or knowledge around the distribution, abundance and population trends of some taxa, or to reflect a reinterpretation of the available data. All marine invertebrates assessed in 2009 were reassessed and an additional 108 taxa were also assessed. Most of the latter were assessed as either data deficient, or naturally uncommon. One taxon that was included in the list produced in 2009 was excluded from the current listing—*Cellana strigilis bollonsi* Powell, 1955, which is now considered to be a synonym of *C. oliveri*. While a number of changes were made to the threat categories assigned to the marine invertebrates we assessed, just one change was the result of an actual decline in abundance. The brachiopod *Pumilus antiquatus* (a monotypic, endemic genus) was listed as Nationally Endangered in 2009, but listed as Nationally Critical in 2013, to reflect an apparent decline in abundance at the sites it has previously been recorded from (Otago Harbour and Lyttleton). No taxa improved in status between 2009 and 2013 as a result of an actual change in distribution or abundance. Six taxa were listed as Nationally Critical and an additional five taxa were also included in the Threatened category. The majority of taxa we assessed were classified as At Risk, with most of these being taxa that are naturally uncommon, such as island endemics. A large number of marine invertebrates were assessed as Data Deficient. However, the majority of the New Zealand marine invertebrate fauna (over 95%) remains unassessed in the New Zealand Threat Classification System. While representatives of phyla not assessed in 2009 were included in the current assessment (e.g. sponges, phylum porifera), the full range of marine invertebrate phyla are not yet represented in the list.

A re-evaluation of marine mammal threat status found that relative to the previous listing, the threat status of two species worsened: the NZ sea lion (*Phocarctos hookeri*) was uplisted to Nationally Critical and the bottlenose dolphin (*Tursiops truncatus*) was uplisted to Nationally Endangered. No species was considered to have an improved status (See Chapter on marine mammals and also Baker et al 2010).

The most recent State of the Environment Report in New Zealand (MfE 2007) covers marine biodiversity in the Oceans section which states:

"Of the almost 16,000 known marine species in New Zealand, 444 are listed as threatened. Well-known species of particular concern include both subspecies of Hector's dolphin, New Zealand sea lion, southern right whale, Fiordland crested penguin, and New Zealand fairy tern. Land-based pressures on the inshore marine environment, as well as pressures on fisheries stocks, can be expected to persist and, therefore, continue to pose a challenge to the health of the marine environment. The increasing number of introduced species brought to New Zealand through marine-based trade and travel, and climate change may exacerbate existing pressures. Further information about our marine environment is needed if we are to help set priorities for future use and protection of our oceans".

Two major knowledge gaps identified by MfE 2007 that hinder resource management are sparse biodiversity baseline information; and the lack of a systematic national-scale approach to monitoring biodiversity trends (i.e. by comparing subsequent studies to the baseline information) in New Zealand.

The most recent summary of knowledge about marine biodiversity in New Zealand is provided by Gordon (2009, 2010, 2012) and Gordon et al (2010). Table 15.1 gives a tally of 17 987 living species in the EEZ, including 4320 known undescribed species in collections.

Species diversity for the most intensively studied animal phyla (Cnidaria, Mollusca, Brachiopoda, Bryozoa, Kinorhyncha, Echinodermata, Chordata) is more or less equivalent to that in the ERMS (European Register of Marine Species) region, an area 5.5 times larger than the New Zealand EEZ (Gordon et al 2010), suggesting that the New Zealand region biodiversity is proportionately richer than the ERMS region (Table 15.1).

In New Zealand, new marine research projects initiated in 2012 include 'Marine Futures' that aims to develop an agreed decision-making framework, enabling participation of all stakeholders (public, iwi, industry, government), that facilitates economic growth, improves marine stewardship and ensures that cumulative stresses placed on the environment do not degrade the ecosystem beyond its ecological adaptive capacity (MBIE project code C01X1227). The 'Ross Sea Climate & Ecosystem' will model likely future changes in the physical environment of the region and potential consequences of these changes on the ecosystem in terms of functional links between the environment and the marine food web (MBIE project code C01X1226). 'Management of offshore mining' will develop a clear framework that will guide appropriate and robust environmental impact assessments and the development of integrated environmental management plans for the marine-mining sector, other resource users and resource management agencies (MBIE project code C01X1228).

One of the largest marine research developments in 2014 has been the launch of the National Science Challenge "Sustainable Seas"[150] The Challenge aims to enhance the utilisation of our marine resources within environmental and biological constraints.

To do this, the Sustainable Seas Challenge will focus on:

- research to describe in detail the make-up of our oceans

[150] http://www.beehive.govt.nz/release/sustainable-seas-national-science-challenge-launched

- developing a better understanding of the dynamics and sensitivities of our ocean and coastal systems
- working towards the effective integrated management of our oceans and coasts that takes into consideration environmental, societal, cultural, Māori and economic concerns and informs governance of marine resources.

Core purpose funding within the Coasts and Oceans Centre at NIWA include "Managing Marine Stressors: Quantifying and predicting the effects of natural variability, climate change and anthropogenic stressors to enable ecosystem-based approaches to the management of New Zealand's marine resources" and within the Fisheries Centre, "Ecosystem Approaches to Fisheries Management: Determine the impact of fisheries on the aquatic environment to inform an ecosystem-based approach to fisheries management and contribute to broader ecosystem-based management approaches in conjunction with the Coasts & Oceans Centre.

15.3.1 THE MPI BIODIVERSITY RESEARCH PROGRAMME

The recognition of increasing societal expectation to use fisheries management measures that will achieve biodiversity conservation was signalled by MPI through Fisheries 2030 [151] in its long-term commitment to– "ecosystem based fisheries management" and to ensuring that "biodiversity and the function of ecological systems, including trophic linkages, are conserved". While New Zealand's environmental performance with regard to fishing is perceived to be relatively high on an international scale, the Ministry is not complacent about the ongoing requirement to monitor and provide evidence that measures to achieve biodiversity conservation needs are being met. This is particularly true of the need to better understand and mitigate the effects of fishing in the areas impacted by fishing.The effects of fishing on the aquatic environment and risks to biodiversity and marine ecosystems are recognised in Fisheries Plans. Research continues to be supported through the Deepwater Research Plan, as well as the Aquatic Environment and Biodiversity Research Programmes.

There are also a range of societal values beyond commercial, customary and recreational take from the sea that are recognised as part of "strengthening our society" (see footnote 12). These include aesthetic and cultural values as well as other economic values such as tourism and marine recreation other than fishing[152]. To link socio-economic values of biodiversity to science supporting fisheries management will require a multi-disciplinary approach only just beginning in New Zealand.

MPI responded to the NZBS in 2000 with the establishment of the MPI Biodiversity Programme which has run successfully for more than 10 years with 64 research projects and a large number of published outputs, presentations and contributions to NZ and CCAMLR management measures.

The Ministry is also one of several New Zealand government agencies with a strong interest and a statutory management mandate in the Ross Sea region of Antarctica through the Antarctic Marine Living Resources Act 1981. MPI Antarctic science contributes strongly to New Zealand's whole-of-government involvement in contributions to the Commission for the Convention on Antarctic Marine Living Resources (CCAMLR) and the Antarctic Treaty. Research conducted under the BioRoss component of the MPI Biodiversity Programme seeks to help New Zealand deliver on its international obligations to support an ecosystem-based approach to management in Antarctic waters. There are strong links with the MPI Antarctic Working Group research and with other Ross Sea ecosystems research carried out under NIWA core purpose Fisheries, and Coast and Oceans Centres (e.g., Sharp et al 2010).

[151] Fisheries 2030 The full document can be downloaded from www.fish.govt.nz/en-nz/Fisheries+2030

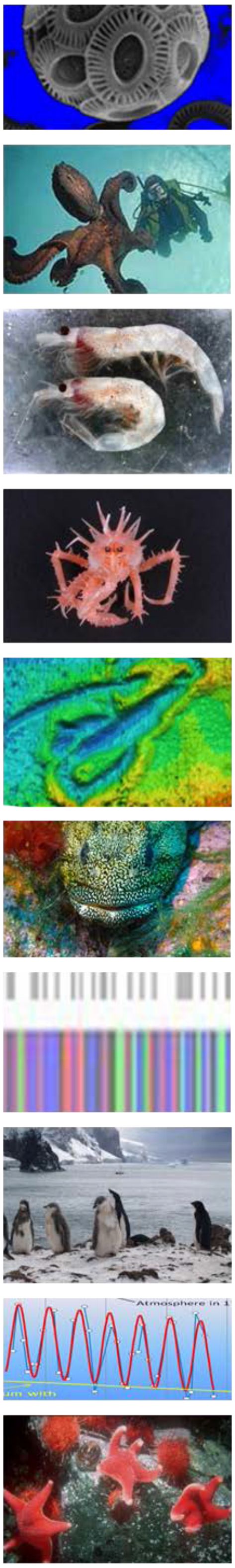
[152] MARBEF: The Valencia Declaration 2008 www.marbef.org/worldconference

Table 15.1: Diversity of marine species found in the New Zealand region (after Gordon 2010, 2012; Gordon et al 2010 and current unpublished NIWA data).

Taxonomic group	No. species[1]	State of knowledge (1 low, 5 high)	No. Alien species naturalised	No. experts	No. ID guides[2]
Superkingdom Prokaryota	**82**	**1-2**	**>1**	**3**	**1**
Cyanobacteria	40	3-4	1	2	1
All other Bacteria	42	1	?	1	0
Superkingdom Eukaryota	**17 905**	**3-4**	**185**	**59**	**77**
Kingdom Protozoa	**53**	**2**	**4**	**5**	**4**
Kingdom Chromista	**2 541**	**3-4**	**14**	**7**	**3**
Ochrophyta	858	3-4	11	1	2
Miozoa (incl. dinoflagellates)	249	3-4	0	2	0
Retaria (incl. foraminifera)	1 217	4-5	3	2	3
All other Chromista	217	2-3	0	1	0
Kingdom Plantae	**711**	**4-5**	**15**	**7**	**6**
Chlorophyta	156	3-4	0	2	2
Rhodophyta	550	4	12	2	2
Tracheophyta	5	5	3	3	2
Kingdom Fungi	**89**	**3**	**1**	**2**	**0**
Kingdom Animalia	**14 511**	**3-4**	**150**	**40**	**68**
Porifera	770	3	7	1	5
Cnidaria	1 114	4	24	0	7
Platyhelminthes	324	2	2	1	3
Mollusca	3 595	4	15	4	2
Annelida	793	3-4	33	1	2
Bryozoa	957	3-4	29	2	4
Arthropoda (esp. Crustacea)	2 979	4	27	11	17
Echinodermata	636	5	0	3	6
Tunicata	193	4	3	1	6
All other invertebrates	1 723	2-5	4	5	12
Fishes	1 254	4-5	6	6	8
All other vertebrates	173	5	0	4	4
TOTAL REGIONAL DIVERSITY[3]	**17 987**	**3-4**	**186**	**62**	**78**

[1]Sources of the tallies: scientific literature, books, field guides, technical reports, museum collections.
[2]Identification guides cited in Gordon et al (2010).
[3]Totals from Gordon (2009, 2010, 2012, 2013), Gordon et al (2010) and Nelson (2013) and unpublished NIWA data.

The biodiversity research programme set up under the NZBS was established with a multi-stakeholder biodiversity research advisory group (BRAG), chaired by the former Ministry of Fisheries (now MPI). The research commissioned for the period 2001–2005 reflected goals set by the NZBS and the BRAG, while remaining compatible with the Ministry of Fisheries Statements of Intent (SOIs). During the first three years of this period, the Ministry of Fisheries also commissioned marine biosecurity research under NZBS, but this was transferred to Biosecurity New Zealand (MAFBNZ) in 2004. From 2006 to 2010, the programme evolved further with the development of a new 5-year work programme to address shortcomings identified in a review of the NZBS by Clark & Green (2006). An overview of the Biodiversity Programme at a glance is given in Figure 15.3.



BIODIVERSITY THEMES	KEY QUESTIONS
BIODIVERSITY PATTERNS & DISTRIBUTION • Fauna and flora (taxonomy, biosystematics) • Distribution & abundance of major groups • Reviews of existing knowledge • Biogeography • Drivers of observed patterns	• What is the abundance and distribution of marine biodiversity in NZ? • What are the key drivers of observed patterns in biodiversity? • How much marine endemism is there in NZ waters? • What is the organism size distribution? • How do patterns in biodiversity change over time?
HABITAT DIVERSITY • Biogenic reefs • Rocky reefs • Rhodolith beds • Seamounts • Soft sediments • Habitat mapping EEZ • Deepsea habitats • Physical and biological characterisation	• What are the relative goods and services offered by each habitat to aquatic environment health? • Can the assemblages and biodiversity of marine habitats in the EEZ be predicted by modelling? • Which habitats are at greatest risk from extraction practices? • What proportion of a given habitat needs to remain intact for healthy ecosystem functioning?
FUNCTIONAL DIVERSITY • The role of different animal/plant groups in the ecosystem • Trophic processes • Bentho-pelagic processes	• How does biodiversity contribute to the resilience of ecosystems to perturbation? • Can we use ecosystem function to classify biodiversity? • Which key processes need to be retained?
GENETIC DIVERSITY • Barcode of Life • Connectivity (populations, areas)	• What are the barriers to connectivity within species? • What is the role of endemism in characterising the evolutionary history and taxonomy?
THREATS TO BIODIVERSITY • Climate change and variability • Invasive organisms; fishing • Land-use effects • Cumulative effects	• What are the key threats? • Does biodiversity increase resilience to climate change? • Which components of the ecosystem will be most at risk from climate change?
METHODS • Measuring biodiversity • Classification • Predictive modelling • Biodiversity indicators • Monitoring biodiversity • Ecosystem approaches	• How can we best measure and portray biodiversity? • How scalable are results from a local scale to an ecosystem scale? • What do we need to monitor to measure risks and change to ecosystem health? • How can we measure the economic value of biodiversity and ecosystem services?
BIOROSS/ & IPY RESEARCH • Bioross coastal biodiversity • Subtidal ice-sea interface • Census of Antarctic marine Life survey for IPY, Ross Sea • Trophic modelling Ross Sea • Balleny Islands survey for MPA • Functional habitats	• What is the connectivity between biodiversity in the Ross Sea and NZ? • How are biota adapted to polar conditions and what is their sensitivity to perturbation? • Are MPAs a useful protection tool for the Ross Sea? • Are climate change effects on the ocean already impacting on the Ross Sea biota?

Figure 15.3: Summary of MPI Biodiversity Research Programme 2000–2013. [Continued on next page]

ACHIEVEMENTS & KNOWLEDGE TO DATE	CURRENT WORK
• Taxonomy of coralline algae and bryozoans (2 ID Guides) • Coral and seapen ID Guides produced • Review of macroalgae distribution on soft sediments • Contribution to several books on marine biodiversity in NZ • EEZ surveys on Fjordland, Spirit's Bay, Kermadec seamounts, Farewell Spit, Norfolk Ridge, Chatham Rise and Challenger Plateau. • Links to MAFBNZ biodiversity mapping; MEC, MFish BOMEC • Extensive new data sets and specimen collections obtained	• Ongoing taxonomic work in relation to deep sea corals (VMEs) • Ongoing taxonomic work on specimens collected from the Chatham-Challenger project and from the IPY –CAML project.
• Ecological input to improve MEC (fish, benthic invertebrates) • Deep-sea habitats, biogenic habitat and soft-sediment reviewed • Ocean Survey 20/20 habitats mapped Chatham-Challenger • Biodiversity of Kermadec and Chatham Rise seamounts mapped • Foveaux Strait habitats mapped • Classification of seamounts and VMEs developed • Testing of MEC with Chatham Challenger data • Rhodolith beds as havens of biodiversity in NZ	• Mapping biogenic structures • Mapping deepsea fisheries habitats in relation to ocean acidification threats from changing saturation horizons • Modelling benthic impacts
• Rocky reef ecosystem function studied • Chatham Rise fish feeding study completed • Productivity in horse mussel and echinoderm benthic communities determined • Bioindicators in estuarine systems in Otago determined • Chatham-Challenger functional component analysis completed • Shellhash habitat function in the coastal zone	• Ocean acidification on shellfish • Response and recovery of seabed to disturbance-modelling project
• Molecular ID of certain fish and plankton determined • EEZ and Ross Seaspecies added to Barcode of Life Database, • Genetic assessment of ocean microbe diversity • Seamount connectivity reviewed	• Connectivity among coastal shellfish fish populations
• Threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation identified • Monitoring of plankton on transect NZ to Ross Sea annually • Changes in coccolithophore diversity and abundance in NZ waters and predicted change as temp and acidification increase asessed • Long-term effects of climate change on shelf ecosystems determined	• Experimental response of shellfish pH and temp. • CPR monitoring • Initial appraisal for MEMP • Acidification in deepwater fish habitat
• Diversity metrics and other indicators to monitor change developed • Large-scale sampling protocols for habitat mapping determined • Acoustic habitat mapping tools developed • Workshop held on qualitative modelling and marine environment monitoring • Development of "OFOP" and DTIS-visual analytical methods • Predictive modelling techniques progressed for biodiversity on different scales • Development of data to end-user portal interfaced with NABIS	• Development of functional biota model for habitat classification • Qualitative and quantitative modelling of rocky reef ecosystem • Predictive modelling VMEs • Measuring risk and resilience (Chat-Chall objective)
• Latitudinal gradient project and ICECUBE completed in Ross sea • Fish taxonomy and ID guide developed for the Ross Sea • Foodweb and role of silverfish vs krill studied • IPY-CAML 2008; Ross Sea 2006, BioRoss 2004 surveys done • Subtidal and offshore biodiversity sampled, Balleny Islands 2006 • Seaweed diversity determined at Balleny Islands • Bioregionalisation of the Ross Sea region completed	• Uptake of biodiversity results to CCAMLR trophic modelling and biomass estimation, VMEs • New spp logged for CAML • Review of squids, octopus

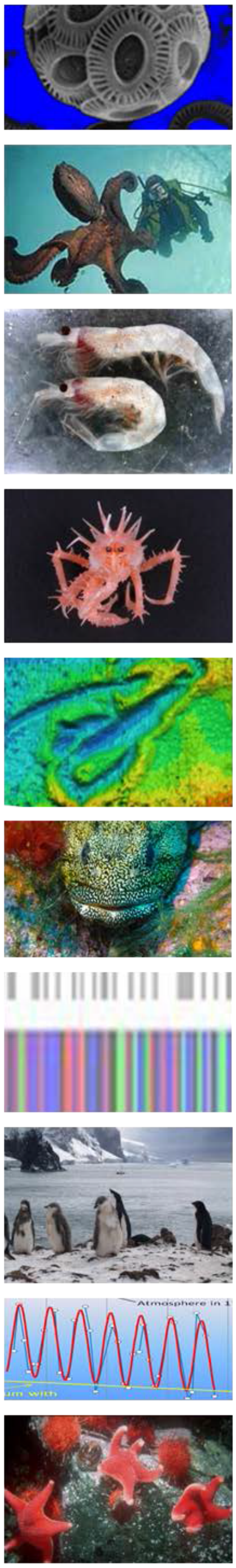


Figure 15.3 [Continued]: Summary of MPI Biodiversity Research Programme 2000–2013.

15.3.2 OVERALL PROGRESS IN MPI MARINE BIODIVERSITY RESEARCH

The MPI Marine Biodiversity Research programme has three overarching science goals:

- To describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed.
- To determine the functional role of different organisms or groups of organisms in marine ecosystems, and assess the role of marine biodiversity in mitigating the impacts of anthropogenic disturbance on healthy ecosystem functioning.
- To identify which components of biodiversity are required to ensure the sustainability of healthy marine ecosystems as well as to meet societal values on biodiversity.

More specific Science Objectives developed below have been modified by BRAG over time and are used to focus the research commissioned:

1. To classify and characterise the biodiversity, including the description and documentation of biota, associated with nearshore and offshore marine habitats in New Zealand.
2. To develop ecosystem-scale understanding of biodiversity in the New Zealand marine environment.
3. To investigate the role of biodiversity in the functional ecology of nearshore and offshore marine communities.
4. To assess developments in all aspects of diversity, including genetic marine biodiversity and identify key topics for research.
5. To determine the effects of climate change and increased ocean acidification on marine biodiversity, as well as effects of incursions of non-indigenous species, and other threats and impacts.
6. To develop appropriate diversity metrics and other indicators of biodiversity that can be used to monitor change.
7. To identify threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation.

To date, 64 research projects have been commissioned. Early studies focused primarily on Objectives 1 and 2 and resulted in reviews, Identification Guides, habitat and community characterisations, and revised taxonomy for certain groups of organisms. These objectives have also resulted in large collaborative ship-based surveys that have contributed to improved seabed classification in New Zealand waters and the exploration of new habitats in the region and in Antarctic waters. Over time, the complexity and scale of studies has increased with projects on the functional ecology of marine ecosystems from localised experimental manipulation to broad-scale observations across hundreds of square kilometres under Objective 3. Such studies have also pursued the development of improved measures of biodiversity and indicators under Objectives 6 and 7. A study on changes in shelf ecosystems over the past 1000 years is yielding insights into the effects of long-term climate change, land-use effects and fishing on marine ecosystems while more recently, some studies have begun to address the effects of ocean acidification on marine biodiversity under Objective 5. A study underway has reviewed genetic variation in the New Zealand marine environment and is conducting field observations on several species to examine genetic variation across latitudinal gradients. Aspects of the seven Objectives have also been addressed through a range of biodiversity projects in the Ross Sea region including the International Polar Year Census of Antarctic Marine Life project (IPY-CAML). A key to study findings is consideration of biodiversity within the context of the carrying capacity of the system and the natural assemblages of biota supported by that system in the absence of human disturbance.

Progress in the MPI Biodiversity Programme is summarised in Table 15.2.

Progression of research understanding	Science objective†	Estuarine/ Coastal 0–30 m	Shelf 30–200 m	Slope 200–1500 m	Deep/Abyss >1500 m	Antarctica All depths
1. Review extent of knowledge of biodiversity (desktop)	1–7					
2. Identify & characterise species and habitat diversity (field work, qualitative analysis, taxonomy & systematics)	1					
3. Quantify biodiversity distribution, abundance (replication, purpose designed surveys)	1					
4. Model and predict biodiversity distribution and abundance	1					
5. Assess or measure functional processes in healthy marine ecosystems (experiments, process studies)	2, 3					
6. Assess the role of genetic diversity	4					
7. Assess interactions and connectivity on ecosystem scale, (genetics, modelling)	2, 5					
8. Develop indicators and measures to monitor bio-diversity, ecosystem health	6					
9. Define key risks and threats to biodiversity	5, 7					
10. Define standards for maintaining biodiversity and healthy ecosystem functioning	6					
11. Examine strategies to mitigate remedy or avoid threats to biodiversity	6					
12. Monitor risks and compliance with standards	6					

† Science objectives are- 1 characterisation and description; 2 ecosystem scale biodiversity; 3 functional role of biodiversity; 4 genetics; 5 ocean climate effects; 6 indicators; 7 threats to biodiversity. The objectives are detailed in MPI Biodiversity Programme: Part 2. Medium Term Research Plan 2011–2014.

Table 15.2: Progress on biodiversity research commissioned by MPI 2000–2014. Dark grey: Significant progress (several projects completed and results emerging from research underway). Light grey: Limited progress (some results emerging, more research needed). White: no substantive research. Diagonal-hatch: progress linked to large whole-of-government projects (e.g. Ocean Survey 2020) and/or other funding outside MPI (e.g. MBIE (MSI) funded projects, DOC Marine Coastal Services, MAFBNZ marine biosecurity research).

The chart depicts a logical flow down the page of increasing conceptual complexity from cataloguing of biodiversity to increasingly complex understanding of environmental drivers and functionality of biodiversity; and ultimately methods to develop standards and protection of biodiversity. Across the chart, the marine environment is graded from the coastline to offshore regions, and Antarctica. A full list of projects can be obtained from Appendix 16 at the back of this document.

Greatest progress has been made in the shallower inshore parts of the marine environment, not least because of cost and ease of access. However, by leveraging from existing offshore projects, significant progress has also been made to depths of 1500 m.

Biodiversity research based in Antarctica lags behind EEZ-based research, simply because of the difficulty in securing additional funding to access and work in such a remote and hostile marine environment. While the top left side of the figure shows the area of greatest progress, it would be a mistake to conclude that biodiversity work is completed in the Southern Ocean.

15.3.3 PROGRESS ON SCIENCE OBJECTIVE 1. CHARACTERISATION AND CLASSIFICATION OF BIODIVERSITY

The characterisation and classification of biodiversity requires an assessment of the abundance and distribution of marine life. Building on earlier research to map fish and squid species (Anderson et al 1998, Bagley et al 2000) and the biodiversity of the New Zealand ecoregion (Arnold 2004), literature reviews, taxonomic studies and habitat mapping surveys have been undertaken.

REVIEWS AND BOOKS

The following lists scientific reviews and books on biodiversity that were commissioned by the programme:

ZBD2000-01 A review of current knowledge describing the biodiversity of the Ross Sea region (Bradford-Grieve & Fenwick 2001, 2002; Fenwick & Bradford-Grieve 2002a, 2002b, Varian 2005).

ZBD2000-06 *"The Living Reef: The Ecology of New Zealand's Rocky Reefs"* (eds. Andrew & Francis 2003).

ZBD2000-08 A review of current knowledge describing New Zealand's Deepwater Benthic Biodiversity (Key 2002).

ZBD2000-09 Antarctic fish taxonomy (Roberts & Stewart 2001).

ZBD2001-02 Documentation of New Zealand Seaweed (Nelson et al 2002).

ZBD2001-04 "Deep New Zealand" (Batson 2003)

ZBD2001-05 Crustose coralline algae of New Zealand (Harvey et al 2005, Farr et al 2009, Broom et al 2008)

ZBD2001-06 Biodiversity of New Zealand's soft-sediment communities (Rowden et al 2012).

ZBD2003-09 Macquarie Ridge Complex Research Review (Grayling 2004).

ZBD2008-27 Scoping investigation into New Zealand abyss and trench biodiversity (Lörz et al 2012a).

In addition a major work which includes marine species – "The New Zealand Inventory of Biodiversity" (Gordon 2009, Gordon 2010, Gordon 2012), has been completed. Field identification guides have also been published by MPI on deepsea invertebrates (projects ENV2005-20 and ZBD2010-39, Tracey et al 2005, 2007, 2011b), bryozoans (project IPA2009/14 Smith & Gordon 2011) and on fish species (IDG2006-01 McMillan et al (2011 a, b, c) which further contribute to the accurate monitoring and identification of biodiversity in New Zealand waters.

PROJECTS

Several hundred new species of marine organisms have been discovered, and the known range of species extended, through exploratory surveys such as the NORFANZ project ZBD2002-16 (Clark & Roberts 2008); MSI's Seamount Programme, mainly commissioned through public-good science, supplemented by MPI projects ZBD2000-04, e.g., Rowden et al 2002, 2003, ZBD2001-10 (Rowden et al 2004), ZBD2004-01 (Rowden et al 2010) and MPI projects ENV2005-15, ENV2005-16 (Clark et al 2010a, Rowden et al 2008) and the Ocean Survey 20/20 programme (Clark et al 2009); inshore surveys of bryozoans at Tasman Bay ZBD2000-03 (Grange et al 2003); Farewell Spit, ZBD2002-18 (Battley et al 2005), Fiordland, ZBD2003-04 (Wing 2005); coralline algae ZBD2001-05, ZBD2004-07 (Harvey et al 2005, Farr et al 2009); soft sediment environments ZBD2003-08 (Neill et al 2012); rhodolith community study ZBD2009- 03 (Nelson et al 2012); offshore surveys of the Chatham Rise and Challenger Plateau funded through Ocean Survey 20/20 programme, ZBD2006-04 (Nodder 2008) and ZBD2007-01 (Nodder et al 2011; Hewitt et al 2011; Bowden 2011, Bowden & Hewitt 2012; Bowden et al 2011b; Bowden et al in press).

Research in the Ross Sea Region (BioRoss projects) have also generated records of new species including MPI projects ZBD2000-02 (Page et al 2001), ZBD2001-03 (Norkko et al 2002), ZBD2002-02 (Sewell et al 2006, Sewell

2005, 2006), ZBD2003-02 (Cummings et al 2003, 2006a), ZBD2003-03 (Rowden et al 2012a, 2013), ZBD2005-03 (MacDiarmid & Stewart 2012), ZBD2006-03 (Cummings et al 2003, 2006b;), ZBD2008-23 (Nelson et al 2010)and IPY2007-01 (Bowden et al 2011a, Clark et al 2010b, Eakin et al 2009, Hanchet, et al 2008a Hanchet et al 2008b, Hanchet et al 2008c, Hanchet et al 2008d. Hanchet 2009, Hanchet 2010, Koubbi et al 2011, Lörz & Coleman 2009, Lörz et al 2012, Mitchell 2008, O'Driscoll et al 2009. O'Driscoll 2009, O'Driscoll, et al 2010, O'Loughlin et al 2011).

HABITAT DIVERSITY, CLASSIFICATION AND CHARACTERISATION

The development of the Marine Environment Classification or "MEC" (Snelder et al 2006) was an important step in the delineation of areas with similar environmental attributes in the offshore environment. However, significant environmental drivers of variability in marine biodiversity, such as substrate type for seafloor organisms, were absent from the classification. In 2005, DOC and MPI jointly commissioned a project to optimise the MEC using fish distribution data. This project (ZBD2005-02) demonstrated a substantial improvement in the MEC classification for offshore habitats (Leathwick et al 2006a, b, c). In 2006, three projects to map coastal biodiversity were completed in the Coromandel scallop, Foveaux Strait oyster and southern blue whiting fisheries as part of fishery plan development for these fisheries (ZBD2005-04, ZBD2005-15, ZBD2005-16). These projects found that the biological distribution of organisms and their habitats were not well predicted by the MEC. MPI project (BEN2006-01) aimed to further optimise the MEC by producing a methodology for a Benthic Optimised MEC (Leathwick et al 2010). MPI Ecological studies to improve habitat classification and vulnerability indices have also been completed through MPI AEWG projects on seamounts (ENV2005-15, ENV2005-16) (e.g., Clark et al 2010c), and to supplement other studies funded by MPI, and MSI (e.g. ZBD2004-01, ZBD2001-10, ZBD2000-04, and CO1X0508).

Distribution maps providing indicative abundance and characterisation of biodiversity are now emerging and have been produced through projects using predictive modelling tools e.g., Compton et al 2012, ZBD2010-40 ; the fish optimised MEC in project ZBD2005-02 (Leathwick et al 2006a, 2006b, 2006c); the benthic optimised MEC (Leathwick et al 2009); Macroalgal diversity associated with soft sediment habitats ZBD2008-05; ***deep-sea benthic biodiversity in trench, canyon and abyssal habitats below 1500 m depth ZBD2008-27***; distribution and associated biodiversity ZBD2009-03; and Chatham-Challenger project ZBD2007-01 (Hewitt et al in prep, Bowden et al 2012, Compton et al 2012).

Progress advanced considerably in recent years with the introduction of the whole-of-government Ocean Survey 20/20 Programme and Biosecurity New Zealand mapping projects (Beaumont et al 2008, 2010) In addition, MPI implemented spatial management tools (Benthic Protection Areas[153]) implemented on the basis of the Marine Environment Classification [154] [155] to address broader statutory responsibilities on the environmental effects of fishing on biodiversity.

New projects are as follows:

ZBD2013-07 Interactive identification keys for easy online use

Project Objective: Generate interactive identification keys for marine Amphipoda families Synopiidae and Epimeriidae for easy and free use online.

Amphipods are a key group of the marine fauna, as they are abundant, functionally important and a major food source for fish. The taxonomic knowledge of amphipods is a prerequisite for many ecological and commercial studies. Correct identification enables further investigations to be soundly based (e.g. modelling the effects of single or multiple stressors in the marine environment, recognising a biosecurity threat, interpreting functional roles within different habitats) as morphologically very similar species may utilize totally different ecological niches, may show different behaviour and can have different physiological requirements. The identification keys currently available for most marine Amphipoda are very out of date, only available in linear format that require a lot of taxonomic

[153] www.fish.govt.nz/en-nz/Environmental/Seabed+Protection+and+Research/Benthic+Protection+Areas.htm

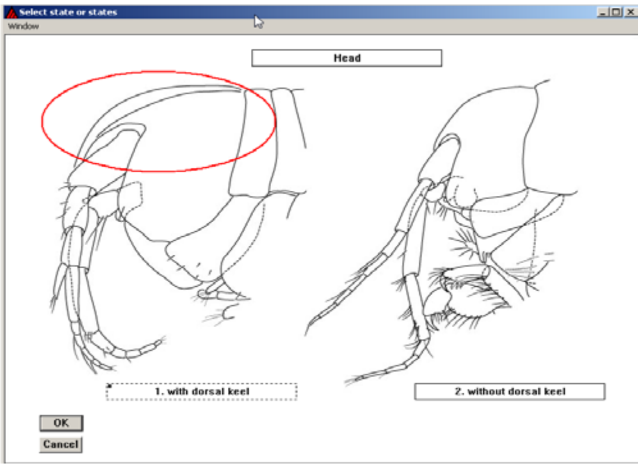
[154] Marine Environmental Classification. (2005). Can be viewed online at http://www.mfe.govt.nz/publications/ser/marine-environment-classification-jun05/index.html

[155] http://seafoodindustry.co.nz/bpa and use of MEC (2005)

expertise to use. Creating interactive keys for internet use, with illustrations of the key characters, will profoundly improve the identification process of these amphipods by making it much faster and easier - and (for the first time) possible for non-taxonomists to correctly identify amphipod samples.

Morphological characters of selected amphipods are stored in a DELTA database, and the digital illustrations and information exported to Intkey, which produces interactive identification systems for web use. Interactive keys enable the end user of taxonomic knowledge (e.g. ecologists) to identify species with the help of character state illustrations (see figure); hence there is no need for the use of the sometimes difficult terminology.

Intkey is an 'eliminative' key- it can be made as an image based key, one click can take you from 100 taxa to 5 to 1- this is completely different from dichotomous keys that have no shortcuts. Intkey is easy and fast to use, also suitable for non experts, because the characters are illustrated.



PROGRESS

We used the NIWA Biodiversity Memoir 127 (Amphipoda, Synopiidae by Lörz & Coleman 2013) as basis for the DELTA characters for species of Synopiidae occurring in New Zealand and Ross Sea waters. In September, October 2014 we expanded the morphological character basis to all Synopiidae of Antarctica – including the Weddell Sea, Antarctic Peninsula. We entered 102 character states for 22 species. Material where only nonsufficient descriptions were available we checked actual specimens held at the Natural History Museum of Berlin. While transferring DELTA to Inkey we encountered several presentation "hickups" in different versions of Intkey (such as eliminating a gap between two words, or not showing species name in italic, or changing colour of marker box etc). We are currently correcting the form of presentation for the internet use.

In November 2014 we will start gathering characters of the family Epimeriidae. We decided to use a more general approach- to focus primarily on the habitus characters. This different approach amongst the two families is based on the "easier" habitus of Epimeriidae (the species are easier to distinguish without dissecting them, contrasting Synopiids) –whereas the mouthparts of epimeriids do not distinguish amongst species (contrasting synopiids, where mouthparts are used for genera diagnosis).

For the first part of this project, an interactive key to the Synopiidae of New Zealand and Antarctica, we created data files that are located on a server on the internet. The instructions for access the interactive identification keys are as follows: DELTA must be installed first. There are two DELTA versions available:

1. the original DELTA package can be found here: http://delta-intkey.com/www/programs.htm, but there may be problems running it under Windows 7 64 bit, and
2. the newer, modern open-source version open-DELTA (https://code.google.com/p/open-delta/), which also supports Linux and MacOS.

We created a starter file "syno.ink", which can be downloaded from http://amphipod.dnsalias.net. The starter "syno-ink" must be downloaded by "right-click save as" on your computer (e.g. on your desktop or download folder). When you later click on this starter file (syno.ink), Intkey will automatically start and load the required files from our server.

ZBD2012-03: Chatham Rise Benthos Ocean Survey 20/20

This project has two objectives: (1) to determine whether there are quantifiable effects on the benthos of gradients of fishing intensity, and (2) to document seabed habitats and fauna in previously unsampled areas of the central crest of Chatham Rise, particularly within the central Chatham Rise Benthic Protection Area (BPA). A single research voyage was undertaken in June 2013 (TAN1306) funded by OS 20/20, MPI, and NIWA, with additional funding from Chatham Rock Phosphate Ltd. (CRP) for research on the crest of the rise (Objective 2). For Objective 1, three towed-camera transects and three multicorer samples were collected from each of six 10 x 10 km survey 'boxes' south of Mernoo Bank and five survey boxes on the southern flank of Chatham Rise along gradients of fishing intensity. For Objective 2, three camera transects were run in each of eight survey boxes within the Central Chatham Rise Benthic Protection Area (BPA).

Objective 1: effects on the benthos of gradients of bottom-contact fishing intensity.

This component of the research is still in progress, with all data sets planned to be ready for statistical analyses to start in early 2015. To date, 1,202 individual seabed photographs have been analysed to extract quantitative measures of benthic epifauna, bioturbation marks (burrows, tracks, etc.), and substratum type. Continuous video imagery is currently being analysed to capture quantitative data on larger, more sparsely-occurring benthic epifauna and bioturbation, and benthic and demersal fishes. Multicorer sediment samples have been analysed for sediment grain size and chemistry, and macro-infauna have been sorted from the sediments and are being identified and counted by taxonomists. Meiofauna samples were also collected from the sediment cores and these are being analysed by the University of Otago.

When complete, the multi-scale data from these analyses, ranging from cm^2 (meio- and macro-infauna, and sediments from multicorer samples), to m^2 (epifauna and substrata from still imagery), 100s m^2 (epifauna, substrata, and fishes from video imagery), and km^2 (multibeam echosounder data) will enable exploration of potential signatures of gradients in trawling disturbance on benthic habitats and communities.

Objective 2: benthic habitats and communities of the central crest region of Chatham Rise.

Work on this objective was completed in 2014, with detailed results and conclusions presented in NIWA Client Reports WLG2012-25 (Rowden et al. 2013) and WLG2014-9 (Rowden et al. 2014), and summarised in two progress reports to MPI.

Data on benthic epifaunal communities and physical substratum type extracted from the analysis of 937 seabed photographs from voyage TAN1306 were combined with comparable data from 3,908 photographs collected by CRP Ltd during a commercial survey of the area in 2012 (RV *Dorado Discovery*) and subsequently analysed by NIWA, to generate a comprehensive data set for the central Chatham Rise. Distribution maps of observed occurrences were generated for individual benthic taxa and for eight main benthic community types identified using multivariate statistical techniques. In addition to maps of observed point-occurrence, continuous coverage maps for individual taxa and communities were generated using the predictive species-environment modelling technique Boosted Regression Trees (BRT), which uses the relationships between observed point occurrences and gradients in physical environmental variables to predict probabilities of suitable habitat existing in unsampled areas.

Point-occurrence data showed that substrata across most of the crest of Chatham Rise, including the BPA, were primarily muddy soft sediments with sparse epifauna. The exception to this was in the central western part of the BPA, between approximately 179° 00' E and 179° 40' W, where areas of exposed hard substrata in the form of gravel-to-boulder sized phosphorite rock were widespread. These hard substrata supported patches of diverse epifaunal communities, often characterised by presence of the scleractinian stony coral *Goniocorella dumosa*. All such G. dumosa dominated habitats recorded were within the BPA and, with one exception, all were within the CRP Ltd, mining licence area (licence #50270). Predictive models, however, suggested that suitable environmental conditions for *G. dumosa* might also exist in an area to the northwest of the BPA that has not, to date, been surveyed. An important caveat for these predictions, however, is that the models do not include a detailed substratum-type layer. Because recruitment of *G. dumosa* and other sessile suspension-feeding taxa is dependent on the availability of exposed hard substrata at the seabed (i.e., rock), suitable oceanographic conditions are not sufficient in themselves to predict the occurrence of these taxa with any confidence.

Other research relevant or specifically linked to the projects above, is listed in Table 15.3.

Table 15.3: Other research linked to Objective 1 habitat classification and characterisation.

MPI	HAB2007-01 Biogenic habitats as areas of particular significance for fisheries management (complete) ZBD2006-02 NABIS (ongoing) Useful data related to defining potential VMEs are collected by MPI scientific fisheries observers working on NZ authorised fishing vessels that operate on the high seas in the South Pacific.
CRI core purpose or MBIE funding	NIWA Coasts & Oceans centre core-funded programmes: Programme 4 - Marine ecosystem structure and function: Programme 6 - Marine biosecurity C01X0907 Coastal Conservation Management (fish habitat classification) CO1X0906 Vulnerable deep-sea communities (mapping and sampling a range of deep-sea habitats (seamounts, slope, canyons, seeps, vents) (NIWA)
DOC	MEC development and application to MPAs, Regional surveys, ; refined habitat suitability modelling for protected coral species in the New Zealand EEZ has been undertaken along with the development of a pilot ecological risk assessment for protected corals. Both reports are currently in the final draft stage. Ongoing project that is developing a biophysical habitat classification system based on the JNCC classification system for the NZ coastal marine environment
OTHER	Victoria University of Wellington - ongoing projects involving marine biodiversity identification; marine protected areas
EMERGING ISSUES	
What portion of a given habitat type should remain intact to support sustainable ecosystems? What are the most effective predictive tools for predicting biodiversity in areas as yet unsampled?	

15.3.4 PROGRESS ON SCIENCE OBJECTIVE 2. ECOSYSTEM-SCALE RESEARCH

Marine ecosystems influence, and are influenced by, a wide array of oceanic, climatic, and ecological processes across a broad range of spatial and temporal scales. Marine communities are generally dynamic, can occur over large areas and have strong links to other communities through processes such as migration and long-distance physical transport (e.g. of larvae, nutrients, and biomass). Patterns observed on a small scale can interact with larger and longer-scale processes that in turn result in large scale patterns. Marine food webs are usually complex and dynamic over time (Link 1999). To distinguish useful descriptors of long-term ecosystem change from short-term fluctuations requires innovative approaches to integrate broad-scale correlative studies from smaller scale manipulative experiments (Hewitt et al 1998, 2007).

Recent theoretical and technical advances show great promise toward the goal of understanding the role of biodiversity in ecosystems. Technologies for remote sensing and deepwater surveying, combined with powerful integrative and interpretive tools such as GIS, climate modelling, qualitative ecosystem modelling, and trophic ecosystem modelling, will contribute to the development of an ecosystem-based approach to management (Thrush et al 1997, 2000), with potential benefits for marine conservation and management. Ecosystem modelling of species distribution (and habitats) with respect to known and projected environmental parameters will improve predictability for both broad and fine-scale biodiversity distribution. This has already resulted in improved definition of environmental classifications addressing biodiversity assessment. It is also important to make progress in establishing the links between biodiversity and the long-term viability of fish stocks under various harvesting strategies. It is also important that modellers consider processes from all ecosystem function perspectives i.e., top-down effects such as predation (e.g. trophic modelling), bottom-up effects such as the environment (e.g., habitat classification based on environmental variable), and wasp-waisted systems where there are major effects in both directions.

PROJECTS

ZBD2002-06A: Impacts of terrestrial run-off on the biodiversity of rocky reefs.
Completed.
(Schwarz et al 2006).

ZBD2004-02: Ecosystem scale trophic relationships of fish on the Chatham Rise.
Completed.
(Connell et al 2010, Dunn 2009, Dunn et al 2010a, b, c, d, Eakin et al 2009, Forman & Dunn 2010, Horn et al 2010, Stevens & Dunn 2011). Follow-up research on isotope

signatures to improve the trophic data from ZBD2004-02 has been incorporated into NIWA's Coast and Ocean programme and trophic modelling is underway in this programme.

ZBD2004-08 Sea-grass meadows as biodiversity and connectivity hotspots.

This contract links closely with the MBIE project Coastal Conservation Management (CO1X0907). National scale sampling across North and South Island seagrass meadows in a range of estuarine and coastal settings has shown that seagrass meadows overall consistently supported higher species richness, biomass, and productivity of invertebrates (infaunal and epifaunal). Associated sampling of small fish assemblages found that while seagrass meadows provided a nursery function to a number of species, this function was most pronounced in northern New Zealand systems, where relatively high numbers of juvenile snapper, trevally, spotties, parore, and garfish/piper were caught. However, there was strong spatial variation across different estuary and coast settings (MBIE91B).

ZBD2004-19 Ecological function and critical trophic linkages in New Zealand soft sediment habitats.

Completed.

(Lohrer et al 2010a,b). This work investigated the isolated and interactive effects of two key species on ecosystem function and trophic linkages in New Zealand soft-sediment habitats. The two indigenous species investigated had contrasting functional roles (one was a large, sedentary, structure-forming, bed-forming, pinnid bivalve—*Atrina zelandica*—and the other was a large, mobile, laterally burrowing, bioturbating, spatangoid urchin—*Echinocardium cordatum*). Each species modified soft-sediment habitats in Mahurangi Harbour, and the biodiversity therein, in opposite ways. The distributions of the two species were observed to overlap, and the interactive effects of the two species on soft-sediment macroinfaunal communities and sediment characteristcs were studied using experimental manipulations and by examining individual habitat patches and habitat transition zones.

ZBD2005-05 Effects of climate variation and human impacts on the structure and functioning of New Zealand shelf ecosystems.

The project is a multidisciplinary study to utilise archeological, paleoecological, and historical data to retrospectively model ecosystem states during different historical and prehistoric time periods. The project is collaborating with the international History of Marine Animal Populations (HMAP) project, itself a part of the Census of Marine Life (CoML) programme. The data have been used as inputs to a mass balance model of the shelf ecosystem starting with the present day Hauraki Gulf. A short video about the NZ Taking Stock project was made by HMAP staff and is currently available on the HMAP website http://hmapcoml.org/projects/nz/. Several presentations have been made at New Zealand and international conferences as results have emerged.

ZBD2008-01 Inshore biogenic habitats.

Existing knowledge on biogenic habitat-formers in the <5 – 200 m depth zone of New Zealand's continental shelf, from sources including structured fisher interviews ("Local Ecological Knowledge" LEK), primary and grey literature, and other sources have been integrated to generate maps of key biogenic habitats in New Zealand coastal waters.

Over 600 targets of interest were identified and marked on marine charts, with more than 200 of these targets being biogenic in nature. Fieldwork has been completed to verify and quantify biodiversity in biogenic habitats using Ocean Survey 20/20 vessel days on Tangaroa and a new MSI project to extend the survey potential of the project. New biogenic habitats have been identified, including extensive worm tube 'meadows' off the east coast of the South Island ("the Hay Paddock" and "Wire-weed"), with associated relatively high epi-faunal invertebrate diversity compared to adjacent bare sediments. Over 60 new species were also collected (dominated by sponges), along with range extensions of many other species. Analyses are underway for key selected areas included in the Tangaroa voyages, including offshore North Taranaki Bight, Ranfurly Bank, the polychaete meadows mentioned above, and the Otago Peninsula bryozoan fields.

IPA2009-11. Trophic Review.

This project publishes a report prepared on the feeding habits of New Zealand fishes 1960 to 2000 (Stevens et al 2011).

DOC research on Ecological Integrity

(Thrush et al. 2011)

The Department of Conservation's Marine Ecosystems Team has, since 2010–11, been developing a monitoring and reporting framework for New Zealand's marine environment, based on the concept of ecological integrity. In 2013, DOC entered a partnership with Air New Zealand (Air NZ) to part-fund the research and development work behind the Marine Ecological Integrity Programme, as a component of PlanBlue (a programme of work within DOC's Science and Capability Group). The objective of this programme is to better understand the concept of ecological integrity in the marine environment, and then develop a suite of effective and comprehensive tools for monitoring and reporting on species and ecosystems, processes, functioning and health in the marine environment. A key area of research and development is identifying and testing indicators of ecological integrity for New Zealand's marine protected areas. The application of these indicators may extend well beyond these conservation areas, to include aspects such as the effects of protected species management and coastal use on ecological integrity.

Other research relevant or specifically linked to the projects above, is listed in Table 15.4.

Table 15.4: Other research linked to ecosystem scale understanding of biodiversity in the marine environment.

MPI	ENV2006-04 Ecosystem indicators for New Zealand fisheries ENV2007-04 Climate and oceanographic trends relevant to New Zealand fisheries ENV2007-06 Trophic relationships of commercial middle depth species on the Chatham Rise ANT2012-01, ANT2013-01 – many objectives concerning ecosystem effects of fishing in the Ross Sea region, including research on spatial modelling of populations, multispecies minimum realistic modelling and biology/ecology of bycatch species DEE2010-05: Environmental Indicators for Deepwater Fisheries (Tuck et al., 2014) ZBD2005-05: Taking stock project ZBD2012-02: Tier 1 Statistic (Oceans) ZBD2008-15: Continuous Plankton Recorder – See Robinson et al. (2014). [and subsequent CPR project]
OTHER	AUT deepsea and subtidal food web dynamics; offshore & coastal biodiversity post graduate studies MBIE contestable: C01X1001 "Protecting Ross Sea Ecosystems" – ecosystem effects of fishing in the Ross Sea region Completed refer to MPI contract MBIE contestable: C01X1226 "Ross Sea Climate and Ecosystems" – effects of climate variability/change on the ecosystems of the Ross Sea region ongoing NZARI "Top predators of the Ross Sea" – Whales, seals and penguins in the Ross Sea region to understand fishery-predator interactions (http://nzari.aq/nzari-funded-projects#p2013-06) extended and ongoing..links to MPI project MBIE contestable: "Marine Futures" – ecosystem modelling and management in the Hauraki Gulf (http://www.niwa.co.nz/coasts-and-oceans/research-projects/marine-futures) complete, mapped into challenge MBIE contestable: "Climate change impacts and implications" – projected effects of climate change on New Zealand terrestrial, coastal and ocean environments and ecosystems (http://ccii.org.nz/) Waikato University: http://www.waikato.ac.nz/eri/research/coastal-and-marine-ecosystems Otago University: http://www.otago.ac.nz/marinescience Victoria University of Wellington - ongoing projects involving marine biodiversity identification; marine protected areas; fisheries, including stock assessment, in an EBM framework; work on global climate change, including OA; biosecurity; rock lobster connectivity University of Auckland : ongoing research on novel methods to measure marine biodiversity, coastal genetics studies, and marine mammal research Centre of Research Excellence: Te Pūnaha Matatini (Centre for Complex Systems and Networks) including a project on modelling biological and economic values of marine food resources (http://www.science.auckland.ac.nz/en/about/our-research/research-in-the-faculty-of-science/te-punaha-matatini.html) SeaChange: Hauraki Gulf Marine Spatial Plan, http://www.seachange.org.nz/ DOC research on marine ecological integrity? Ongoing, suite of recommended indicators

15.3.5 PROGRESS ON SCIENCE OBJECTIVE 3. THE ROLE OF BIODIVERSITY IN THE FUNCTIONAL ECOLOGY OF NEARSHORE AND OFFSHORE COMMUNITIES

An identified outcome of the Biodiversity Strategy is that by 2020 *"New Zealand's natural marine habitats and ecosystems are maintained in a healthy functioning state. Degraded marine habitats are recovering."* Sustaining ecosystem integrity in marine habitats requires a thorough understanding of the ecological and anthropogenic drivers affecting biodiversity and ecosystem function, and the ability to manage human impacts in marine environments.

Near-shore environments range from wetlands to estuaries, coasts and continental shelf ecosystems, they contain a variety of habitats and often contain species that are particularly important, either for cultural, recreational, and commercial reasons, or because the species exerts disproportionate influence on community structure and ecosystem function. Near-shore ecosystems are the multi-use ecosystems most subjected to multiple stressors. Due to ocean-coast and land-coast interactions these ecosystems will be subjected to the greatest range of stresses associated with global warming. Near-shore environments may also contain habitats that are particularly important for biodiversity in other environments, for instance by providing larval/juvenile nursery areas or by exporting nutrients. The MPI Biodiversity Programme has directed funds into research examining the implications of environmental and human impacts on the functional ecology of these key species and habitats.

Near-shore ecosystems are complex and changes in diversity and community composition may be driven by multiple variables. Interactions between variables are likely to be non-linear, with disturbance thresholds and the potential for multiple stable states. As a consequence, it is often difficult to distinguish 'natural' from 'anthropogenic' impacts affecting ecosystem dynamics. MPI BioInfo research seeks to help disentangle this complexity, recognising that there will be contributions to this from both biodiversity research and Fisheries Services research.

Regional Councils and universities support some research projects and survey programmes in coastal and estuarine waters by investigating the effects of sedimentation, pollution, ocean outfalls, sand dredge spoils, sand mining and nutrient enrichment on the marine ecosystem[156]. Although this workstream applies to offshore areas as well as near-shore, research to date has focussed on the near-shore.

PROJECTS

ZBD2005-09 Rocky reef ecosystems - how do they function?

The draft report for this project has been submitted and reviewed (Beaumont et al 2011).

The Hauraki Gulf in north-eastern New Zealand offers one of the best opportunities to investigate how rocky reef ecosystems function and what impact fishing and other human activities may have on them. This study took advantage of these circumstances to first review the extensive literature to set the parameters of a model of how north-eastern New Zealand reef ecosystems function. The study used the model to identify key species and interactions, and explore the impacts of fishing. Field work was then undertaken across the range of reefs within the Hauraki Gulf to test the model predictions, describe spatial variation in patterns of abundance of key species, determine trophic relationships and investigate the linkages of reefs to other habitats.

A qualitative model of northeast New Zealand rocky reef ecosystems was developed to explore the complexity of interactions amongst New Zealand rocky reef species and the impacts of exploitation. This model was developed on the basis of a review and summary of interactions among reef components. A key modelling outcome was the highly predictable but opposite responses by small lobsters and large predatory invertebrates to changes in the abundance of a range of other groups. This suggests that these two groups are ideal candidates as variables for monitoring reef ecosystem responses to perturbations. The modelling agreed with a well-documented example of responses to a perturbation in fishing pressure in the Leigh Marine Reserve. However, the predictability was low for all responses. This implies, for example, that the reduction of kina in the Leigh Marine Reserve and the subsequent increase in macro-algae subsequent to an increase in lobster abundance may not necessarily occur in another area.

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156 See MFish Biodiversity Research Programme 2010: Part 4. Reference Materials and Other research

Field sampling at ten rocky reef sites across the Hauraki Gulf revealed differences among sites in community structure of macroalgae and invertebrates within all habitat strata. Of the environmental factors available, depth, followed by a measure of water clarity (mean secchi disc depth), explained the most variation in the dependent variables (invertebrate taxa) from the quadrat data. Fish abundance data showed a similar, although weaker, trend across sites with depth, distance across the Gulf, and water clarity being the most important factors. The strong association between depth and water clarity and abundances of key taxa was expected and is similar to that found in earlier studies. With the exception of crayfish, there was no apparent overall relationship between invertebrate and fish abundances and marine reserve status of study sites, although the baited underwater video data showed snapper to be significantly larger within marine reserve sites than at fished sites.

Stable isotope analysis of tissue samples collected from key species from all study sites allowed insight into the functional relationships among species as well as dietary sources of carbon. Many of the study taxa, from the primary producers through to the predators, had the most depleted δ13C values at the furthest inshore and offshore sites (e.g. Poor Knights and Long Bay) and the highest δ13C values at the coastal sites (e.g. Leigh, Tawharanui and Kawau). Without direct modelling of end point source signatures we cannot definitively determine the percentage contribution of each carbon source. However, we suggest that the depleted δ13C of taxa from offshore sites is the result of a pelagic source of C and the enriched δ13C at coastal sites is the result of a more benthic input of C than at offshore sites, with sources including kelp detritus. Taxa at the inner gulf sites are also likely to be subjected to a proportion of benthic-derived enriched δ13C. There were no obvious effects of marine reserve status on the isotopic signatures of study taxa with the exception of slightly enriched δ13C of kina and snapper at Leigh, and of kina at Tawharanui.

Otolith microchemistry results for parore and snapper indicate strong connectivity between reef and non-reef systems within the wider Hauraki Gulf ecosystem. The majority of fishes sampled (both species) were likely to have originated as juveniles from lower salinity water environments such as estuaries fringing the Gulf. For snapper, the data suggest that only a small percentage of juveniles derive from reefs themselves. However, greater sampling replication is now required across a range of reef sites to better define the ratio of reef- versus estuary-derived juveniles, given the low percentage of reef-derived snapper.

DOC research on functional trait diversity

(see also DOC contract report, Hewitt et al. 2014)

As part of DOC's Ecological Integrity Programme, the use of a traits-based functional approach to the analysis of video imagery was explored. Functional traits that could be determined from video were derived from international literature and tested using video data collected by DOC. Six broad functional categories were used (living position, growth form, body flexibility, mobility, feeding mode, and size; these represent traits that are important for vulnerability, resilience, recovery as well as aspects of ecosystem functioning). A Biological Traits Analysis (BTA) supplemented by estimates of spatial heterogeneity (habitat transitions) and vertical habitat complexity was used to determine functional integrity. BTA fulfil most of the requirements of a good bio-monitoring tool, being well rooted in ecological theory, demonstrated to show responses to changes in environmental conditions and human disturbances and stability across regional species pools and time, and are directly and indirectly related to ecological functions and ecosystem goods and services. This project demonstrated the first step to an index of ecological integrity by successfully converting video data to functional traits data, in a way expected to be habitat independent.

Other research relevant or specifically linked to the projects above, are listed in Table 15.5 (next page).

Table 15.5: Other research linked to investigation of the role of biodiversity in the functional ecology of nearshore and offshore marine communities.

MPI	BEN2007-01 Assessing the effects of fishing on soft sediment habitat, fauna, and processes ongoing HAB2007-01 Biogenic habitats as areas of particular significance for fisheries management complete ZBD201202 Tier 1 Statistic Oceans, ZBD201302 VME – Genetic Connectivity ZBD201303 Continuous Plankton Recorder-2.
CRI Core purpose	C01X1005— Management Of Cumulative Effects Of Stressors On Aquatic Ecosystems ongoing; CO1X0907 Coastal Conservation Management, Freshwater and Estuaries and Coasts and Oceans
DOC	Conservancy surveys as part of EI project functional trait project
MPI Biosecurity	Biosecurity surveys- every 6 months marine high risk site surveillance
OTHER	Universities; National Science Challenge
EMERGING ISSUES	
Cumulative footprint of human activities; understanding cumulative impacts and risks; marine spatial planning	
Land-base effects on marine biodiversity and inshore/offshore habitats;	
Ecosystem-based management and integrative governance. Science challengehttp://www.sustainableseaschallenge.co.nz/	
Defining marine ecosystem services, linking them to ecosystem function and societal values	

15.3.6 PROGRESS ON SCIENCE OBJECTIVE 4. MARINE GENETIC BIODIVERSITY

Genetic biodiversity can be measured directly at the scale of genes and chromosomes or indirectly by measuring physical features at the organism scale (assuming that they have a genetic basis).

Genetic diversity is fundamental to the long-term survival, stability and success of a species. Central to this is the "metapopulation" concept where populations are sufficiently genetically distinct from each other to be identifiable as individual units. A low level of recruitment between populations counters the effects of both random genetic drift and inbreeding depression of genetic diversity.

Human activities can profoundly affect genetic diversity both within populations and between populations. For example, shipping activity (movement across the globe) and aquaculture practices (transfer of organisms to different areas) can increase population connectivity such that genetic biodiversity may decrease between populations. In extreme cases, populations can become the same genetically (homogeneous) although considerable within population diversity may remain. In the event of increased genetic connectivity, a species may become more susceptible to extinction through biological or catastrophic stochasticity. That is, in the absence of between population diversity there is insufficient genetic variance to adapt to the effects of climate change, disease epidemics and so on.

In contrast, under the much more common scenario of habitat fragmentation caused by human activities (fishing, pollution), decreased connectivity between populations will result in greater between-population diversity, but a reduction of within-population diversity. This also results in a decrease in a species survival (fitness) because fragmented or isolated populations may become extinct through environmental and genetic stochasticity or localised depletion. Periodic fluctuations in annual temperature for example can lead to small scale population extinction, which in the absence of recruitment between populations will result, over time, in the demise of all populations.

To reduce the risk of species loss, information about the genetic diversity both within populations (population isolation) and between populations (population connectivity) is needed. Without such information, the effects of perturbation on a species persistence and survival cannot be predicted. Furthermore, the links between genetic diversity, the dispersal capacity (mode of reproduction and life history development) of a species and the minimum viable population (MVP) size required in the marine environment to ensure population persistence, are little understood. For example, the MVP size for a species with a large dispersal capacity is likely to be quite different from that of a species with a relatively restricted dispersal capacity. Examining the connectivity between populations in the marine environment is fundamental to resolving some of the central challenges in ecology and has almost been ignored in the management of New Zealand fisheries and protection of biodiversity.

Understanding marine genetic diversity is also being enhanced through phylogenetic investigations of the relationships of the New Zealand marine biota using molecular sequence data. With some groups of the flora and fauna, genetic data are essential to understanding relationships and species identities. The research undertaken to date has important applications in both the documentation of diversity and in the recognition of foreign taxa (e.g. central to investigations of diversity of coralline algae in New Zealand - ZBD2001-05, ZBD2004-07; recognition of diversity – D'Archino et al 2011; distinguishing native and foreign taxa – Heesch et al 2007, 2009).

PROJECTS

ZBD2002-12 Molecular identification of cryptogenic/invasive marine species – gobies.
Complete.
(Lavery et al 2006.)

ZBD2009/10 Multi-species analysis of coastal marine connectivity
Following the completion of an extensive literature review of published and unpublished information and the identification of gaps in knowledge about taxa, habitats and spatial coverage of sampling, research focussed on the development of a standardised collecting protocol and the development and application of microsatellite markers to quantify the population genetic structure and the coastal connectivity of these taxa (Gardner et al. 2010). Open sandy shores and estuarine environments were highlighted as needing attention. For this, two PhD students carried out field work, genetic analyses, and interpretation of patterns of genetic population structure and the identification of barriers to gene flow in two species of shellfish (tuatua and pipi) and two species of flatfish (yellow-bellied flounder and sand flounder). Both PhD theses are now complete (examined, revised and submitted to the VUW library). Work is currently underway, in conjunction with the scallop work described below, to complete the writing of an Aquatic Environment and Biodiversity Report, and to compile an integrated library of references for submission to MPI. Further publications from the two PhD theses are also in preparation.

The coastal connectivity project has been extended to incorporate a new component of coastal connectivity, with work on the New Zealand scallop, *Pecten novaezelandiae*. This work focusses on population genetic structure and genetic connectivity at two different spatial scales and uses microsatellite markers (consistent with the study already concluded for the 4 species of the original

First, the extension work focusses on scallops across New Zealand (the full range of this species' distribution). Samples have been sourced from several regions including the fiords, the far north, and central New Zealand. Genetic analyses and writing up (in the form of a PhD thesis chapter) have been done and this study is now complete. Second, the extension work focusses on scallops in the Hauraki Gulf and Coromandel Peninsula region where an important fishery exists. Scallops have been collected from several populations in this region and genetic connectivity is being assessed to determine linkages among populations at small spatial and temporal scales. This information will be of particular relevance to support management of the Coromandel scallop fishery.

ZBD2013-02 Vulnerable marine ecosystems (VME) genetic connectivity
VMEs are ecosystems comprising species, communities and/or habitats that are highly vulnerable to disturbance, yet little is known about the distribution of biodiversity or genetic relationships within and between VMEs in the deep seas surrounding New Zealand. This project addresses the critical lack of data concerning deep sea genetic connectivity of VME indicator taxa, and will clarify the spatial relationships and distribution of biodiversity of several protected invertebrate VME species within New Zealand's EEZ and beyond.

One postdoctoral research fellow and one research assistant joined the project (April 2014). Following systematic examination of specimens preserved in the NIWA Invertebrate Collection (NIC), five species in two VME orders were identified as having sufficient representation over a wide geographic range within and beyond New Zealand's EEZ. These species are *Enallopsammia rostrata*, *Desmophyllum dianthus* (Order: Scleractinia, stony corals), *Leipoathes secunda*, *Bathypathes patula* and *Stichopathes variabilis* (Order: Antipatharia, black corals). Scleractinian specimens are by far the most numerous in the NIC, and the RV Tangaroa TAN1402 cruise to the Louisville Ridge (Jan -Mar2014) yielded prolific collections of *D. dianthus* in particular. The scleractinian species choice complements ongoing VME genetic connectivity work at Victoria University of Wellington, and data from both projects will provide the most comprehensive dataset on deep sea coral connectivity in New Zealand. Black corals are globally abundant yet poorly understood deep sea invertebrates, and are all protected in New Zealand. Several specimens of *Bathypathes patula* were collected in Antarctica, therefore connectivity between New Zealand and this area may also be inferred. Furthermore, *Enallopsammia rostrata*, *D. dianthus* and *B. patula* are cosmopolitan species and data from this research will be of interest to the wider deep sea community.

Genetic markers are currently being optimised for each species and include a combination of DNA sequences from various genes, microsatellites and single nucleotide polymorphisms (SNPs). Preliminary genetic analyses suggest a lack of concordant connectivity patterns between species, indicate potential genetic isolation in Louisville, and have identified potential cryptic speciation within *L. secunda*. Genetic analyses will continue into 2015, and data will be incorporated into a hydrodynamic modelling framework during the next stage of the South Pacific VME project. Octocorals are also omnipresent in deep sea communities and are well represented in the NIC, albeit with poor species-level identifications. In 2015, genetic connectivity analyses on octocorals will commence, providing much needed data for another abundant, poorly understood and highly vulnerable deep sea taxon.

Other research relevant or specifically linked to the projects above, are listed in Table 15.6.

Table 15.6: Other research linked to marine genetic biodiversity.

MPI	ENH2007-01 Stock enhancement of blackfoot paua GEN2007-01 Genetic population profile of blackfoot paua ENH2007-02 Outbreeding depression in invertebrate populations IPY2007-01 Objective 11. Barcode of life
NIWA core funding	*Marine Biosecurity.* NIWA Coasts & Oceans core funded Programme 6: Identifying and evaluating biosecurity threats to marine ecosystems from non-indigenous species and developing tools and approaches to prevent entry, reduce establishment and mitigate impacts. Programme includes Cawthron development of molecular tools for identification of non-indigenous species.
OTHER	Universities
EMERGING ISSUES	
Can genetics combined with hydrographic models usefully contribute to the identification of biodiversity hot-spots and/or to source-sink relationships within ecosystems?	

15.3.7 PROGRESS ON SCIENCE OBJECTIVE 5. EFFECTS OF CLIMATE CHANGE AND VARIABILITY ON MARINE BIODIVERSITY

Cyclical changes or trends in climate and oceanography and associated effects (such as increased ocean acidification) and how they affect the marine ecosystem as a whole have long-term implications for trophic interactions and biodiversity, as well as functional aspects of the system e.g. biogeochemical processes. With significant improvement in remote sensing tools and global monitoring of climate change, new patterns are emerging indicating that there are long-term cycles. Examples include the Interdecadal Pacific Oscillation as well as shorter periods of change in relation to the El Niño Southern Oscillation that affect ocean ecosystems. Further, physical phenomena such as the deep subtropical gyre 'spin-up' in the South Pacific which resulted in a warmer ocean around New Zealand from 1996–2002, can have flow-on effects on ecosystem functioning.

A new report was launched in 2010 by the United Nations on ocean acidification[157] Among other findings, the study shows that increasing ocean acidification will mean that by 2100 some 70% of cold water corals, (a key refuge and feeding ground for some commercial fish species), will be exposed to corrosive waters (see also Tracey et al 2011b).

[157] http://www.un.org/apps/news/story.asp?NewsID=36941&Cr=emissions&Cr1 Downloadable Report The Environmental Consequences of Ocean Acidification

In addition, given the current greenhouse gas emission rates, it is predicted that the surface water of the highly productive Arctic Ocean will become under-saturated with respect to essential carbonate minerals by the year 2032, and the Southern Ocean by 2050 with disruptions to large components of the marine food source, in particular those calcifying species, such as foraminifera, pteropods, and coccolithophores, which rely on calcium carbonate.

Emerging research suggests that many of the effects of ocean acidification on marine organisms and ecosystems will be variable and complex and will affect different species in different ways. Evidence from naturally acidified locations confirms, however, that although some species may benefit, biological communities in acidified seawater conditions are less diverse and calcifying (calcium-reliant) species are absent whereas algae tend to dominate.

Many questions remain regarding the biological and biogeochemical consequences of ocean acidification for marine biodiversity and ecosystems, and the impacts of these changes on ecosystems and the services they provide, for example, in fisheries, coastal protection, tourism, carbon sequestration and climate regulation.

Studies to predict changes in biodiversity in relation to climate change in more than a rudimentary way are beyond the state of current knowledge in New Zealand. Nevertheless, surveys of biodiversity that have occurred or are planned will provide a snapshot against which future research results or trends can be compared.

Meeting the challenges of climate change and identifying crucial issues for marine biodiversity is an area of high political interest internationally[158] and has been identified as a gap in biodiversity research in New Zealand[159]. A refresh of the New Zealand Biodiversity Strategy is underway by DOC and will include a chapter on climate change.

PROJECTS

ZBD2005-05 Long-term effects of climate variation and human impacts on the structure and functioning of New Zealand shelf ecosystems.

This is a large scale project to investigate changes in shelf ecosystems over a 1000 year time-scale to provide context and perspective on issues of natural variation versus human impacts on marine biodiversity. The project is a multidisciplinary study to collate and synthesize paleoecological, archaeological, historical, and contemporary data relating to changes in the structure and functioning of New Zealand shelf ecosystems since human arrival about 750 years ago. The data have been used to model present and four past states of the Hauraki Gulf ecosystem over the last 1000 years.

Eighteen reports stemming from this project have been submitted to the Ministry and are at various stages of review, acceptance and publication. The report most relevant to this section is Pinkerton (submitted) which reports the results of modelling the present day and historical Hauraki Gulf ecosystem. Other reports of interest include: Carroll et al. (2014) on historical harvests of southern right whales around New Zealand; Jackson et al. (submitted) on the population trajectory of southern right whales around New Zealand since 1800; Lalas et al. (accepted a; b) on prey consumption rates by NZ fur seals and sea lions; Lalas & MacDiarmid (accepted) on the recovery of a NZ fur seal population on the Otago-Catlins coast; Lorrey et al. (2013) on changes in New Zealand climate over the last 1000 years using environmental proxy data; MacDiarmid et al (submitted a) on analysis of historical data on exploitation of marine resources; MacDiarmid et al. (submitted b) on a catch history for snapper in the Hauraki Gulf using archaeological, historical and contemporary data; Maxwell & MacDiarmid (submitted) on oral histories of marine resource use by customary fishers and gatherers; Neil et al. (accepted) on the use of fish otoliths from Māori middens to determine ancient marine climates and fish growth rates; Paul (2012) on the disappearance of green lipped mussel beds in the inner Hauraki Gulf ; and Parsons et al. (2011) on using historical anecdotes to provide insight into the history of exploitation of snapper in the Hauraki Gulf. MacDiarmid et al. (submitted c) provide an overview and synthesis of information provided in the other reports stemming from this project.

The Taking Stock project has the objective of elucidating how the structure and functioning of New Zealand shelf

[158] http://biodiversity-l.iisd.org/news/ungas-second-committee-considers-biodiversity-and-sustainable-development/

[159] Green, W.; Clarkson, B. (2006). Review of the New Zealand Biodiversity Strategy Themes

ecosystems have changed during human occupation in response to climate variation and human activity. The Hauraki Gulf was chosen as the first case study. Amongst the objectives, was an aim to model the Hauraki Gulf foodweb through human occupation. Five balanced food-web models of the Hauraki Gulf region were developed representing: (1) present day; (2) 1950 AD, just prior to onset of industrial-scale fishing; (3) 1790 AD, before European whaling and sealing; (4) 1500 AD, early Maori settlement phase; (5) 1000 AD, before human settlement in New Zealand (Pinkerton, 2013). In summary, the historical ecosystem models of the Hauraki Gulf reveal changes in the pattern of trophic importance during human occupation, with a decrease in trophic importance of top predators (seals and whales especially), but less change lower down the food-web.

ZBD2008-11 Predicting plankton biodiversity & productivity with ocean acidification.

All sample collection, experiments, and data analysis has been completed for the 6 objectives in this project, with Final Reports completed for 5 of the objectives. Objective 1 provided a survey of coccolithophore diversity in NZ waters with 46 species identified, of which 31 were new or recently identified species. The Subtropical front along the Chatham Rise region was the primary region for coccolithophores, with highest abundance and diversity. The objective provided a baseline for coccolithophore diversity, abundance and biogeography against which future responses to climate change can be assessed. A paper describing a new coccolithophore species has been published (Hoe, 2013), and a second describing coccolithophore biodiversity across the EEZ submitted (Hoe et al.).

Emiliania huxleyi was the dominant coccolithophore in NZ waters, reaching densities exceeding 106/litre, which is fortuitous, as this species is applicable to measurement by remote sensing. The unique light-scattering properties of the coccoliths of *E. huxleyi* has underpinned the development of a global optical algorithm for estimating surface water particulate inorganic carbon (PIC) associated with *E. huxleyi*. In Objective 3 this algorithm was validated for NZ waters by comparison with in situ PIC concentrations, and then applied to SeaWifs and MODIS ocean colour datasets for 1997-2014 to produce a "coccolithophore atlas" for NZ waters including seasonal and interannual climatologies of PIC. The 15-year time-series record showed a low, but statistically significant, increase in PIC, and so *E. huxleyi*, in a zonal band between 42 and 47^{o}S around the Subtropical Front. A second remote sensing approach confirmed an increase in *E. huxleyi* bloom frequency in this region, but also indicated an increase in northern sub-tropical waters not apparent in the PIC data. Examination of biophysical coupling revealed a positive correlation between Sea Surface Temperature and PIC in the Subtropical Front, potentially indicating that *E. huxleyi* abundance may increase with warming of surface waters. There was no apparent correlation of PIC with change in pH in SubAntarctic waters since 2000, although there was a low, but significant, decline in PIC in Subtropical waters that may reflect ocean acidification or warming, or the interaction of these stressors. Consequently the results indicate differences in potential future responses in coccolithophore abundance in the two primary water masses in NZ waters. Objective 3 confirmed the value of remote sensing of *E. huxleyi* in NZ waters and provided a baseline against which future change in *E. huxleyi* distribution and biomass can be assessed.

Incubations were carried out in the laboratory and at sea in Objective 4, to determine the individual, and combined, impact of temperature and ocean acidification. Unispecific cultures of *E. huxleyi* showed no sensitivity to dissolved CO2 concentration, in terms of growth rate and particulate organic carbon (POC) production, although there was a significant decrease in calcification. Comparison with the responses of *E. huxleyi* in published unispecific culture experiments including strains from NZ waters, showed variability in response, although the decline in PIC:POC under elevated CO2 was a consistent response. This reduction in PIC:POC in *E. huxleyi* may have implications for their survival in the future surface ocean, and also for strength of the ocean carbon sink. A similar response was not apparent in incubations carried out at sea using natural mixed plankton communities containing coccolithophores, in which pH was adjusted and maintained using an in-line spectrophotometer (Hoffmann et al, 2013). The results suggest that the effects of ocean acidification may by ameliorated by increased temperature, and also masked by ecosystem interactions that are not present in unispecific cultures. Obj. 4 results indicate that *E. huxleyi* abundance may not change significantly in response to future ocean acidification and climate changes, despite declining cellular PIC:POC, and also highlight the value of using complementary experimental approaches for examining future change in the surface ocean.

Other important plankton groups with carbonate shells that may be affected by ocean acidification include the Pteopods (zooplankton) and Foraminifera (protozoa). A baseline of Foraminifera and Pteropod biodiversity, abundance and phenology was established using sediment traps at stations in Subtropical and Subantarctic waters over a 12-year time series (2000-2011) in Objective 2. Foraminiferal fluxes were generally higher in SubAntarctic waters but showed high inter-annual variability which obscured any long term trends in both water mass types. Conversely pteropod abundance was considerably higher in Subtropical waters, and, although seasonality was apparent, there was also significant interannual variability series at both sites. Although this obscured any long term trend, there was no evidence of a decline in pteropod abundance contrary to that reported in other SubAntarctic time series. Projected decline in carbonate availability may result in reduction in pteropod carbonate production and so abundance, and the time series record obtained in Objective 2 provides a valuable baseline against which this can be assessed.

Objective 5 established the distribution of nitrogen-fixing phytoplankton in subtropical waters around New Zealand, and the associated nitrogen fixation rate. Using the presence of the *nifh* gene, which encodes for the protein used in nitrogen fixation, four different phylotypes were identified on water samples from three research voyages in the Tasman Sea region (Law et al, 2011; Hasseler et al, 2014), with a declining poleward distribution associated with decreasing surface seawater temperature. The different phylotypes were generally closely associated, with higher abundances, particularly for the large colonial nitrogen-fixer, *Trichodesmium* sp., primarily in waters north of the Tasman Front. Total *nifh* abundance, and the presence and expression of *nifh* in the predominant smaller unicellular phylotype UCYN A, showed a correlation with nitrogen fixation rate. Temperature was an environmental determinant of nitrogen fixation, and this correlation was used to estimate the contribution of nitrogen fixation to new nitrogen supply in the subtropical NZ waters. A transect from north of NZ into the South-West Pacific gyre in winter showed exceptionally low nitrogen fixation in this ultra-oligotrophic region, with a corresponding absence of the main nitrogen-fixing phylotypes, with only gammaproteobacteria present. With the predicted warming of the ocean and potential extension of sub-tropical waters into the NZ EEZ, the distribution, abundance and activity of the nitrogen-fixing plankton, and associated nitrogen fixation, established in Obj. 5 will underpin projections of future plankton community composition and nutrient supply in NZ waters.

Nitrogen fixers such as *Trichodesmium* may benefit from ocean acidification, as a number of studies have shown that this species can increase carbon and nitrogen fixation under elevated CO2 (Hutchins et al, 2009). Objective 7 determined the effect of elevated CO2 and temperature on natural mixed plankton communities, containing nitrogen fixers, from NZ Subtropical waters. Contrary to other observations, nitrogen fixation was not stimulated by elevated CO2 alone, or in combination with elevated temperature, at any of the four sites tested. This reflects that the main nitrogen fixers were the smaller unicellular UCYN A phylotype; as these are photoheterotophs they may gain little benefit from the elevated CO2 (Law et al, 2012). The results of Objectives 4 and 7 highlight the importance of studying endemic natural mixed plankton communities, to determine how climate change and ocean acidification will influence plankton biodiversity and productivity in NZ waters.

ZBD2014-01 Age and growth study of deepsea coral in aquaria.

Research funding has been provided to improve our understanding of the impacts of ocean acidification on deep-sea coral growth. An initial study was carried out to evaluate the feasibility of successfully collecting live specimens at sea and maintaining deepsea corals in the laboratory. One live colony of the reef–forming scleractinian stony coral (*Solenosmilia variabilis*) was successfully sampled from 840–872 m. The coral was kept alive at sea and then in a hatchery facility for 14 months from collection date, a world 1st for *S. variabilis* as it appears to be a robust species for in aquaria studies. A new project to sample coral colonies from the Louisville Seamount Chain region and laboratory trials on live deepsea corals to investigate growth, resilience, and ocean acidification impacts has now begun. The corals are being held in the NIWA OA facility where 69 small pieces from several coral colonies are in held in chambers in the dark, and in optimal temperature 3.5 degrees flow rate based on current velocity data for the region, (flow rate of, 120 mL/min and 240 mL/min.) turning over the volume of the chambers every 15 minutes. The corals are fed twice a week with KorallFluid and eight months on the colonies are alive with tentacles extending from many of the individual calyces.

Ocean acidification and temperature manipulation are now underway to look at the physiological responses (e.g., growth) to future predicted environmental conditions. To date radial and linear extension and buoyant weight have been measured as 1st steps to observe changes in morphology and measure growth. Some species of deepsea coral up-regulate their intracellular pH when exposed to acidified conditions. This serves as an adaptive response by increasing the internal carbonate saturation state, alleviating the affect that pH reduction has on the availability of carbonate and ease of calcification. Intracellular pH measurements on *S. variabilis* live polyps will be made in January and November, 2015 to determine whether this species of coral up-regulate intracellular pH when exposed to acidified conditions. Respiration rates will also be taken to determine what energetic costs may be associated with up-regulation and calcification under acidified conditions.

ZBD2012-01 Development of a Tier 1 National Reporting Statistic for New Zealand's Marine Biodiversity

The marine ecosystem is demonstrably New Zealand's most biodiverse ecosystem, and is a global hotspot for marine biodiversity (Gordon et al. 2010, MacDiarmid 2007, Arnold 2005). New Zealand has made an international commitment under the Convention on Biological Diversity to halt the current decline in indigenous biodiversity. The New Zealand Biodiversity Strategy also contains an explicit commitment to address the paucity of knowledge of biodiversity, resulting in better, more widely used information. In October 2012, the New Zealand Government signed off on the development of new environmental Tier 1 Statistics, including a "Marine Biodiversity" Statistic to report on the wellbeing and knowledge state of marine biodiversity in New Zealand waters. This project evaluated the utility and feasibility of developing the variables published by Costello et al. (2010), and recommended marine biodiversity statistics for Tier 1 National reporting on the state of marine biodiversity in New Zealand (Lundquist et al. 2014).

Costello et al (2010) evaluated biodiversity with respect to four metrics: 1) species richness per square km; 2) state of knowledge index; 3) proportion of endemic species; and 4) number of threatened species. These potential metrics were evaluated for New Zealand based on data availability and quality for calculating statistics, likelihood of showing change over reporting periods, and compatibility with international reporting statistics and official Tier 1 National Reporting Statistics protocols and principles. Development of the statistics involved a collaborative and consultative approach, and two workshops were held with Natural Resources Sector agency staff and biodiversity scientists to ensure that the statistics were developed in a robust manner, included best available information, and were relevant to agency requirements for reporting on biodiversity.

This preliminary investigation of marine biodiversity in New Zealand allowed evaluation primarily of our current state of knowledge of marine biodiversity. While >600,000 biodiversity records were available for this analysis, there is a strong spatial bias in sampling of the marine environment, with sampling coverage focussed on coastal areas, and areas of particular interest for resource extraction (e.g., the Chatham Rise). This lack of information is in itself of interest for a publicly available statistic on New Zealand's marine biodiversity, in that it shows the public how much more there is to learn about our nation's biodiversity. Documenting this spatial bias can be used to prioritise future sampling in areas for which we have poor information on biodiversity. Other aspects of New Zealand's biodiversity, such as high rates of endemism, though unlikely to change, are of interest to the general public in demonstrating why international experts consistently rank New Zealand's waters as a hotspot for marine biodiversity. Reporting on non-indigenous marine species and threatened species can indicate trends in the health of New Zealand's marine biodiversity.

ZBD2012-02 Tier 1 Statistic (Oceans)

(Pinkerton et al, 2014)

This study has considered a wide variety of data that may be relevant to reporting on changes to the New Zealand marine, coastal and estuarine environment resulting from the effects of climate variability and change. The purpose was to recommend a set of indicators which together would form a new tier 1 statistic on oceanic climate change. Eleven recommended indicators are given in Pinkerton et al., (2014), with a preliminary ranking. Some of these recommended indicators are likely to be included in the National Environment Reporting 2015 Synthesis report (Marine Domain), led by MfE.

ZBD2013-06: Impacts of environmental change on shell generation and maintenance of important aquaculture species

Ocean acidification is a real and imminent threat to calcifying organisms, including shellfish. A recent study of potential effects of near future conditions on NZ paua, flat oysters and cockles revealed effects on survival and condition, and suggested that effects on shell generation and/or integrity may have been a contributing factor. In this new project, involving collaboration between NIWA and University of Otago, shells of individuals of each species will undergo detailed analysis to determine how the decreased pH/increased temperature modified their shell (i) thickness, (ii) mineralogy and (iii) construction. A comparison of the responses of these species, which have different mineralogies and forms and occupy different habitats, to identical experimental conditions, will allow better predictions of their differential susceptibilities to future environmental conditions.

Other research relevant or specifically linked to the projects above, are listed in Table 15.7.

Table 15.7: Other research linked to effects of climate change and variability on marine biodiversity.

MPI	SAM2005-02 Effects of climate on commercial fish abundance ENV2007-04 Climate and oceanographic trends relevant to New Zealand fisheries
MBIE	C01X502 Coasts & Oceans Centre
DOC	Baseline surveys; protected deepsea corals (Tracey et al 2011b; Baird et al 2012)
OTHER	University of Otago-NIWA shelf carbonate geochemistry and bryozoans Geomarine Services-foraminiferal record of human impact Regional Council monitoring programmes NIWA Coast and Ocean core programme US-NZ Joint Commission Meeting for scientific and technological exchange. Ongoing ocean acidification work and deepsea coarl identification
EMERGING ISSUES (this objective)	
How does climate change influence marine microbial diversity, species mix and biogeochemical roles? How will harmful toxic algal blooms be affected by warming seas? (e.g. Chang & Mullan 2003, Chang et al 2003) How will climate change affect primary industries in the sea, and ecosystem services on which industry depends?	

15.3.8 PROGRESS ON SCIENCE OBJECTIVE 6. BIODIVERSITY METRICS AND OTHER INDICATORS FOR MONITORING CHANGE

In the mid 1990s, monitoring of marine biodiversity and the marine environment was a topic of considerable discussion, yielding several reports on developing MfE indicators [160] However, since the publication of MfE's indicators in 2001, a much reduced set of core indicators that relate to the marine environment have been reported on[161]. A new international initiative launched in 2010 "Biodiversity Indicators Partnership"[162] provides guidelines and examples of biodiversity indicators developed around the globe, however, Oceania does not appear to have any partnership identified. The link between this initiative and OECD environmental indicators is unclear.

A serious gap identified by Green & Clarkson (2006) in their review of progress on implementation of the NZBS was the lack of development of an integrated national monitoring system (see Biodiversity Research Programme 2010: Part 4). Efforts to respond to this gap within the

[160] Downloadable MfE reports Confirmed indicators for the marine environment 2001, ME398; An analysis of potential indicators for marine biodiversity 1998 TR44; Environmental Performance Indicators: an analysis of potential indicators for fishing impacts 1998 TR43; Environmental Performance Indicators: Summary of Proposed Indicators for the Marine Environment 1998, ME296; Environmental Performance Indicators: Marine environment potential indicators for physical and chemical processes, and human uses and values 1998 TR45; Potential coastal and estuarine indicators - a review of current research and data 1997 TR40; Monitoring and indicators of the coastal and estuarine environment - a literature review 1997 TR39

[161] http://www.mfe.govt.nz/environmental-reporting/about/tools-guidelines/indicators/core-indicators.html

[162] www.bipnational.net/IndicatorInitiatives

Biodiversity Programme resulted in the immediate initiation of a 5-year Continuous Plankton Recorder project, and a series of workshops to determine how best to approach monitoring on a national scale (ZBD2008-14). [One objective of monitoring would be to test the effectiveness of management measures.]

PROJECTS

ZBD2008-14 What and where should we monitor to detect long-term marine biodiversity and environmental changes?

Two workshops and a follow up meeting were held with stakeholders in 2008/09 to discuss a marine environmental monitoring programme (MEMP) for New Zealand, to detect long-term changes in the marine environment, building on existing time series and data collection (Livingston 2009). The MEMP was formulated into a developmental project staged over 3 years and submitted to the former Ministry of Research Science and Technology's Cross Departmental Research Pool (CDRP) for funding starting July 2010. Since that time, CDRP funding has been withdrawn. Instead a call for proposals taking a more modest approach to developing MEMP beginning with collation of all potential data series into a metadata database, a scientific evaluation of the existing time series as to their 'fit to purpose' for MEMP was made.

Monitoring change in the marine environment is the only way we can measure long-term trends, mitigate risk and provide evidence of changes which may require policy or management practice response. DOC has since been developing an integrated approach to monitoring biodiversity particularly on the land but also in marine reserves[163].

ZBD2008-15 Continuous Plankton Recorder (CPR) Project: implementation and identification.

Complete.

(Robinson et al. In prep 2013). This project adopted the methods used in a long-term international programme that has proved highly relevant to measuring biological changes in the ocean, i.e., the Continuous Plankton Recorder Programme in the North Atlantic (SAHFOS) and more recently the Southern Ocean[164]. The Continuous Plankton Recorder Time Series objective was to map changes in the quantitative distribution of epipelagic plankton, including phytoplankton, zooplankton and euphausiid (krill) life stages in New Zealand's EEZ and transit to the Ross Sea, Antarctica. The Continuous Plankton Recorder (CPR) method of sampling provides a cost-effective, scientifically-rigorous way of measuring zooplankton biodiversity, abundance and distribution over large ocean areas (1000s of km) and over extended time periods (decades).

Five years of annual sampling from 2008–2013 was carried out using Sanford Limited's San Aotea II while en route to and from the Ross Sea toothfish fishery in November/December and February/March each year.

Data from the Ross Sea region were compared with data from the Southern Ocean CPR survey based in the East Antarctic region below Australia. Results indicate that latitudinal patterns in species composition were similar between the Ross Sea and the upstream regions of the East Antarctic, however, data from the present study show that zooplankton abundance in the Ross Sea region was substantially higher than in the East Antarctic region during the study period. Chlorophyll-*a* (chl-*a*) concentrations were also higher in the Ross Sea region than in the East Antarctic. There is an indication that variability in zooplankton abundance in the Ross Sea region is also higher than in the East Antarctic region. For example, especially high zooplankton abundances occurred in December 2009 as a result of a more than ten-fold increase of *Fritillaria* sp. This high abundance corresponded to unusually high chl-*a* throughout the Ross Sea in December 2009. There has been a statistically significant trend of increasing zooplankton abundance in all oceanic zones of the East Antarctic region since 1991, but no increasing trend in zooplankton abundance in the Ross Sea region was discernible over the sampling period 2006–2013.

ZBD2013-03 Continuous Plankton Recorder (CPR)-Phase 2

The overall objective of the Continuous Plankton Recorder (CPR)-Phase 2 project is to map changes in the quantitative distribution of epipelagic plankton, including phytoplankton, zooplankton and euphausiid (krill) life

[163] The Department of Conservation Biodiversity Monitoring and Reporting System Fact Sheet July 2010.

[164] Southern Ocean CPR programme http://data.aad.gov.au/aadc/cpr/

stages, in New Zealand's EEZ and transit to the Ross Sea, Antarctica.

The original project was established in 2008 for a five-year period with sampling carried out annually in the Austral summer. Sanford Limited continues to provide the FV *San Aotea II* and crew to take the samples, and sample analysis is carried out by the laboratory at NIWA Christchurch.

The current project, ZBD2013-03, continues this annual programme of CPR sampling and is funded for a further five years. This will enable a continuation of the data time series and provide a more robust dataset with which to make comparisons with the Southern Ocean CPR survey and potentially determine any trends in the plankton community.

To date, one summer sampling run has been completed (2013-14). Nine CPR runs were carried out between 30 November 2013 and 11 February 2014. The processing of the samples from these runs is well advanced and should be completed before the end of the second year of sampling, which is again due to commence from Nov/Dec 2014. At this stage, the new data is being collated and stored in the Southern Ocean CPR Survey meta-database.

ZBD2010-42 Marine Environmental Monitoring Programme. In 2010 MPI commissioned a review of current levels of marine environmental monitoring, with the aim of developing a comprehensive long-term marine environmental monitoring programme for New Zealand's marine environment (including oceans, coasts and estuaries) from existing sampling programmes. The project has been completed and the details are now in the process of being published as a *New Zealand Aquatic Environment and Biodiversity Report*.

The study had four components: 1 the development of an online meta-data catalogue of existing marine environmental monitoring programmes in New Zealand; 2 an evaluation of which datasets could best be used to detect long-term trends in the state of our marine environment at a national scale; 3 recommendations on a robust monitoring design focused around present monitoring; and 4 propose improvements to data collection, analysis and storage to provide greater cohesion for marine environmental reporting at the national scale.

In all, 136 databases were identified and meta-data on them stored online with access through http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand.

Thirty-five variables (biological, physical and chemical from both the seafloor and the water) were examined in detail for their fitness for purpose for national monitoring, including their present spatial and temporal coverage, their ability to be surrogates for other measures and their use internationally. The variables determined to be useful included: sea level height and sea-surface temperature; sea-surface chlorophyll-a (across the EEZ); suspended sediment surface concentrations (nearshore areas); intertidal soft-sediment macroinvertebrate counts and sediment characteristics (mud content, metal contamination and nutrient concentrations); and demersal fish counts are collected on a regular basis from many estuaries and harbours around the country.

Reporting on any of these variables at a national level would, however, require development of an analytical and reporting regime. Most variables would also require some extension of data collection, analytical methodological research and technique validation to be fully robust.

At this stage, insufficient data are being collected on water chemistry, water column biodiversity (excluding demersal fish), coastal ecological communities, and broad-scale habitats for these to be robustly reported on at a national scale. In some cases, methods for improving the collection of such data are under development (e.g., remote assessment of nutrients and habitats). In other cases, the strategies for data collection are under development (e.g., effective monitoring strategies for water quality and acidification are presently under investigation in New Zealand, in conjunction with international efforts (such as Australia's Integrated Marine Observing System, Monterey Bay Aquarium Research Institute, Global Ocean Acidification Observing Network).

Monitoring all potential variables at a national scale would be cost-prohibitive at present and research to determine new cost-effective measures that provide a wide range of information will be key to national-level reporting of the status of New Zealand's marine environment. Such research is ongoing in a number of areas and this report has been seen as critical to focussing attention on specific knowledge gaps.

Other research relevant or specifically linked to the projects above, are listed in Table 15.8.

Table 15.8: Other research linked to biodiversity metrics and other indicators for monitoring change.

MPI	ENV2006-15: Database and fishing indicator on seamount habitats (Rowden et al 2008) BEN2009-02 (Tuck et al 2010) ENV2006-04: Fisheries indicators from trawl surveys (Tuck et al 2009) DEE2010-04 Development of a methodology for Ecological Risk Assessments for Deepwater Fisheries DEE2010-05 Development of a suite of ecosystem and environmental indicators for deepwater fisheries (completed) DEE2010-06 Design a programme to monitor trends in deepwater benthic communities
MBIE	Core funding for Coasts and Oceans Centre
DOC	Conservancy projects-Hawke's Bay
OTHER	Regional Councils, Universities Ministry of the Environment draft Environmental Reporting Bill and associated Technical support, Otago University development of the Ocean Acidification Monitoring Network (Kim Currie).
EMERGING ISSUES	
Monitoring coastal waters and New Zealand's oceans to report on a national scale remains a major gap that will be addressed in part by the proposed Tier 1 statistic on Oceans and the Environmental Reporting Bill.	

15.3.9 SCIENTIFIC OBJECTIVE 7. IDENTIFYING THREATS AND IMPACTS TO BIODIVERSITY AND ECOSYSTEM FUNCTIONING

Many marine ecosystems in New Zealand have been modified in some way through the harvesting of marine biota, the selective reduction of certain species and size/age classes, modification of food webs, including the detritus components and habitat destruction. Benthic communities including seamount communities, volcanic vent communities, bryozoans, corals, hydroids and sponges are vulnerable to human disturbance. The mechanical disturbance of marine habitats that occurs with some activities such as trawling, dredging, dumping, and oil, gas and mineral exploration and extraction; can substantially change the structure and composition of benthic communities. The invasion of alien species into New Zealand waters is also a real threat, with evidence of nuisance species already well established[165].

A number of inshore marine ecosystems (especially estuaries and other sheltered waters) have been modified by sediment, contaminants and nutrients derived from human land use activities (Morrison et al 2009). Coastal margin development has had a major impact on some inshore marine communities.

A recent project commissioned by the MPI Aquatic Environment Programme, which identifies key threats to the marine environment (BEN2007-05) is complete and has listed and ranked the top threats to New Zealand's marine environment, as perceived by expert opinion. Relevant findings are that the highest ranking threats are ocean acidification, increasing sea water temperatures and bottom trawling (across all habitats) and that the most threatened habitats are intertidal reef systems in harbours and estuaries (MacDiarmid et al 2012). Ecological risk assessment (ERA) methods have also been reviewed (under ENV2005-15, Rowden et al 2008), and a trial Level 2+ assessment completed on Chatham Rise seamounts to estimate the relative risk to seamount benthic habitat from bottom trawling (under ENV2005-16, Clark et al 2011). An MPI project (DEE2010-04) has resulted in a new ecological risk assessment being developed that is tailored for New Zealand deepwater fisheries.

PROJECTS

ZBD2009-25 Predicting impacts of increasing rates of disturbance on functional diversity in marine benthic ecosystems

This project expanded on a spatially explicit patch dynamic model as a framework to illustrate how increasing rates of disturbance to benthic marine ecosystems influence functional diversity, and ultimately, other elements of

[165] http://www.biosecurity.govt.nz/biosec/camp-acts/marine http://www.biosecurity.govt.nz/pests/salt-freshwater/saltwater http://www.biosecurity.govt.nz/about-us/our-publications/technical-papers

biodiversity and ecosystem function (such as the abundance of rare species, ecosystem productivity, and the provisioning of biogenic habitat structure). The aim of the model is to provide a heuristic tool that can be used when considering seafloor disturbance regimes in the context of spatial planning and other ecosystem-based management (Lundquist et al. 2013).

Eight functional groups were defined for the model, representing key aspects of the way organisms in seafloor communities modify their environment and interact with each other. These include: opportunistic early colonists with limited substrate disturbance; opportunistic early colonists with considerable substrate disturbance; substrate stabilisers (e.g., tube mat formers); substrate destabilisers; shell hash-creating species; emergent epifauna; burrowers; and predators and scavengers. While we did not define each functional group as having a sensitivity to disturbance, each functional group is allocated a selection of life history traits based on review of the scientific literature and expert knowledge (i.e., age of maturity, maximum lifespan, seasonality of reproduction, larval dispersal distance).

When disturbance is added, the model predicts changes in the occupancy of functional groups within the model seascape. Response to disturbance and recovery rates differ between the eight functional groups, reflecting the different life history characteristics and dispersal characteristics simulated by the model. Some functional groups respond negatively to disturbance, including those known to be sensitive to, and recover slowly from, disturbance (e.g., emergent epifauna). Other groups (e.g., opportunistic taxa) respond favourably to disturbance in the model, as we would expect.

The model was run to compare with available inshore (Tasman and Golden Bays) and offshore (Chatham Rise and Challenger Plateau) empirical datasets. These datasets included video data with broad coverage of the seafloor, but relatively poor representation of small-bodied and infaunal groups, in combination with benthic sled, grabs, or cores that better sampled these groups. We used a fuzzy logic approach based on functional traits (e.g., feeding, motility, position in the sediment, size) to allocate 1056 individual taxonomic units (e.g., species) into one of eight functional groups, and compare relative abundance of functional groups from inshore and offshore surveys to model predictions.

Model predictions were consistent with changes in functional group abundance with increasing rates of disturbance in both the inshore and offshore datasets, with declines in functional group abundance occurring at the approximate disturbance rates predicted by the model. The strong similarity between model and observed community changes with disturbance showcases the value of this heuristic tool, based on fundamental biological parameters, for investigating disturbance and recovery dynamics in seafloor communities. Future research can build on this model framework, varying parameters and assumptions within model scenarios, to inform ecosystem-based management approaches for seafloor communities.

Other research relevant or specifically linked to the projects above, are listed in Table 15.9 (next page).

Table 15.9: Other research linked to threats to and impacts on biodiversity.

MPI	BEN2007-05 Assessment of anthropogenic threats to New Zealand marine habitats. MacDiarmid et al 2012 DEE2010-04
MBIE	CO1X0906 Vulnerable deep-sea communities (mapping and sampling a range of deep-sea habitats (seamounts, slope, canyons, seeps, vents), and determining relative risk to their benthic communities from human activities culminates in risk assessments; megafauna contestable?
MFE	MFE12301 Expert risk assessment of activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf. MacDiarmid et al 2011 MFE14301 Environmental risk assessment of discharges of sediment during prospecting and exploration for seabed minerals. MacDiarmid et al. 2014
EMERGING ISSUES	

The socio-economic valuation of biodiversity in NZ has not been adequately addressed.
The cumulative footprint of anthropogenic activities on the NZ marine environment has not been assessed. Potential development of seabed mining makes this a priority in deepwater environments as well as coastal.

15.3.10 BIODIVERSITY IN ANTARCTICA: BIOROSS PROJECT SUMMARIES AND PROGRESS

The objectives of BioRoss are to improve understanding of the biodiversity and functional ecology of selected marine communities in the Ross Sea. These objectives are being achieved by commissioning directed research on the diversity and function of selected marine communities in the Ross Sea region. BioRoss is committed to linking with ongoing Ross Sea ecosystems research through the Antarctic Working Group, and supporting climate change related research, especially at high latitudes.

Data acquisition from the Antarctic marine environment is logistically difficult and expensive. Nevertheless, the seven biodiversity Science Objectives listed above also drive BioRoss research projects. The BioRoss survey in 2004 and the Latitudinal Gradient Project ICECUBE have provided significant new information on biodiversity, species abundance and distribution that are now facilitating research into functional ecology and longer term monitoring programmes. This research has the potential to lead into other research on genetic diversity, climate variability and the development of indicators. The research results are also being used in the MPI Antarctic Research Programme projects on ecosystem modelling of the Ross Sea.

The MPI Antarctic Research and BioRoss Programmes are also directly involved in supporting the development of protection measures around the Balleny Islands. In 2005 MPI scientists and Ministry of Foreign Affairs and Trade (MFAT) personnel prepared a paper for submission to CCAMLR justifying MPA designation around the islands to protect ecosystem processes occurring there that may be important for the stability and function of the wider Ross Sea regional ecosystem.

To collect data in support of the MPA proposal, MPI BioRoss funded a targeted research voyage to the Balleny Islands in February 2006 (ZBD2005-01), and also provided supplementary funding to carry out opportunistic biological sampling at the Balleny Islands on a voyage to the Ross Sea that was primarily funded by LINZ to do bathymetric mapping.

The field sampling of these projects were successful, both providing important data and specimens from the Balleny Islands area and supplementary information for the Antarctic Working Group Research Programme. The results will inform research planning for subsequent projects. Support for Ross Sea region biodiversity will remain a high priority for future research in the BioRoss Programme.

In addition, BioRoss funded a further ICECUBE project to sample the Antarctic coastline during the summer season of 2006/07 (ZBD2006-03). ICECUBE is a key part of the international Latitudinal Gradient Project to explore hypotheses about environmental drivers of structure and function in sub-tidal ecosystems along the western Ross Sea coastline (Cummings et al 2008). This project acquired funding for three seasons (2007/08, 08/09, 09/10) as part of the MBIE IPY contestable round (see also Cummings et al 2011 and Thrush & Cummings 2011). Published reports and papers from the MPI Ross Sea coastal projects include Cummings et al 2003, 2006b, 2008, 2010, 2011. De Domenico et al 2006, Grotti et al 2008, Guidetti et al 2006, Norkko et al 2002, 2004, 2005, 2007; Pinkerton et al 2006, Schwarz et al 2003, 2005, Sharp et al 2010, Sutherland 2008, Thrush et al 2006, 2010 and submitted.

The New Zealand Government provided one-off funding for a Census of Antarctic Marine Life (CAML) survey to the Ross Sea from R.V. Tangaroa as part of New Zealand's involvement in the 2007–08 International Polar Year activities. The CAML Voyage was a large cooperative research effort under the banner of Ocean Survey 20/20 with considerable international collaboration, simultaneously utilising a number of different vessels with different strengths and capabilities. Progress on the two projects IPY2007-01 and IPY2007-02, is detailed below.

PROJECTS

ZBD2003-03 Biodiversity of deepwater invertebrates and fish communities of the north western Ross Sea.
Completed.

An AEBR report were produced by Rowden et al (2013) and a Voyage Report, Mitchell & Clark 2004. A number of papers have also been published in the scientific literature using specimens or data from the 2004 biodiversity survey (e.g. De Domenico et al 2006, Schiaparelli et al 2010, Rehm et al 2007, Kröger & Rowden 2008, Clark et al 2010c)

ZBD2005-01 Balleny Islands Ecology Research, Tiama Voyage (2006).

This voyage collected a large amount of new data from the Balleny Islands and surrounding waters using a range of methods, including bird and mammal observations, whale biopsy sampling, shore-based penguin colony surveys, SCUBA dive quadrats and transects, tissue collections for stable isotope analyses, and continuous acoustic/bathymetric data collection (Smith 2006). Some of the specimens and data have been used for other studies.

ZBD2005-03 Opportunistic biological data during 2006 Ross Sea voyage utilising Tangaroa.

Complete

(MacDiarmid & Stewart 2012).In brief it proved feasible to assess demersal fish abundance using the camera and lights. Because sampling was restricted to areas outside the main fishery, no toothfish were observed. The camera system, (a predecessor to the deep towed imaging system (DTIS) proved capable of characterizing the demersal fish habitat associations. Sampling using a variety of methods yielded specimens and tissue samples of a wide variety of benthic and pelagic organisms. The acoustic information collected on water column organisms was less useful than desired because of interference from the bottom profiling aspects of the voyage. Marine mammals and seabirds were routinely recorded and automated sampling of the surface waters using a continuous plankton recorder and instruments to record sea surface temperature, salinity and chlorophyll-a concentration was successful.

ZBD2008-23 Macroalgae diversty and benthic community structure at the Balleny Islands.

Complete.

As a result of this study, the known macroalgal flora of the Balleny Islands has increased from 13 to 27 species, and there are two new records for the Ross Sea in addition to the three new records reported by Page et al (2001). The biodiversity however remains poorly known, and detailed comparisons with other parts of the Antarctic region would be premature. A high proportion of the taxa reported here are known from only one collection, with a further group of taxa known from either two or three collections. Many of the taxa cannot be fully documented as there is insufficient mature material available.

The samples collected as part of a benthic survey at Borradaile Island, one of the Balleny Islands group, during the 2006 Tiama expedition have been analysed to provide an assessment of benthic community structure. The Borradaile Island sites were located in a high energy environment, sediments had relatively high organic and chlorophyll a content, and considerably lower concentrations of degraded plant material (phaeophytin) than noted in previously surveyed southern Ross Sea locations. Borradaile Island macrofaunal diversity was within the range noted for the more southern sites; macrofaunal abundance however, was more variable. Epifaunal diversity was very low, with the seastar *Odontaster validus* the only large epifaunal taxon found. In contrast, the Borradaile Island dive sites had high macroalgal diversity. Although not observed at these dive sites, the *Tiama* voyage researchers noted shallow water areas with high diversities of encrusting organisms. This study has provided the first analysis of shallow water benthic communities of the Balleny Islands. While it has shown some interesting similarities and contrasts in benthic diversity with other coastal Ross Sea locations, this information from Borradaile Island may not be representative of the entire Balleny area, and further surveys from other sites within the Balleny group are recommended (Nelson et al 2010).

ZBD2008-20 Ross Sea Ecosystem function: predicting consequences of shifts in food supply.

Complete.

Detailed information on the uptake and incorporation of different primary food sources to key epibenthic species help predict consequences of potential environmental change. Over a two year period, in situ investigations into responses to, and utilisation of, primary food sources by a common ophiuroid, were conducted at two contrasting coastal Ross Sea locations, Granite Harbour and New Harbour. At both locations, benthic net primary production was measured and the contributions of large macrobenthic organisms to ecosystem functions such as organic matter processing and nutrient recycling were quantified. Granite Harbour benthic soft-sediments supplied overlying waters with regenerated ammonium and phosphate, and the ophiuroid significantly increased the rates of nutrient release. Ultimately, the nutrients will be used by microalgae in the water column and under the ice. Detrital algae (phaeophytin) were present in sediments at greater concentrations than fresh microalgal material (chlorophyll a), and appears to be functionally important; it was a significant predictor of dissolved oxygen, phosphate, ammonium and nitrate-plus-nitrite flux. Benthic organisms in predominantly ice covered Ross Sea locations such as Granite Harbour probably feed on degraded detrital algae for much of year, given the limited amount of fresh microalgae available due to the dimly lit environment, and the consequently low rates of in situ benthic primary production. Results of the New Harbour investigations contrast those of Granite Harbour, reflecting the very different ice conditions at these two locations (Cummings et al 2010; Lohrer et al 2012b).

Other research relevant or specifically linked to the projects above, are listed in Table 15.10.

Table 15.10: Other research linked to MPI Ross Sea Antarctic biodiversity programme.

MPI	ANT2011-01 Stock modelling, fishery effects and ecosystems of the Ross Sea IPY2007-01 and 02 NZ IPY CAML projects are now complete
MBIE	C01X1001 Protecting Ross Sea Ecosystems. Comparative distribution and ecology of *Macrourus caml* and *M. whitsoni* in the Ross Sea region; feeding relationships of fish species in the Ross Sea region; Spatial processes, including spatial marine protection; Ecosystem modelling of the Ross Sea region).(Pinkerton et al 2012, Murphy et al 2012)
OTHER	Universities NIWA; Lincoln, Canterbury, Otago, Auckland, Waikato; Marsden, Cummings and Lohrer, effects of ocean acifidification and warming on under-ice algal productivity and nutrient uptake in coastal Ross Sea habitats
EMERGING ISSUES	
Coastal research and functional ecology-ongoing need Taxonomic issues for fish and invertebrates (from IPY)ANT 2005-02 Water samples from throughout water column to assess microbial content (from IPY)	

15.4 PROGRESS AND RE-ALIGNMENT

Given that the MPI Biodiversity programme has been running for more than 11 years, and that a number of new strategic documents and directions are emerging across government, it is time to look both back and forward and review the programme to ensure its alignment with more recent strategic documents.

In 2000, five strategic outcomes were built into the MPI (formerly MFish) Biodiversity Research Programme:

That by 2010:

i. *the MPI Biodiversity programme will have become an integral part of the research effort devoted to understanding New Zealand's marine environment.*
ii. *research planning will benefit from close cooperative relationships within the Ministry of Fisheries, with other government agencies, and with external stakeholders.*
iii. *mutually beneficial collaborative research projects will be carried out alongside other New Zealand and international research providers, especially for vessel-based research.*
iv. *MPI Biodiversity projects will have contributed substantially to an improved understanding of New Zealand's marine biodiversity and its role in marine ecosystem function, yielding scientifically rigorous outputs for a national and international professional audience.*
v. *results generated by MPI Biodiversity projects will be incorporated into management policy, with clear benefits for the New Zealand marine environment.*

The Biodiversity Programme has been highly effective in delivering on the first four and part of the fifth of these five outcomes. A missing element is some measure of *"clear benefits for the New Zealand marine environment"*. In recent years, significant all-of-government projects have been administered through the programme, and one-off funding applications made jointly with other stakeholders have been successful. The Programme has made a significant contribution to increasing understanding about biodiversity in the marine environment. Achievements in each outcome are addressed below.

i. *Has the Biodiversity Research Programme become integrated with New Zealand's research effort to understand the marine environment?*

Seven science objectives were developed by multiple stakeholders through the Biodiversity Research Advisory Group. The agreed objectives include ecosystem-scale studies in the New Zealand marine environment, the classification and characterisation of the biodiversity of nearshore and offshore marine habitats, the role of biodiversity in the functional ecology of marine communities, connectivity and genetic marine biodiversity, the assessment of the effects of climate change and increased ocean acidification, identification of indicators of biodiversity that can be used to monitor change, identification of key threats to biodiversity, identification of threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation.

Projects ranged from localised experiments on seabed communities of shellfish and echinoderms, to integrated studies of rocky reef systems and offshore fishery-scale trophic studies. The effects of ocean climate change (temperature, acidification) are being explored on shellfish, rhodolith communities, plankton productivity and the microbial productivity engines of polar waters. A major project to investigate shelf communities in relation to climate over the past 1000 years has resulted in the development of new methods and insights to past changes and human impact on New Zealand's marine environment.

A total of 64 projects were commissioned and managed within this 14 year period, yielding over 100 final research reports, most of which have been published through MPI Publications (Marine Biosecurity and Biodiversity Reports and Aquatic Environment and Biodiversity Reports), books, Identification Guides and mainstream scientific literature. A number of other publications are still in preparation. In addition, several workshops have been run through the Programme, including qualitative modelling techniques, how to set up a marine monitoring programme and predictive modelling. A large number of science providers, including NIWA, Cawthron Institute, University of Auckland, Auckland University of Technology, University of Waikato, Victoria University of Wellington, University of Otago, University of Canterbury and Massey University have been directly commissioned or sub-contracted to take part in or conduct research projects through the Programme during the 10-year period. For some, the projects have provided critical synergies with MBIE funded OBIs or projects, while others have provided one-off opportunities for marine biodiversity investigation or opportunistic leveraging for research voyages.

Research into the biodiversity of habitats such as seamounts has been completed and new methods to assess the vulnerability of seabed habitats have been developed. The land-sea interface is being investigated and projects have shown how land use in a given catchment can affect nutrient transfer and the living conditions and impact diversity and functioning of estuarine and coastal organisms. Publication and presentation of the results from these projects has resulted in widespread contribution to the development of Marine Science in New Zealand. Partnership with overseas researchers and presentations to international meetings and conferences has added to the growing global initiatives on marine biodiversity research questions.

Feedback from stakeholders has indicated that the move to a 5 year research planning horizon was welcomed by research providers, but some stakeholders felt that Requests for Proposals should be at a higher level than individual projects to safeguard intellectual property on new ideas and methods.

ii. *Does research planning now benefit from close cooperative relationships within the Ministry of Fisheries, with other government agencies, and with external stakeholders?*

The Biodiversity Programme is very co-operative. Of 38 projects underway in the last 5 years, 14 have formal collaborative components across government departments, with other stakeholders or multiple research providers and 10 have formal linkages to international research programmes. Within MPI and with other stakeholders (NGOs, industry, other government departments), the Biodiversity Projects have contributed to discussions about Marine Stewardship Council (MSC) certification, to decision papers on aspects of Antarctic management under CAMLR, fulfilling MPI commitments to the NZ Biodiversity Strategy, and to MPI progress towards recognising the role of the ecosystem in underpinning sustainable and healthy fisheries production. There are many other examples, e.g. the programme has contributed towards DOC and MPI decisions on marine protected areas. The interaction at the research and policy advice stages of resource management feeds back into the BRAG planning for future research.

There are close links with the MPI Aquatic Environment research programme, the National Aquatic Biodiversity Information System (NABIS), an MPI web-based interactive data access and mapping tool, and the MPI Antarctic Research programme. These and other links have enabled contributions resulting from progress on land-sea interface research, habitats of significance to fisheries management, trophic studies (MSC Certification), climate change (effects on shellfish) and habitat classification (fish optimised MEC, testing of MEC and BOMEC). The successful involvement of the Biodiversity Programme in major all-of-government projects such as Ocean Survey 20/20 and IPY-CAML, has also raised the profile of MPI and the research it has commissioned both across New Zealand and internationally.

Datasets, voucher specimens and samples from all biodiversity research projects have resulted in a substantial amount of material that has been physically preserved and housed in the Te Papa Fish Collection and NIWA National Invertebrate Collection, and Herbarium (macroalgae). All data are held in databases either at MPI, NIWA or Te Papa, and accessibility is being improved. The recent Bay of Islands Ocean Survey 20/20 Portal was very well received and nominated for NZ Government Open Source awards. It will also incorporate data access from Chatham Challenger and IPY projects. Data from a number of MPI biodiversity projects have also been entered into international biodiversity databases such as OBIS and from there into the Global Biodiversity Information Facility (GBIF).

Biodiversity Research planning receives regular input from DOC, SeaFIC, MfE, Cawthron Institute, NIWA, GNS, LINZ, MAFBNZ, Te Papa, University of Auckland, AUT, University of Otago, MoRST, MFAT, Regional Councils and others. Research planning for 2013–14 and beyond will include a re-alignment of the current research programme to take account of new developments such as Fisheries 2030, MfE's environmental reporting programme, DOC's integrated coastal monitoring programme, Statistics New Zealand's Environmental Domain Plan[166], and international commitments such as the recent CBD COP10 Aichi-Nagoya Agreement.

Feedback and support for projects by external stakeholders has shown that the Programme has been effective in promoting inter-agency collaboration. The Programme has also had close links with Research Data Management and the Observer Programme for certain projects (e.g trophic studies on the Chatham Rise, ZBD2004-02). With the former restructure of the Ministry of Fisheries and the merger with MAF, and the move to Fisheries 2030 and Fisheries Plans, it important that the Programme develops strong relationships within MPI.

iii. *Have mutually beneficial collaborative research projects been carried out alongside other New Zealand and international research providers, especially for vessel-based research?*

As discussed above, collaborative research projects across government and among research providers have resulted in many mutually beneficial data and specimen collection, surveys of New Zealand marine biodiversity in NZ territorial seas, the EEZ and the Ross Sea, groundbreaking research into seamount biodiversity and the identification of VMEs, and research for international collaboration, particularly vessel based studies. Large scale vessel dependent oceanic research projects have made significant gains in baseline knowledge about the distribution and abundance of biodiversity in the EEZ/Ross Sea region. Vessel-based projects include: NORFANZ (Norfolk Island-Australia-New Zealand survey of biodiversity on Norfolk Ridge and Lord Howe Rise); BioRoss (MPI-LINZ, first NZ survey of biodiversity in the Ross Sea); Chatham-Challenger (LINZ-MPI-NIWA-DOC first Ocean Survey 20/20 project), NZ IPY-CAML (MPI-LINZ-NIWA (with international and NZ wide collaboration) survey of the Ross Sea as part of International Polar Year; Biodiversity of seamounts (MPI-NIWA-LINZ-MBIE voyages to the Kermadec Arc and on the Chatham Rise). These projects have generated huge geo-referenced datasets and thousands of specimens for Te Papa and National Invertebrate Collections. They have also resulted in the identification of new species, new genera and new families, as well as new records extending the known

[166] http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/environment-domain-plan-stocktake-paper.aspx

distribution of species. These surveys have contributed to habitat classification, identified areas of high biodiversity and challenged paradigms on the environmental drivers that determine biodiversity. More recently they have provided new information on the effects of ocean acidification on the productivity of polar seas, and in New Zealand waters.

Vessel dependent coastal projects have also generated significant new understanding about the distribution of inshore biota, and the role they play in maintaining a healthy ecosystem. Experimental field work on the productivity of the seabed has been carried out in NZ waters (Fiordland, Otago, Bay of Islands, Hauraki Gulf, Kaipara and Manukau Harbours), and along the west coast of the Ross Sea. The impact of land practices on the land-sea interface has also highlighted real downstream effects on the productivity of the coastal environment. These projects have provided new insights into the connectivity between different species groups, and data are being used in a number of ways to assist with spatial planning by RMAs.

Feedback from stakeholders has indicated that the collaborative voyages administered through the Programme have successfully created synergy and opportunity for New Zealand scientists as well as facilitating new international collaborations.

iv. *Have MPI [MFish] Biodiversity projects contributed substantially to an improved understanding of New Zealand's marine biodiversity and its role in marine ecosystem function, yielding scientifically rigorous outputs for a national and international professional audience?*

In the early years, the Programme focussed primarily on taxonomy and the description of marine biodiversity. As the Programme matured, projects to address biodiversity roles in ecosystem function were introduced. Some were experimental and on a local scale while others were on a regional scale. Recent projects have addressed patterns of marine biodiversity in relation to environmental drivers with ecosystem function. This enabled modelling to predict the distribution of biodiversity in unsurveyed areas of ocean, and evaluation of the vulnerability of biodiversity to perturbations such as climate change, as well as the modelling of trophic interactions among key fish species. Presentations of research results have been made to numerous overseas and New Zealand science audiences, and publications in the mainstream literature have been encouraged.

v. *Have results generated by MPI [MFish] Biodiversity projects been incorporated into management policy, with clear benefits for the New Zealand marine environment?*

Examples of incorporation into management policy with clear benefits for the marine environment include the increased awareness of research topics initiated in the biodiversity programme by policy analysts to core Aquatic Environment research projects and Fishery Plans, (land-use effects, climate change in the ocean, habitat classification); links to the Antarctic research programme and uptake into CCAMLR (ecotrophic studies, ecosystem baselines, VME risk assessment, bioregionalisation), spatial management (seamount closures, BPAs, MPAs, RMAs), the need by MfE to report on the marine environment at a national scale (plankton recording programme, Marine Environmental Monitoring Programme). MPI biodiversity advice is frequently requested to contribute to cross-government initiatives including Ocean Survey 20/20, DOC Sub-Antarctic Islands Forum National Monitoring, Statistics New Zealand Tier 1 statistic review and Environmental Domain Stocktake, International Year of Biodiversity, OECD and CBD reports, International Oceans Issues, SPRFMO, NRS marine issues paper, the Antarctic Science Framework, Ocean Fertilisation and IPCC Finally, the programme has contributed to New Zealand's efforts in the international Census of Marine Life and an ongoing assessment of New Zealand's progress in Marine Biodiversity has been proposed as a new Tier 1 Environmental Statistic. However, the benefits to the marine environment are more inferred than demonstrated. There is substantially increased awareness within MPI and across government, that the health of fisheries and other valued uses of the sea depend on intact ecosystem services provided by the diversity of organisms, the diversity of habitats and the genetic diversity found in the marine environment. Statements of intent and long-term strategic documents such as Fisheries 2030 and Fish Plans have biodiversity protection and an ecosystem approach to fisheries management objectives explicitly stated. Future research questions will also need to address follow-up of management decisions to assess whether and to what extent the objectives have been achieved.

In 2000, the concept of research on marine biodiversity was hotly debated among stakeholders and the benefit of the research (other than to scientists) was not widely accepted. In 2010, it is clear that much of the research in this biodiversity programme has been about defining and mapping the biological diversity of the sea, its roles in marine ecosystem function, threats to these roles and how best biodiversity and its successful protection can be measured. Huge advances have been made in providing new identification tools for major groups (e.g. Coralline algae). Much progress has been made, and the programme has successfully raised the profile of biodiversity in coastal and ocean environmental management, in particular fisheries management, and biodiversity research uptake into policy and management decisions within MPI and across government.

15.5 CONCLUDING REMARKS

New Zealand is moving into an era of unprecedented and increasing interest in the utilisation of marine resources (Business Growth Agenda 2014). Mineral, petroleum and gas resources are estimated to be worth billions of dollars to the economy (Glasby & Wright 1990), and new environmental legislation has been enacted (the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012). Changes inshore are also taking effect with the Environmental Protection Authority Act passed by Parliament on 11 May 2011. This Act establishes a new Environmental Protection Authority (EPA) as a standalone crown agent from 1 July 2011 which has responsibility for regulating activities under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012.

The Government has also set national policy direction under the Resource Management Act 1991 to guide decisions affecting freshwater and coastal environments (National Policy Statement for Freshwater Management 2014; New Zealand Coastal Policy Statement 2010).

New Zealand is also a signatory to the CBD Aichi-Nagoya Agreement with a new International Decade for Biodiversity that runs 2011–2020 and New Zealand's contribution to the identification of EBSAs in the SW Pacific, and to GOBI. Progress in our knowledge of the marine biodiversity and ecosystem services provided by the marine environment has clearly been made over the last decade. However, we need a more co-ordinated approach across government to link science to policy needs. Essentially we need to know three things; what is out there in the marine environment to use, protect, or manage; how does the ecosystem function; and what are the impacts of natural and human induced changes, and what tools will allow for effective monitoring and management of environmental impacts? For example, there is a compelling need for large-scale projects such as mapping seafloor habitats and establishing long-term nationwide monitoring and reporting schemes to measure the effects of ocean climate change, regular assessment of the cumulative effects of anthropogenic activities and multiple stressors in the ocean and the effectiveness of their management. Without these, we face the risks that New Zealand's "green" branding will be increasingly challenged, and that tipping points in the health of the aquatic environment may be reached too soon for evasive action to be taken.

Consumer driven pressures and social awareness of human impacts on the environment, including marine biodiversity, has been increasing and New Zealand's newly launched science challenge, "Sustainable Seas" takes a conventional ecological approach integrated with a social science approach to ecosystem-based management.

CURRENT NZ/EU PARTNERSHIPS:

- BAYESIANMETAFLATS - Spatial organization of species distributions: hierarchical and scale-dependent patterns and processes in coastal seascapes http://www.kg.eurocean.org/proj.jsp?load=100553
- Chess - Biogeography of Deep-Water Chemosynthetic Ecosystems http://www.kg.eurocean.org/proj.jsp?load=103314
- INDEEP - International Network for Scientific Investigation of Deep-Sea Ecosystems http://www.kg.eurocean.org/proj.jsp?load=103321
- PHARMASEA - Increasing Value and Flow in the Marine Biodiscovery Pipeline - http://www.kg.eurocean.org/proj.jsp?load=100504

- MAREFRAME - Co-creating Ecosystem-based Fisheries Management Solutions - http://www.kg.eurocean.org/proj.jsp?load=500
- BENTHIS - studies the impacts of fishing on benthic ecosystems and will provide the science base to assess the impact of current fishing practices http://www.benthis.eu/en/benthis.htm

15.6 REFERENCES

Allcock, A; Norman, M; Smith, P; Steinke, D; Stevens, D; Strugnell, J (2010) Cryptic speciation and the circumpolarity debate: A case study on endemic Southern Ocean octopuses using the COI barcode of life. Deep-Sea Research II (2010), doi:10.1016/j.dsr2.2010.05.016

Anderson, O F; Bagley, N W; Hurst, R J; Francis, M P; Clark, M R; McMillan, P J (1998) Atlas of New Zealand fish and squid distributions from research bottom trawls. NIWA Technical Report 42. 303 p.

Andrew, N. Francis, M. (eds.) (2003). The Living Reef: The Ecology of New Zealand's Rocky Reefs. Craig Potton Publishing, Nelson, New Zealand.

Anon (2000) The New Zealand Biodiversity Strategy. Our chance to turn the tide. Department of Conservation and Ministry for the Environment. 146 p.

Arnold A, (editor). (2004) Wellington: WWF-New Zealand;. Shining a spotlight on the biodiversity of New Zealand's Marine Ecoregion.

Arnold, A. (2005). Shining a spotlight on the biodiversity of New Zealand's marine ecoregion: Experts workshop on marine biodiversity, 27-28 May 2003, Wellington, New Zealand. World Wildlife Fund for Nature, Wellington, New Zealand. 85 p.

Asnaghi, V; Bertolotto, R; Giussani, V; Mangialajo, L; Hewitt, J; Thrush, S; Moretto, P; Castellano, M; Rossi, A; Povero, P; Cattaneo-Vietti, R; Chiantore, M (2012) Interannual variability in Ostreopsis ovata bloom dynamic along Genoa coast (North-western Mediterranean): a preliminary modeling approach. Cryptogamie Algologique 33:181–189.

Ausubel, J H; Crist, D T; Waggoner, P E (Eds) (2010) First census of marine life 2010 highlights of a decade of discovery Contributors: 2,700 marine scientists from around the globe. A publication of the Census of Marine Life Census of Marine Life International Secretariat Consortium for Ocean Leadership Washington, DC USA www.coml.org

Baco, A R; Rowden, A A; Levin, L A; Smith, C R; Bowden, D (2009) Initial characterization of cold seep faunal communities on the New Zealand margin. Marine Geology 272:251–259 doi: H10.1016/j.margeo.2009.06.015H.

Bagley, N W; Anderson, O F; Hurst, R J; Francis, M P; Taylor, P J (2000) Atlas of New Zealand fish and squid distributions from midwater trawls, tuna longline sets, and aerial sightings. NIWA Technical Report 72. 171 p.

Baird, S J; Tracey, D; Mormede, S; Clark, M (2013) The distribution of protected corals in New Zealand waters. NIWA Client Report No: WLG2012-43 prepared for Department of Conservation, Wellington. 93 p.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. New Zealand Journal of Marine and Freshwater Research 44: 101–115.

Batson, P (2003) Deep New Zealand: Blue Water, Black Abyss. Christchurch:Canterbury University Press.

Battley, P F; Melville, D S; Schuckard, R; Ballance, P F (2005) Quantitative survey of the intertidal benthos of Farewell Spit, Golden Bay. Marine Biodiversity Biosecurity Report No. 7. 19 p.

Beaumont, J; MacDiarmid, A B; Morrison, M (in prep). Rocky reef ecosystems – how do they function? Final Research Report for project ZBD2005-09. 296 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Beaumont, J; MacDiarmid, A; D'Archino, R (2010) Mapping the environmental values of New Zealand's marine ecosystem: A meta-analysis. Biosecurity New Zealand Technical Paper 2010:1–76.

Beaumont, J; Oliver, M; MacDiarmid, A (2008) Mapping the values of New Zealand's coastal waters. 1. Environmental values. Biosecurity New Zealand Technical Paper 2008/16:1–89.

Bostock, H; Tracey, D; Cummings, V; Mikaloff-Fletcher, S; Williams, M; Guy, C; Neil, H; Currie, K (2012) Ocean acidification in fisheries habitat (ZBD201041). Research Progress Report prepared for the Ministry of Primary Industries Fisheries. 39 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bowden, D A (2011) Benthic invertebrate samples and data from the Ocean Survey 20/20 voyages to the Chatham Rise and Challenger Plateau, 2007. New Zealand Aquatic Environment and Biodiversity Report No. 65. 40 p.

Bowden, D A; Compton, T J; Snelder, T H; Hewitt, J E (2011a) Evaluation of the New Zealand Marine Environment Classifications using Ocean Survey 20/20 data from Chatham Rise and Challenger Plateau. New Zealand Aquatic Environment and Biodiversity Report No. 77. 27 p.

Bowden, D A; Hanchet, S M; Marriott, P M (in prep.) Population estimates of Ross Sea demersal fish: a comparison between video and trawl methods. (Submitted as short note to Fisheries Research)

Bowden, D A; Hewitt J (2012) Recommendations for surveys of marine benthic biodiversity: outcomes from the Chatham-Challenger Ocean Survey 20/20 Post-Voyage Analyses Project. New

Zealand Aquatic Environment and Biodiversity Report No. 91. 34 p.

Bowden, D A; Hewitt, J; Verdier, A-L; Pallentin, A (in prep) (Project ZBD200701 Objective 14, The potential of multibeam echosounder data for predicting benthic invertebrate assemblages across Chatham Rise and Challenger Plateau. Draft Aquatic Environment and Biodiversity Report, Ministry of Fisheries, New Zealand, Wellington (Unpublished report held by Ministry for Primary Industries.)

Bowden, D A; Hewitt, J; Verdier, A-L; Pallentin, A (in press) (Project ZBD2007-01 Objective 14. The potential of multibeam echosounder data for predicting benthic invertebrate assemblages across Chatham Rise and Challenger Plateau. Draft Aquatic Environment and Biodiversity Report.

Bowden, D A; Schiaparelli, S; Clark, M R; Rickard, G J (2011b) A lost World? Archaic crinoid-dominated assemblages on an Antarctic seamount. Deep Sea Research Part II. Topical Studies in Oceanography 58:119–127.

Boyd, P W; Law, C S; Doney, S C (2011) A climate change atlas for the Ocean. Oceanography. 24(2):13–16.

Bradford-Grieve, J (2008) Absence of government leadership is damaging the health of systematics and taxonomy in the UK. New Zealand Science Review 65:84–88.

Bradford-Grieve, J; Fenwick, G (2001) A review of the current knowledge describing the biodiversity of the Ross Sea region. Final Research Report. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford-Grieve, J; Fenwick, G (2002) A review of the current knowledge describing the biodiversity of the Balleny Islands. Final Research Report ZBD2000-01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford-Grieve, J; Probert, K; Lewis, K; Sutton, P; Zeldis, J (2006) New Zealand shelf region In: Robinson AR, Brink KH, editors. The global coastal ocean: regional studies and syntheses. The Sea 14. New York: John Wiley & Sons, Inc;. pp. 1451–1492.

Broom, J E S; Hart, D R; Farr, T J; Nelson, WA; Neill, K F; Harvey, A H; Woelkerling, W J (2008) Utility of psbA and nSSU for phylogenetic reconstruction in the Corallinales based on New Zealand taxa. Molecular Phylogenetics & Evolution 46: 958–973.

Brown, C J; Fulton, E A; Hobday, A J; Matear, R J; Possingham, H P; Bulman, C; Christensen, V; Forrest, R E; Gehrke, P C; Gribble, N A; Griffiths, S P; Lozano-Montes, H; Martin, J M; Metcalf, S; Okey, T A; Watson, R; Richardson, A J (2010) Effects of climate-driven primary production change on marine food webs: implications for fisheries and conservation. Global Change Biology, 16 (4): 1194–1212.

Capson, T. L., Guinnotte, J (2014) Future proofing New Zealand's shellfish aquaculture: monitoring and adaptation to ocean acidification. New Zealand Aquatic Environment and Biodiversity Report No. 136

Carroll, E; Jackson, J A; Paton, D; Smith, T (in prep). Estimating 19th and 20th century right whale catches and removals around east Australia and New Zealand. Final Research Report ZBD2005-05, MS12 Part C. (Unpublished report held by MPI, Wellington.)

Chang FH 2013. *Syracosphaera pemmadiscus* sp. *nov*. (Prymnesiophyceae), an extant coccolithophore from the southwest Pacific Ocean near New Zealand. Phycologia 52(6): 618-624

Chang FH and L Northcote. Species composition of extant coccolithophores, with new records, from the southwest Pacific near New Zealand. J. Biodiversity, submitted

Chang, F H; Mullan, B (2003) Occurrence of major harmful algal blooms in New Zealand: is there a link with climate variations? Climate Update 53(11):4.

Chang, F H; Williams, M J M; Schwarz, J; Hall, J; Stewart, R; Maas, E W (2013) Spatial variation of phytoplankton assemblages and biomass in the New Zealand sector of the Southern Ocean during the late austral summer 2008. Polar Biology 36 (3): 391–408.

Chang, F H; Zeldis, J; Gall, M; Hall, J (2003) Seasonal and spatial variation of phytoplankton assemblages, biomass and cell size from spring to summer across the north-eastern New Zealand continental shelf. Journal of Plankton Research 25:737–758.

Cheung, L; Lam, V W Y; Sarmiento, J L; Kearney, K; Watson, R; Pauly, D (2009) Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries 10(3):235–251.

Clark, M R; Bowden, D A; Baird, S J; Stewart, R (2010a) Effects of fishing on the benthic biodiversity of seamounts of the "Graveyard" complex, northern Chatham Rise. New Zealand Aquatic Environment and Biodiversity Report No. 46. 40 p.

Clark, M R; Dunn, M R; McMillan, P J; Pinkerton, M H; Stewart, A; Hanchet, S M (2010b) Latitudinal variation of demersal fish assemblages in the western Ross Sea. CCAMLR document WG-FSA-10/P3. 13 p. (Antarctic Science, 2010. http://dx.doi.org/10.1017/S0954102010000441)

Clark, M R; O'Driscoll, R (2003) Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. Journal of Northwest Atlantic Fisheries Science 31:441–458.

Clark, M R; Roberts, C D (2008) Fish and invertebrate biodiversity on the Norfolk Ridge and Lord Howe Rise, Tasman Sea (NORFANZ voyage, 2003). New Zealand Aquatic Environment and Biodiversity Report No. 28. 131 p.

Clark, M R; Rowden, A A (2009) Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. Deep-Sea Research I. 56:1540–54.

Clark, M R; Stokes, K; Baird, S J (in prep). Development of a methodology for ecological risk assessments for New Zealand deepwater fisheries. New Zealand Aquatic Environment and Biodiversity Report.

Clark, M R; Tittensor, D P (2010) An index to assess the risk to stony corals from bottom trawling on seamounts. Marine Ecology 31(supplement 1): 200–211.

Clark, M R; Tracey, D M; Pallentin, A; Schnabel, K; Anderson, O F; Bowden, D (2009) Voyage report of a survey of “seamounts” on the northwest and southeast Chatham Rise (TAN0905). 49 p. (Unpublished report available from NIWA, Wellington).

Clark, M R; Watling, L; Rowden, A A; Guinotte, J M; Smith, C R (2010c) A global seamount classification to aid the scientific design of marine protected area networks. Journal of Ocean and Coastal Management 54: 19–36.

Clark, M R; Williams, A; Rowden, A A; Hobday, A J; Consalvey, M (2011) Development of seamount risk assessment: application of the ERAEF approach to Chatham Rise seamount features. New Zealand Aquatic Environment and Biodiversity Report No. 74. 18 p.

Clark, M., Leduc, D., Nelson, W., Mills, S. (2014) Benthic invertebrate data within New Zealand's Benthic Protection and Seamount Closure Areas. NIWA Client Report No: WLG2014-43, pp. 22

Clark, M; O'Shea, S (2001) Hydrothermal vent and seamount fauna from the southern Kermadec Ridge, New Zealand. InterRidge News.;10(2):14–17.

Coleman, C O; Lörz, A-N (2010) A new species of *Camacho* (Crustacea, Amphipoda, Aoridae) from the Chatham Rise, New Zealand. Zoosystematics and Evolution 86(1): 33–40.

Compton, T J; Bowden, D A; Pitcher, C R; Hewitt, J E; Ellis, N (2012) Biophysical patterns in benthic assemblage composition across contrasting continental margins off New Zealand. Journal of Biogeography DOI 10.1111/j.1365-2699.2012.02761.x

Compton, T J; Julian, K; Leathwick, J R; Bowden, D A (Project ZBD200701 Objective 12, in prep) Modelling distributions of benthic invertebrate taxa across Chatham Rise and Challenger Plateau in relation to environmental variables. (Draft New Zealand Aquatic Environment and Biodiversity Report, held by MPI Wellington.)

Connell, A M; Dunn, M R; Forman, J (2010) Diet and dietary variation of New Zealand hoki *Macruronus novaezelandiae*. New Zealand Journal of Marine and Freshwater Research 44(4):289–308.

Constable HB. 2014. Population structure, temporal stability and seascape genetics of two endemic New Zealand Pleuronectids, *Rhombosolea plebeia* (sand flounder) and *R. leporina* (yellowbelly flounder). PhD thesis, Victoria University of Wellington.

Costello, M J; Coll, M; Danovaro, R; Halpin, P; Ojaveer H; Miloslavich, P (2010) A Census of Marine Biodiversity Knowledge, Resources, and Future Challenges. PLoS ONE 5(8): e12110. doi:10.1371/journal.pone.0012110

Costello, M.J.; Coll, M.; Danovaro, R.; Halpin, P.; Ojaveer, H.; Ojaveer, H.; Miloslavich, P. (2010). A Census of Marine Biodiversity Knowledge, Resources, and Future Challenges. PLoS ONE 5(8): e12110. doi:10.1371/journal.pone.0012110.

Coutts, A D M; Dodgshun, T J (2007). The nature and extent of organisms in vessel sea-chests: a protected mechanism for marine bioinvasions. Marine Pollution Bulletin 54:875–886.

Cranfield, H J; Gordon, D P; Willan, R C; Marshall, B A; Battershill, C N; Francis, M P; Nelson, W A; Glasby, C J; Read, G B (1998). Adventive marine species in New Zealand. NIWA Technical Report 34: 1–48.

Cranfield, H J; Manighetti, B; Michael, K P; Hill, A (2003) Effects of oyster dredging on the distribution of bryozoan biogenic reefs and associated sediments in Foveaux Strait, southern New Zealand. Continental Shelf Research 23:1337–1357.

Cryer, M; Hartill, B; O'Shea, S (2002) Modification of marine benthos by trawling: toward a generalization for the deep ocean? Ecological Applications 12:1824–1839.

Cummings, V J; Thrush, S F; Marriott, P M; Funnell, G A; Norkko, A; Budd, R G (2008) Antarctic coastal marine ecosystems (ICECUBE). Final Research Report for Ministry of Fisheries Research Project ZBD2006-03 73 p. (Unpublished report held by Ministry for Primary Industries Wellington.)

Cummings, V J; Thrush, S F; Norkko, A; Andrew, N L; Hewitt, J E; Funnell, G A; Schwarz, A-M (2006b) Accounting for local scale variability in benthos: implications for future assessments of latitudinal trends in the coastal Ross Sea. Antarctic Science 18(4): 633–644.

Cummings, V J; Thrush, S; Chiantore, M; Hewitt, J; Cattaneo-Vietti, R (2010) Macrobenthic communities of the north-western Ross Sea shelf: links to depth, sediment characteristics and latitude. Antarctic Science, 22:793–804.

Cummings, V; Hewitt, J; Van Rooyen, A; Currie, K; Beard, S; Thrush, S; Norkko, J; Barr, N; Heath, P; Halliday, J; Sedcole, R; Gomez, A; McGraw, C; Metcalf, V (2011) Ocean acidification at high latitudes: potential effects on functioning of the Antarctic bivalve *Laternula elliptica*. PLoS ONE 6(1):e16069.

Cummings, V; Thrush, S; Andrew, N; Norkko, A; Funnell, G; Budd, R; Gibbs, M; Hewitt, J S; Mercer, S; Marriott, P; Anderson, O (2003) Ecology and biodiversity of coastal benthic communities in McMurdo Sound, Ross Sea: emerging results. Final Research Report for Ministry of Fisheries Research Project ZBD2002/01 Objectives 1 & 2. National Institute of Water and Atmospheric Research. 105 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cummings, V; Thrush, S; Schwarz, A-M; Funnell, G; Budd, R (2006a) Ecology of coastal benthic communities of the northwestern Ross Sea. New Zealand Aquatic Environment and Biodiversity Report No 6. 67 p.

Currey, R.J.C.; Boren, L.J.; Sharp, B.R.; Peterson, D. (2012): A risk assessment of threats to Maui’s dolphins. Ministry for

Primary Industries and Department of Conservation, Wellington. 51 p

D'Archino R., Nelson W.A., Zuccarello G.C. (2014). *Amalthea* and *Galene*, two new genera of Halymeniaceae (Rhodophyta) from New Zealand. Botanica Marina 57: 185–201

D'Archino R.; Nelson W.A.; Zuccarello G.C. (2011). Diversity and complexity in New Zealand Kallymeniaceae (Rhodophyta): recognition of the genus *Ectophora* and description of *E. marginata sp. nov. Phycologia* 50: 241-255

D'Archino, R; Neill, K F; Nelson, W A (2012) Recognition and distribution of *Polysiphonia morrowii* (Rhodomelaceae, Rhodophyta) in New Zealand. Botanica Marina 56:41–47.

D'Archino, R; Sutherland, J E (2013) First record of the genus *Dudresnaya* (Dumontiaceae, Rhodophyta) in New Zealand waters. Phycological Research. 61: 191–198.

De Domenico, F; Chiantore, M; Buongiovanni, S; Paola Ferranti, M; Ghione, S; Thrush, S; Cummings, V; Hewitt, J; Kroeger, K; Cattaneo-Vietti, R (2006) Latitude versus local effects on echinoderm assemblages along the Victoria Land coast, Ross Sea, Antarctica. Antarctic Science 18(4): 655–662.

Dettai et al (+45 authors). (2011) DNA barcoding and molecular systematics of the benthic and demersal organisms of the CEAMARC survey. Polar Science 5: 298–312.

Dodgshun, T; Coutts, A (2003) Opening the lid on sea chests. Seafood NZ 11:35.

Dunn, M R (2009) Feeding habits of the ommastrephid squid *Nototodarus sloanii* on the Chatham Rise, New Zealand. New Zealand Journal Marine and Freshwater Research 43:1103–1113.

Dunn, M R; Connell, A M; Forman, J; Stevens, D W; Horn, P L (2010a) Diet of Two Large Sympatric Teleosts, the Ling (*Genypterus blacodes*) and Hake (*Merluccius australis*). PLoS ONE 5(10):

Dunn, M R; Griggs, L; Forman, J; Horn, P L (2010b) Feeding habits and niche separation among the deep-sea chimaeroid fishes *Harriotta raleighana*, *Hydrolagus bemisi* and *Hydrolagus novaezealandiae*. Marine Ecology Progress Series 407: 209–225.

Dunn, M R; Horn, P L; Connell, A M; Stevens, D W; Forman, J; Pinkerton, M; Griggs, L; Notman, P; Wood B (2010c) Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the Chatham Rise. Final Research Report for Ministry of Fisheries Project ZBD2004-02. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Dunn, M R; Szabo, A; McVeagh, M S; Smith, P J (2010d) The diet of deepwater sharks and the benefits of using DNA identification of prey. Deep-Sea Research Part 1. 57(7): 923–930.

Eakin, R A; Eastman, J T; Near, T J (2009) A new species and a molecular phylogenetic analysis of the Antarctic Fish Genus *Pogonophryne* (Notothenioidei: Artedidraconidae). Copeia 2009, No. 4, 705–713.

Eléaume, M; Hemery, L G; Bowden, D A; Roux, M (2011) A large new species of the genus *Ptilocrinus* (Echinodermata, stalked Crinoidea, Hyocrinidae) from Antarctic seamounts. Polar Biology 34:1385–1397.

Farr, T; Broom, J; Hart, D; Neill, K; Nelson, W (2009) Common coralline algae of northern New Zealand: an identification guide. NIWA Information Series No. 70.

Fenwick, G; Bradford-Grieve, J (2002a) Recommendations for future directed research to describe the biodiversity of the Ross Sea region. Final Research Report ZBD2000/01 (Unpublished report held by Ministry for Primary Industries, Wellington.)

Fenwick, G; Bradford-Grieve, J (2002b) Human pressures on Ross Sea region marine communities: recommendations for future research. Final Research Report ZBD2000/01 (Unpublished report held by Ministry for Primary Industries, Wellington.)

Floerl O; Hewitt J (2012) Chatham-Challenger OS 20/20 Post Voyage Analyses: Objective 9- Patterns in species composition. New Zealand Aquatic Environment and Biodiversity Report No. 97. 40 p.

Forman, J S; Dunn, M R (2010) HThe influence of ontogeny and environment on the diet of lookdown dory, *Cyttus traverse* H. New Zealand Journal of Marine and Freshwater ResearchH 44 (4H): 329 – 342.

Freeman, D J; Marshall, B A; Ahyong, S T; Wing, S R; Hitchmough, R A (2010) The conservation status of New Zealand marine invertebrates, 2009. New Zealand Journal of Marine and Freshwater Research 44: 129–148.

Frost, M T; Jefferson, R; Hawkins, S J (Editors). (2006) The evaluation of time series: their scientific value and contribution to policy needs. Report prepared by the Marine Environmental Change Network (MECN) for the Department for Environment, Food and Rural Affairs (DEFRA). Marine Biological Association, Plymouth. Contract CDEP 84/5/311. Marine Biological Association Occasional Publications No. 22. 94 p.

Fulton, E A; Smith, A D M; Webb, H; Slater, J (2004) Ecological indicators for the impacts of fishing on non-target species, communities and ecosystems: Review of potential indicators. AFMA Final Research report R99/1546: 119 p.

Garcia, A (2010) Comparative study of the morphology and anatomy of octopuses of the family Octopodidae. (AUT MAppSc).247 p.

Garcia, S M; Rosenberg, A A; (2010) Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives. Philosophical Transactions of the Royal Society B 365, 2869–2880 doi:10.1098/rstb.2010.0171

Gardner, J P A; Bell, J J; Constable, H B; Hannan, D A; Ritchie, P A; Zuccarello, G C. (2010) Multi-species coastal marine connectivity: a literature review with recommendations for further research. New Zealand Aquatic Environment & Biodiversity Report 58: 1-47. ISSN 1176-9440.

Gardner, J P A; Bell, J J; Constable, H B; Hannan, D; Ritchie, P A; Zuccarello, G C (2010) Multi-species coastal marine connectivity: a literature review with recommendations for further research. New Zealand Aquatic Environment and Biodiversity Report No. 58. 47 p.

Ghiglione, J-F; Galand, P E; Pommier, T; Pedrós-Alió, C; Maas, E W; Bakker, K; Bertilson, S; Kirchman, D L; Lovejoy, C; Yager, P L; Murray, A E (2012) Pole-to-pole biogeography of surface and deep marine bacterial communities. Proceedings of the National Academy of Sciences 109(43):17633–17638. <http://dx.doi.org/10.1073/pnas.1208160109>

Glasby, G P; Wright, I C (1990) Marine mineral potential in New Zealand's Exclusive Economic Zone. Marine Mining 9:403–427.

Gordon, D P (2000) The Pacific Ocean and global OBIS: a New Zealand perspective. Oceanography 13:41–47.

Gordon, D P (2013) New Zealand's genetic diversity, pp. 162–191 in Dymond, J R (ed.), Ecosystem Services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln. ix + 539 p.

Gordon, D P (Ed.) (2009) New Zealand Inventory of Biodiversity Volume One. Kingdom Animalia: Radiata, Lophotrochozoa, Deuterostomia. Canterbury University Press, Christchurch. 568+16 p.

Gordon, D P (Ed.) (2010) New Zealand Inventory of Biodiversity Volume Two. Kingdom Animalia: Chaetognatha, Ecdysozoa and Ichnofossils. Canterbury University Press, Christchurch. 528+16 p.

Gordon, D P (Ed.) (2012) New Zealand Inventory of Biodiversity Volume Three. Kingdoms Bacteria, Protozoa, Chromista, Plantae, Fungi. Canterbury University Press, Christchurch. 616+16 p.

Gordon, D P; Beaumont, J; MacDiarmid, A; Robertson, D A; Ahyong, S T (2010) Marine Biodiversity of Aotearoa New Zealand. PLoS ONE 5(8): e10905. doi:10.1371/journal.pone.0010905

Gordon, D P; Bisby, F A (2009) Introduction. In: Gordon, D P, editor. New Zealand inventory of biodiversity. Volume 1. Kingdom Animalia: Radiata, Lophotrochozoa, Deuterostomia. Christchurch: Canterbury University Press. pp. 9–12.

Gordon, D P; Hosie, A M; Carter, M C (2008) Post-2000 detection of warm-water alien bryozoan species in New Zealand — the significance of recreational vessels. Virginia Museum of Natural History Special Publications 15:37–48.

Gordon, D.P; Beaumont, J; MacDiarmid, A; Robertson, D,A; Ahyong, S T; (2010a). Marine biodiversity of Aotearoa New Zealand. PLoS ONE 5(8): e10905. Doi:10.1371/journal.pone.0010905.

Gould, B; Ahyong, S T (2008) Marine Invasive Taxonomic Service. Biosecurity 85:18–19.

Grange, K R; Tovey, A; Hill, A E (2003) The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay. Marine Biodiversity Biosecurity Report No. 4. 22 p.

Grayling, S (2004) A review of scientific studies conducted on the Macquarie Ridge. Final Research Report (ZBD2003-09) (Unpublished report held by Ministry for Primary Industries.) 33 p.

Green, W; Clarkson, B (2006) Review of the New Zealand Biodiversity Strategy Themes. http://doc.govt.nz/documents/conservation/nz-biodiversity-strategy-themes.pdf

Grotti, M; Soggia, F; Lagomarsino, C; Dalla Riva, S; Goessler, W; Francesconi, K A (2008) Natural variability and distribution of trace elements in marine organisms from Antarctic coastal environments. Antarctic Science 20(1): 39–51.

Guidetti, M; Marcato, S; Chiantore, M; Patarnello, T; Albertelli, G; Cattaneo-Vietti, R (2006) Exchange between populations of *Adamussium colbecki* (Mollusca: Bivalvia) in the Ross Sea. Antarctic Science 18(4): 645–653.

Guinotte, J M; Bartley, J D; Iqbal, A; Fautin, D G; Buddemeier, R W (2006) Modeling habitat distribution from organism occurrences and environmental data: case study using anemonefishes and their sea anemone hosts. Marine Ecology Progress Series, 316: 269–283.

Hanchet, S M (Compiler) (2009) New Zealand IPY-CAML Progress Report. August 2009. 76 p. (Unpublished report held by Ministry for Primary Industries)

Hanchet, S M (Compiler) (2010) New Zealand IPY-CAML Progress Report. July 2010. (Unpublished report held by Ministry for Primary Industries)

Hanchet, S M; Fu, D; Dunn, A (2008a) Indicative estimates of biomass and yield of Whitson's grenadier (*M. whitsoni*) on the continental slope of the Ross Sea in Subareas 88.1 and 88.2. WG-FSA-08/32.

Hanchet, S M; Mitchell, J; Bowden, D; Clark, M; Hall, J; O'Driscoll, R (2008b) Ocean survey 20/20: New Zealand IPY-CAML Final Voyage Report. NIWA Client Report: WLG2008-74, October 2008. 193 p.

Hanchet, S M; Mitchell, J; Bowden, D; Clark, M; Hall, J; O'Driscoll, R; Pinkerton, M; Robertson, D (2008c) Preliminary report of the New Zealand RV Tangaroa IPY-CAML survey of the Ross Sea region, Antarctica in February-March 2008. Unpublished NIWA report to CCAMLR working group on ecosystem monitoring and management. WG-EMM-08/18. 15 p.

Hanchet, S M; Stevenson, M L; Jones, C; Marriott, P M; McMillan, P J; O'Driscoll, R L; Stevens, D; Stewart, A L; Wood, B A (2008d) Biomass estimates and size distributions of demersal finfish on the Ross Sea shelf and slope from the New Zealand IPY-CAML survey, February-March 2008. WG-FSA-08/31.

Hanchet, S M; Stewart, A L; McMillan, P J; Clark, M; O'Driscoll, R L; Stevenson, M L (2013) Diversity, relative abundance, new locality records, and updated fish fauna of the Ross Sea, Antarctica. Antarctic Science. 25: 619–636. doi:10.1017/S0954102012001265

Hannan DA. 2014. Population genetics and connectivity in *Paphies subtriangulata* and *Paphies australis* (Bivalvia: Mesodesmatidae). PhD thesis, Victoria University of Wellington.

Harvey, A S; Woelkerling, W J; Farr, T J; Neill, K F; Nelson, W A (2005) Coralline algae of central New Zealand: an identification guide to common 'crustose' species. NIWA Information Series No. 57.

Hassler, C S; Ridgway, K R; Bowie, A R; Butler, E C V; Clementson, L A; Doblin, M A; Davies, D M; Law, C; Ralph, P;, van der Merwe, P; Watson, R; Ellwood, M J. 2014 Primary productivity induced by iron and nitrogen in the Tasman Sea: an overview of the PINTS expedition. Marine and Freshwater Research 65(6) 517-537 http://dx.doi.org/10.1071/MF13137

Heimeier, D; Lavery, S; Sewell, M A (2010) Using DNA barcoding and phylogenetics to identify Antarctic invertebrate larvae: Lessons from a large scale study. Marine Genomics 3:165–177.

Hewitt J, Lundquist, C J; Bowden, D A (2011) Chatham-Challenger Ocean Survey 20/20 Post Voyage Analyses: Diversity Metrics. New Zealand Aquatic Environment and Biodiversity Report No. 83. 62 p.

Hewitt, J E; Anderson, M J; Hickey, C; Kelly, S; Thrush, S F (2009) Enhancing the ecological significance of contamination guidelines through integration with community analysis. Environmental Science and Technology 43:2118–2123.

Hewitt, J E; Thrush, S F (2010) Empirical evidence of an approaching alternate state produced by intrinsic community dynamics, climatic variability and management actions. Marine Ecology Progress Series, 413:267–276.

Hewitt, J E; Thrush, S F; Cummings, V J; Turner, S J (1998) The effect of changing sampling scales on our ability to detect effects of large-scale processes on communities. Journal of Experimental Marine Biology and Ecology 227: 251–264.

Hewitt, J E; Thrush, S F; Dayton, P D (2008) Habitat variation, species diversity and ecological functioning in a marine system. Journal of Experimental Marine Biology and Ecology 366:116–122.

Hewitt, J E; Thrush, S F; Dayton, P K; Bonsdorff, E (2007) The effect of spatial and temporal heterogeneity on the design and analysis of empirical studies of scale-dependent systems. The American Naturalist 168 (3): 398–408.

Hewitt, J; Julian, K; Bone, E K; (2011). Chatham–Challenger Ocean Survey 20/20 Post-Voyage Analyses: Objective 10 – Biotic habitats and their sensitivity to physical disturbance. New Zealand Aquatic Environment and Biodiversity Report 81

Hewitt, J; Thrush, S; Lohrer, A; Townsend, M (2010) A latent threat to biodiversity: consequences of small-scale heterogeneity loss. Biodiversity and Conservation, 19:1315–1323.

Hobday, A J; Okey, T A; Poloczanska, E S; Kunz, T J; Richardson, A J (eds) (2006) Impacts of Climate Change on Australian Marine Life, CSIRO Marine and Atmospheric research report to the Australian Greenhouse Office, Canberra.

Hoffmann LJ, Breitbarth E, McGraw C, Law, CS, and K A Hunter. 2013. A trace-metal clean, pH controlled incubator system for ocean acidification studies. Limnology and. Oceanography: Methods 11: 53–61.

Horn, P L; Dunn, M R (2010) Inter-annual variability in the diets of hoki, hake, and ling on the Chatham Rise from 1990 to 2009. New Zealand Aquatic Environment and Biodiversity Report No. 54. 57 p.

Horn, P L; Forman, J; Dunn, M R (2010) Feeding habits of alfonsino *Beryx splendens*. Journal of Fish Biology 76:2382–2400.

Hurst, R J; Bagley, N W; Anderson, O F; Francis, M J; Griggs, L H (2000) Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. NIWA Technical Report 84:1–612.

Hutchins DA; Fu F-X; Mulholland MR 2009. Nutrient Cycles and Marine Microbes in a CO2-Enriched Ocean. Oceanography 22: 128-145.

Jackson, J; Carroll, E; Smith, T D; Patenaude, N; Baker, C S (in prep) Taking Stock: the historical demography of the New Zealand right whale (the Tohora) 1830–2008. Final Research Report ZBD200505, MS12 Part D. (Unpublished report held by Ministry for Primary Industries.)

Juffe-Bignoli, D., Burgess, N.D., Bingham, H., Belle, E.M.S., de Lima, M.G., Deguignet, M., Bertzky, B., Milam, A.N., Martinez-Lopez, J., Lewis, E., Eassom, A., Wicander, S., Geldmann, J., van Soesbergen, A., Arnell, A.P., O'Connor, B., Park, S., Shi, Y.N., Danks, F.S., MacSharry, B., Kingston, N. (2014). Protected Planet Report 2014. UNEP-WCMC: Cambridge, UK.

Key, J M (2002) A review of current knowledge describing New Zealand's deepwater benthic biodiversity. Marine Biodiversity Biosecurity Report No. 1. 25 p.

Koubbi, P; Masato, M; Duhamel, G; Goarant, A; Hulley, P-A; O'Driscoll, R; Takashi, I; Pruvost, P; Tavenier, E; Hosie, G (2011) Ecological importance of micronektonic fish for the ecoregionalisation of the Indo-Pacific sector of the Southern Ocean: role of myctophids. Deep Sea Research II 58: 170–180.

Lalas, L; MacDiarmid AB; Abraham, E. (in prep). : Estimates of annual food consumption by a population of New Zealand fur seals. Final

Research Report ZBD2005-05 MS12 Part F. (Unpublished report held by MPI, Wellington.)

Lalas, L; MacDiarmid AB; Abraham, E. (in prep). : Estimates of annual food consumption by a population of New Zealand sea lions. Final Research Report ZBD2005-05 MS12 Part G. (Unpublished report held by MPI, Wellington.)

Lalas, L; MacDiarmid, A B (in prep). Rapid re-colonisation of south-eastern South Island by New Zealand fur seals *Arctocephalus forsteri*. Final Research Report ZBD2005-05 MS12 Part E. (Unpublished report held by MPI, Wellington.)

Lavery, S; Clements, K; Hickey, A (2006) Molecular identification of cryptogenic/invasive gobies in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No 5. 48 p.

Law CS, Breitbarth E, Hoffmann LJ, McGraw CM, Langlois RJ, LaRoche J, Marriner A, and Safi K.A. 2012. No stimulation of nitrogen fixation by non-filamentous diazotrophs under elevated CO2 in the South Pacific, Global Change Biology, 18:3004–3014, doi: 10.1111/j.1365-2486.2012.02777.x

Le Quesne, W J F; Pinnegar, J K (2012) The potential impacts of ocean acidification: scaling from physiology to fisheries. Fish and Fisheries, 13:333–344 doi: 10.1111/j.1467-2979.2011.00423.x

Leathwick, J R; Dey, K L; Julian, K (2006a) Development of a marine environmental classification optimised for demersal fish. NIWA Client report HAM2006–063

Leathwick, J R; Elith, J; Francis, M P; Hastie, T; Taylor, P (2006b) Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees. Marine Ecology Progress Series 321:267–281.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2010) Development of a benthic-optimised marine environment classification for waters within the New Zealand EEZ. Final Research Report for Ministry of Fisheries Research Project BEN200601, Objective 5. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Leathwick, J; Francis, M; Julian, K (2006c) Development of a demersal fish community map for New Zealand's Exclusive Economic Zone. NIWA Client Report HAM2006-062, prepared for Department of Conservation. National Institute of Water & Atmospheric Research, Hamilton, New Zealand.

Leduc, D; Rowden, A A; Bowden, D A; Probert, P K; Pilditch, C A; Nodder, S D (2012a) A unimodal relationship between biomass and species richness of deep-sea nematodes: implications for the link between productivity and diversity. Marine Ecology Progress Series 454: 53–64.

Leduc, D; Rowden, A A; Nodder, S D; Berkenbusch, K; Probert, P K; Hadfield, M G (in press). Unusually high food availability in Kaikoura Canyon linked to distinct deep-sea nematode community. Deep-Sea Research II.

Leduc, D; Rowden, A A; Pilditch, C A; Maas, E; Probert, P K (2013) Is there a link between deep-sea biodiversity and ecosystem function? Marine Ecology 34: 334–344.

Leduc, D; Rowden, A A; Probert, P K; Pilditch, C A; Nodder, S N; Vanreusel, A; Duineveld, G C A; Witbaard, R (2012c) Further evidence for the effect of particle-size diversity on deep-sea benthic biodiversity. Deep-Sea Research I. 63: 164–169.

Leduc, D; Rowden, A A; Probert, P K; Pilditch, C A; Nodder, S; Bowden, D A; Duineveld, G C A; Witbaard, R (2012b) Nematode beta diversity on the continental slope of New Zealand: spatial patterns and environmental drivers. Marine Ecology Progress Series, 545 :37–52.

Levin, L A; Gambi, M C; Barry, J P; Genin, A; Thrush, S (2011) The Dayton legacy: baselines, benchmarks, climate, disturbance and proof. Marine Ecology: 32:261–165.

Link, J (1999) Reconstructing Food Webs and Managing Fisheries. Ecosystem Approaches for Fisheries Management. Proceedings of the 16th Lowell Wakefield Fisheries Symposium. AK-SG-99-01:571-588.

Livingston, M (2004) A sampling programme to construct and quantify food-webs in two key areas supporting important fish and invertebrate species in New Zealand. Final Research Report for Ministry of Fisheries Project ENV2002-07, Objective 1. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Livingston, M E (2009) Towards a National Marine Environment Monitoring Programme in New Zealand. A discussion paper submitted to the Biodiversity Research Advisory Group Workshop on Marine Environmental Monitoring, July 2009. (Unpublished report held at Ministry for Primary Industries, Wellington.)

Lohrer, A M; Chiaroni, L D; Thrush, S F; Hewitt, J E (2010a) Isolated and interactive effects of two key species on ecosystem function and trophic linkages in New Zealand soft-sediment habitats. New Zealand Aquatic Environment and Biodiversity Report No. 44. 69 p.

Lohrer, A M; Cummings, V J; Thrush, S F (2012a) Altered sea ice thickness and permanence affects benthic ecosystem functioning in coastal Antarctica. Ecosystems 10.1007/s10021-012-9610-7.

Lohrer, A M; Halliday, N J; Thrush, S F; Hewitt, J E; Rodil, I F (2010b) Ecosystem functioning in a disturbance-recovery context: contribution of macrofauna to primary production and nutrient release on intertidal flats. Journal of Experimental Marine Biology and Ecology 390:6–13.

Lohrer, A M; Hewitt, J E; Hailes, S F; Thrush, S F; Ahrens, M; Halliday, J (2011) Contamination on sandflats and the decoupling of linked ecological functions. Austral Ecology 36:378–388.

Lohrer, A M; Rodil, I F; Townsend, M; Chiaroni, L D; Hewitt, J E; Thrush, S F (2013) Biogenic habitat transitions influence facilitation in a marine soft-sediment ecosystem. Ecology 94:136–145.

Lohrer, A M; Townsend, M; Rodil, I F; Hewitt, J E; Thrush, S F (2012b) Detecting shifts in ecosystem functioning: the decoupling of fundamental relationships with increased pollutant stress on sandflats. Marine Pollution Bulletin.64:2761–2769.

Lorrey, A.; Goff, J.; McFadgen, B.; Chagué-Goff, C.; Neil, H.; MacDiarmid, A. (2013b). A synthesis of climatic and geophysical activity in New Zealand and environmental changes during the last 1000 years. Final Research Report to the Ministry for Primary Industries ZBD200505 MS6 Part A, 48 p(Unpublished report held by Ministry for Primary Industries, Wellington.)

Lörz A-N; Maas E; Linse, K; Coleman, C O (2009) Do circum-Antarctic species exist in peracarid Amphipoda? A case study in the genus *Epimeria* Costa, 1851 (Crustacea: Peracarida: Epimeriidae). Zookeys (18): 91–128.

Lörz, A N (2010) Deep-sea *Rhachotropis* (Crustacea: Amphipoda: Eusiridae) from New Zealand and the Ross Sea with key to the Pacific, Indian Ocean and Antarctic speciesH. Zootaxa (2482): 22–48.

Lörz, A N (2011a) Pacific Epimeriidae (Amphipoda: Crustacea): Epimeria. Journal of the Marine Biological Association of the United Kingdom 91(2): 471–477.

Lörz, A N; Berkenbusch, K; Nodder, S; Ahyong, S; Bowden, D; McMillan, P; Gordon, D; Mills, S; Mackay, K (2012a) A review of deep-sea benthic biodiversity associated with trench, canyon and abyssal habitats below 1500 m depth in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 92. 133 p.

Lörz, A N; Linse, K; Smith, P; Steinke, D (2012b) First evidence for underestimated biodiversity of *Rhachotropis* (Crustacea, Amphipoda) with description of a new species. PloS ONE 7(3): e32365.

Lörz, A N; Smith, P J; Linse, K; Steinke, D (2012c) High genetic diversity within *Epimeria georgiana* (Amphipoda) from the southern Scotia Arc. Marine Biodiversity 42:137–159. available online at http://dx.doi.org/10.1007/s12526-011-0098-8

Lörz, A-N (2009) Synopsis of Amphipoda from two recent Ross Sea voyages with description of a new species of *Epimeria* (Epimeriidae, Amphipoda, Crustacea). Zootaxa (2167): 59–68.

Lörz, A-N (2011b) Biodiversity of an unknown New Zealand habitat: bathyal invertebrate assemblages in the benthic boundary layer. Marine Biodiversity 41(2): 299–312.

Lörz, A-N; Coleman, O (2009) Living gems: jewel-like creatures from the deep. Water and Atmosphere 17(1): 16–17.

Lundquist, C J; Ramsey, D; Bell, R; Swales, A; Kerr, S (2011) Predicted impacts of climate change on New Zealand's biodiversity. Pacific Conservation Biology 17: 179–191.

Lundquist, C J; Thrush, S F; Coco, G; Hewitt, J E (2010) Interactions between distributions and dispersal decrease persistence thresholds of a marine benthic community. Marine Ecology Progress Series 413: 217–228.

Lundquist, C.J.; Julian, K.; Costello, M.; Gordon, D.; Mackay, K.; Mills, S.; Neill, K.; Nelson, W.; Thompson, D. (2014). Development of a Tier 1 National Reporting Statistic for New Zealand's Marine Biodiversity. New Zealand Aquatic Environment and Biodiversity Report No. XX. xx p.

Lundquist, C.J.; Pritchard, M.; Thrush, S.F.; Hewitt, J.E.; Greenfield, B.L.; Halliday, N.J.; Lohrer, A.M. 2013. Bottom disturbance and seafloor landscapes: Development of a model of disturbance and recovery dynamics for marine benthic ecosystems. New Zealand Aquatic Environment and Biodiversity Report No. 118. 58 p.

Maas, E M; Voyles, K M; Pickmere, S; Hall, J A; Bowden, D A; Clark, M R (2010) Bacterial and Archaeal diversity and exo-enzyme activity in Ross Sea, Antarctica sediments. Poster presented at SAME 11- Symposium on Aquatic Microbial Ecology, Piran, Slovenia, 30th August - 4th September 2010.

Maas, E W; Law, C S; Hall, J A; Pickmere, S; Currie, K I; Chang, F H; Voyles, K M; Caird, D (2013) Effect of ocean acidification on bacterial abundance, activity and diversity in the Ross Sea. Aquatic Microbial Ecology 70:1–15.

Maas, E W; Voyles, K M; Caird, D; Pickmere, S; Hall, J A (2012) Bacterioplankton abundance, activity and diversity in the Ross Sea Antarctica. Aquatic Microbial Ecology (in review).

MacDiarmid, A (Editor) (2007) A summary of the biodiversity in the New Zealand Marine Ecoregion. Wellington: WWF-New Zealand;. The treasures of the sea: Ngā taonga a Tangaroa.

MacDiarmid, A B; Cleaver, P; Stirling, B (in prep). Historical evidence for exploitation of the marine environment in the Hauraki Gulf and along the Otago/Catlins shelf 1790–1930. Draft New Zealand Aquatic Environment and Biodiversity Report held by Ministry for Primary Industries, Wellington.

MacDiarmid, A B; Smith, I; Paul, L; Francis, M; McKenzie, A; Parsons, D; Hartill, B; Stirling, B; Cleaver, et al (in prep) A complete history of the exploitation of an ecologically important inshore finfish species in the Hauraki Gulf, New Zealand: a synthesis of archaeological, historical and fisheries data. Draft New Zealand Aquatic Environment and Biodiversity Report held by Ministry for Primary Industries, Wellington.

MacDiarmid, A. (editor) (2007). The Treasures of the Sea: Ngā Taonga a Tangaroa. A Summary of Biodiversity in the New Zealand Marine Ecoregion. Wellington, New Zealand, WWF-New Zealand.

MacDiarmid, A.; Beaumont, J.; Bostock, H.; Bowden, D.; Clark, M.; Hadfield, M.; Heath, P.; Lamarche, G.; Nodder, S.; Orpin, A.; Stevens, C.; Thompson, D.; Torres, L.; Wysoczanski, R. (2011). Expert risk assessment of activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf. NIWA Client Report WLG2011-39 for MfE, 145 p.

MacDiarmid, A.B.; Boschen, R; Bowden, D.; Clark, M.; Hadfield, M.; Lamarche, G.; Nodder, S.; Pinkerton, M.; Thompson, D. (2014). Environmental risk assessment of discharges of sediment during prospecting and exploration for seabed minerals. NIWA Client Report WLG2013-66 for MFE, 53 p.Maxwell, K; MacDiarmid, A B (in prep). Oral histories of marine fish and shellfish state and use in the Hauraki Gulf and along the Otago/Catlins coast 1940–2000. Draft Aquatic Environment and Biodiversity Report. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

MacDiarmid, A.B.; E. Abraham, C. S. Baker, E. Carroll, , C. Chagué-Goff, P. Cleaver, M. Francis, J. Goff, P. Horn, J. Jackson, C. Lalas, A. Lorrey, P. Marriot, K. Maxwell, B. McFadgen, A. McKenzie, H. Neil, D. Parsons, N. Patenaude, D. Paton, L. Paul, T. Pitcher, M. Pinkerton, I. Smith, T. Smith, B. Stirling (2014). Taking Stock – the impacts of humans on New Zealand marine ecosystems since first settlement: synthesis of major findings, and policy and management implications. New Zealand Aquatic Environment and Biodiversity Report No. XX. ISSN 1176-9440 (print), ISSN 1179-6480 (online).

MacDiarmid, A; McKenzie, A; Sturman, J; Beaumont, J; Mikaloff-Fletcher, S; Dunne, J (2012) Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93. 255 p.

MacDiarmid, A; Stewart, R (2012) Ross Sea and Balleny Islands biodiversity: routine observations and opportunistic sampling of biota made during a geophysical survey to the Ross Sea in 2006. Draft Aquatic Environment and Biodiversity Report held by Ministry for Primary Industries, Wellington.

McKenzie, A; MacDiarmid, A B (in prep) Biological parameters and biomass estimates for some commercial fish stocks in the Hauraki Gulf and Otago-Catlins shelf for the period 1930–2006. Draft Aquatic Environment and Biodiversity Report, 97 p. held by Ministry for Primary Industries, Wellington.)

McMillan, P J; Francis, M P; James, G D; Paul, L J; Marriott, P J; Mackay, E; Wood, B A; Griggs, L H; Sui, H; Wei, F (2011a) New Zealand fishes. Volume 1: A field guide to common species caught by bottom and midwater fishing. New Zealand Aquatic Environment and Biodiversity Report 68.

McMillan, P J; Francis, M P; Paul, L J; Marriott, P J; Mackay, E; Baird, S J; Griggs, L H; Sui, H; Wei, F (2011b) New Zealand fishes. Volume 2: A field guide to less common species caught by bottom and midwater fishing. New Zealand Aquatic Environment and Biodiversity Report 78.

McMillan, P J; Griggs, L H; Francis, M P; Marriott, P J; Paul, L J; Mackay, E; Wood, B A; Sui, H; Wei, F (2011c) New Zealand fishes. Volume 3: A field guide to common species caught by surface fishing. New Zealand Aquatic Environment and Biodiversity Report 69.

McMillan, P J; Iwamoto, T; Stewart, A; Smith, P J (2012) A new species of grenadier, genus *Macrourus* (Teleostei, Gadiformes, Macrouridae) from the southern hemisphere and a revision of the genus. Zootaxa, 3165, 1–24.

McWethy, D B; Whitlock, C; Wilmshurst, J M; McGlone, M S; Fromont, M; Li, X; Dieffenbacher-Krall, A; Hobbs, W O; Fritz, S C; Cook, E R (2010) Rapid landscape transformation in South Island, New Zealand, following initial Polynesian settlement. Proceedings of the national Academy of Sciences 107: 21 343–21 348.

MfE (2007) Environment New Zealand 2007.

Ministry for Primary Industries (2012) Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1194 p.

Mitchell, J (2008) Initial environmental evaluation (IEE) NZ IPY-CAML voyage 2008 report. Report prepared for Antarctic Policy Unit, Ministry of Foreign Affairs and Trade. May 2008. 35 p.

Mitchell, J; Clark, M (2004) Voyage report TAN04-02. Western Ross Sea voyage 2004. Hydrographic and biodiversity survey RV Tangaroa 27 January to 13 March 2004. Cape Adare, Cape Hallett, Possession Islands and Balleny Islands, Antarctica. NIWA Voyage Report TAN04-02. 102 p. (Unpublished report held in NIWA library, Wellington.)

Mitchell, J; MacDiarmid, A (2006) Voyage Report TAN06-02 EASTERN ROSS SEA VOYAGE. Voyage report for Ministry of Fisheries project ZBD2005-03. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Morrison, M; Lowe, M; Parsons, D; Usmar, N; McLeod, I (2009) A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 37. 100 p.

Murphy, E J; Cavanagh, R D; Hofmann, E E; Hill, S L; Constable, A J; Costa, D P; Pinkerton, M H; Johnston, N M; Trathan, P N; Klinck, J M; Wolf-Gladrow, D A; Daly, K L; Maury, O; Doney, S C (2012) Developing integrated models of Southern Ocean food webs: including ecological complexity, accounting for uncertainty and the importance of scale. Progress in Oceanography 102:74–92 http://dx.doi.org/10.1016/j.pocean.2012.03.006.

Needham, H C; Pilditch, C A; Lohrer, A M; Thrush, S F (2011) Context-specific bioturbation mediates changes to ecosystem functioning. Ecosystems, 14:1096–1109.

Needham, H C; Pilditch, C A; Lohrer, A; Thrush, S (2010) Habitat dependence in the functional traits of *Austrohelice crassa*, a key bioturbating species. Marine Ecology Progress Series, 414:179–193.

Needham, H R; Pilditch, C A; Lohrer, A M; Thrush, S F (2013) Density and habitat dependent effects of crab burrows on sediment erodibility. Journal of Sea Research 76: 94–104.

Neil, H; et al (in prep). Insights into historical marine productivity using ancient fish otoliths. Final Research Report: ZBD200505 MS 6 Part B. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Neill, K; D'Archino, R; Farr, T; Nelson, W (2012) Macroalgal diversity associated with soft sediment habitats in New Zealand. New

Zealand Aquatic Environment and Biodiversity Report 87. 127 p.

Nelson, W.A., Neill, K.F., D'Archino, R., Anderson, T., Beaumount, J., Dalen, J. 2014. Beyond diving depths: deepwater macroalgae in the New Zealand region. Marine Biodiversity. DOI 10.1007/s12526-014-0293-5

Schnabel, K., Nelson, W., Kelly, M., Anderson, O., Chin, C., Davey, N., Forman, J., Gordon, D., Lörz, A-N., Mills, S., Neill, K., Page, M., Stevens, D., Tracey, D., Jones, E., Morrison, M. (2014). Unlocking biodiversity data in the NIWA Invertebrate Collection (NIC) through identification of specimens and updating databases. (COBR1408, objective: Identification of Invertebrates). NIWA Client Report No: WLG2014-42, pp. 40.

Silva CNS, Gardner JPA 2014. Development and characterisation of 12 microsatellite markers for the New Zealand endemic scallop *Pecten novaezelandiae*. Conservation Genetics Resources. 6(2): 327-328.

Neill, K.F., Nelson, W.A., D'Archino, R., Leduc, D., Farr, T.J. 2014. Northern New Zealand rhodoliths: assessing faunal and floral diversity in physically contrasting beds. Marine Biodiversity DOI 10.1007/s12526-014-0229-0

Nelson, W A (2013) New Zealand Seaweeds – An illustrated guide. Te Papa Press, Wellington. 328 p

Nelson, W.A., D'Archino, R., Neill, K.F., Farr, T.J. 2014. Macroalgal diversity associated with rhodolith beds in northern New Zealand. Cryptogamie, Algologie 35: 27-47

Nelson, W A; Gordon, D P (1997) Assessing New Zealand's marine biological diversity — a challenge for policy makers and systematists. New Zealand Science Review 54:58–66.

Nelson, W A; Neill, K; Farr, T; Barr, N; D'Archino, R; Miller, S; Stewart, R (2012) Rhodolith beds in northern New Zealand:characterisation of associated biodiversity and vulnerability to environmental stressors. New Zealand Aquatic Environment and Biodiversity Report 99. 102 p.

Nelson, W.A., Neill, K.F., D'Archino, R., Anderson, T., Beaumount, J., Dalen, J. 2014. Beyond diving depths: deepwater macroalgae in the New Zealand region. Marine Biodiversity. DOI 10.1007/s12526-014-0293-5

Nelson, W A (2013) New Zealand Seaweeds – An illustrated guide. Te Papa Press, Wellington. 328 p

Nelson, W A; Gordon, D P (1997) Assessing New Zealand's marine biological diversity — a challenge for policy makers and systematists. New Zealand Science Review 54:58–66.

Nelson, W A; Neill, K; Farr, T; Barr, N; D'Archino, R; Miller, S; Stewart, R (2012) Rhodolith beds in northern New Zealand:characterisation of associated biodiversity and vulnerability to environmental stressors. New Zealand Aquatic Environment and Biodiversity Report 99. 102 p.

Nelson, W A; Villouta, E; Neill, K F; Williams, G C; Adams, N M; Slivsgaard, R (2002) Marine Macroalgae of Fiordland, New Zealand Tuhinga 13: 117–152.

Nelson, W; Cummings, V; D'Archino, R; Halliday, J; Marriott, P; Neill, K (2010) Macroalgae and benthic biodiversity of the Balleny Islands, Southern Ocean. New Zealand Aquatic Environment and Biodiversity Report No. 55. 99 p.

Nelson, W A (2009) Calcified macroalgae - critical to coastal ecosystems and vulnerable to change: A review. Marine and Freshwater Research 60:787–801.

Nelson, W.A., Sutherland, J.E., Farr. T.J., Hart, D.R., Neill, K.F., Kim, H.J., Yoon, H.S. (in press) Multigene analyses illuminate diversity and relationships of coralline red algae and support recognition of the *Hapalidales* ord. nov. Journal of Phycology.

Nodder, S D (2008) OS 20/20 Chatham Rise & Challenger Plateau Hydrographic, Biodiversity & Seabed Habitats, NIWA Client Report: WLG2008-27, National Institute of Water & Atmospheric Research, Wellington, New Zealand

Nodder, S; Maas, E; Bowden, D; Pilditch, C (2011) Physical, Biogeochemical and Microbial Characteristics of Sediment Samples from the Chatham Rise and Challenger Plateau. New Zealand. New Zealand Aquatic Environment and Biodiversity Report No 70.

Norkko, A; Andrew, N; Thrush, S; Cummings, V; Schwarz, A-M; Hawes, I; Mercer, S; Budd, R; Gibbs, M; Funnell, G; Hewitt, J; Goring, D (2002) Ecology and biodiversity of coastal benthic communities in McMurdo Sound, Ross Sea: development of sampling protocols and initial results. Final Research Report for Ministry of Fisheries Research Project ZBD2001/02, Objectives 1, 2 & 3. 119 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Norkko, A; Thrush, S F; Cummings, V J; Funnell, G A; Schwarz, A-M S; Andrew, N L; Hawes, I (2004) Ecological role of *Phyllophora antarctica* drift accumulations in coastal soft-sediment communities of McMurdo Sound, Antarctica. Polar Biology 27: 482–494.

Norkko, A; Thrush, S F; Cummings, V J; Gibbs, M M; Andrew, N L; Norkko, J; Schwarz, A-M (2007) Trophic structure of coastal Antarctic food webs associated with changes in sea ice and food supply. Ecology 88: 2810–2820.

Norkko, J; Norkko, A; Thrush, S F; Cummings, V J (2005) Growth under environmental extremes: spatial and temporal patterns in nucleic acid ratios in two Antarctic bivalves. Journal of Experimental Marine Biology and Ecology 326: 114–156.

Norkko, J; Norkko, A; Thrush, S F; Valanko, S; Suurkuukka, H (2010) Conditional responses to increasing scales of disturbance, and potential implications for threshold dynamics in soft-sediment communities. Marine Ecology Progress Series, 413:253–266.

O'Driscoll, R L; Macaulay, G J; Gauthier, S; Pinkerton, M; Hanchet, S (2011) Distribution, abundance and acoustic properties of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea. Deep-Sea Research II http://dx.doi.org/10.1016/j.dsr2.2010.05.018H)

O'Driscoll, R L (2009) Preliminary acoustic results from the New Zealand IPY-CAML survey of the Ross Sea region in February-March 2008. Final Research Report for MFish project IPY200701 objective 8. 14 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

O'Driscoll, R L; Hanchet, S M; Miller, B S (2012) Can acoustic methods be used to monitor grenadier (Macrouridae) abundance in the Ross Sea region? Journal of Ichthyology 53: 700–708.

O'Driscoll, R L; Macaulay, G J; Gauthier, S; Pinkerston, M; Hanchet, S (2011) Distribution, abundance, and acoustic properties of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea. Deep Sea Research II 58: 181–195.

O'Loughlin, M P; Paulay, G; Davey, N; Michonneau, F (2011) The Antarctic region as a marine biodiversity hotspot for echinoderms: Diversity and diversification of sea cucumbers. Deep Sea Research Part II: Topical Studies in Oceanography 58:264–275.

Paavo, B; Jonker, R; Thrush, S; Probert, P K (2011) Macrofaunal community patterns of adjacent coastal sediments with wave-reflecting or wave-dissipating characteristics. Journal of Coastal Research, 27:515–528.

Page, M J; Alcock, N; Gordon, D; Kelly-Shanks, M; Nelson, W; Neill, K; Watson, J (2001) Preliminary assessment of the biodiversity of benthic macrofauna of the western Ross Sea, Antarctica. Final Research Report to the Ministry of Fisheries. 29 p (Unpublished report held by Ministry for Primary Industries, Wellington.)

Pakhomov, E A; Hall, J; Williams, M J M; Hunt, B P V; Stevens, C J (2011) Biology of *Salpa thompsoni* in waters adjacent to the Ross Sea, Southern Ocean, during austral summer 2008. Polar Biology 34: 257–271. (DOI 10.1007/s00300-010-0878-9)

Parker, S J; Mormede, S; Tracey, D; Carter, M. (2009a) Evaluation of VME taxa monitoring by scientific observers from New Zealand in the Ross Sea Antarctic toothfish longline fishery during the 2008–09 season. Document WG-TASO 09/08. CCAMLR, Hobart, Australia. 13 p.

Parker, S J; Penney, A J; Clark, M R (2009b) Detection criteria for managing trawl impacts on vulnerable marine ecosystems in high seas fisheries of the South Pacific Ocean. Marine Ecology Progress Series, 397: 309–317.

Parravicini, V; Thrush, S F; Chiantore, M; Morri, C; Croci, C; Bianchi, C N (2010) The legacy of past disturbance: Chronic angling impairs long-term recovery of marine epibenthic communities from acute date-mussel harvesting. Biological Conservation, 143:2435–2440.

Parsons, D; Morrison, M A; MacDiarmid, A B; Stirling, B; Cleaver, P; Smith, I W G; Butcher, M (2012) Risks of shifting baselines highlighted by anecdotal accounts of New Zealand's snapper fishery. New Zealand Journal of Marine and Freshwater Research 43: 965–983.

Paul, L (2012). A history of the Firth of Thames dredge fishery for mussels: use and abuse of a coastal resource. New Zealand Aquatic Environment and Biodiversity Report No. 94, 27 p.

Paul, L (2014). Trends in the exploitation of finfish from the Hauraki Gulf, 1850–2006. New Zealand Aquatic Environment and Biodiversity Report No. 124, 156 p.

Peart, R; Serjeant, K; Mulcahy, K (2011) Governing our oceans. Environmental reform for the exclusive Economic Zone. Environmental Defence Society Policy Paper; Available as e-book: Hhttp://www.eds.org.nz/H.

Pinkerton, M (in prep) Mass balance modeling of a NZ shelf ecosystem since 1200AD. New Zealand Aquatic Environment and Biodiversity Report No. (Unpublished report held by Ministry for Primary Industries.)

Pinkerton, M H; Bradford-Grieve, J; Hanchet, S M (2010) A balanced model of the food web of the Ross Sea, Antarctica. CCAMLR Science 17:1–31.

Pinkerton, M H; Dunn, A; Hanchet, S M (2007) Ecological risk management and the fishery for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea, Antarctica, 22 p. Document EMM-07-24, CCAMLR, Hobart, Australia.

Pinkerton, M H; Forman, J; Bury, S J; Brown, J; Horn, P; O'Driscoll, R L (2013) Diet and trophic niche of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea, Antarctica. Journal of Fish Biology 82: 141–164.

Pinkerton, M H; Forman, J; Stevens, D W; Bury, S J; Brown, J (2012) Diet and trophic niche of Macrourus spp. (Gadiformes, Macrouridae) in the Ross Sea region of the Southern Ocean. Journal of Ichthyology, Special Issue on Grenadiers (Ed: Alexei Orlov) 52: 787–799.

Pinkerton, M.H. (2013). Ecosystem modelling of the present day and historical periods. Draft Final Research Report for Ministry of Fisheries project ZBD2005/05, "Long-term Change in New Zealand Coastal Ecosystems". Pp 113. Includes 10 appendices (Pp 185).

Pinkerton, M.H.; Cummings, V.; Forman, F.; Brown, J.; Bury, S.J. (2009a). Trophic connections in the Ross Sea: information from stomach contents analysis and stable isotopes of carbon and nitrogen. Report to Ministry of Fisheries, project IPY200701 Obj10, pp 18. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Pinkerton, M.H.; R. Bell; S.M. Chiswell; K. Currie; A.B. Mullan; G. Rickard; C. Stevens; P. Sutton (2014). Reporting on the state of the marine environment: recommendations for tier 1 oceanic statistics. Draft report for project ZBD2012-02. Pp 82. June 2014.

Pinkerton, M; Hanchet, S; Bradford-Grieve, J; Cummings, V; Wilson, P; Williams, M (2006) Modelling the effects of fishing in the Ross Sea. Final Research Report for Ministry of Fisheries Research Project ANT2004-05. 169 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Probert, P K; McKnight, D G; Grove, S L (1997) Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems 7:27–40.

Ramirez-Llodra, E; Tyler, P A; Baker, M C; Bergstad, O A; Clark, M R; Escobar, E; Levin, L A; Menot, L; Rowden, A A; Smith, C R; Van Dover, C L (2011) Man and the Last Great Wilderness: Human Impact on the Deep Sea. PLoS ONE 6(8): e22588. doi:10.1371/journal.pone.0022588

Reid, D J; Chiaroni, L D; Hewitt, J E; Lohrer, A M; Matthaei, C D; Phillips, N R; Scarsbrook, M R; Smith, B J; Thrush, S F; Townsend, C R; Van Houte-Howes, K S S; Wright-Stow, A E (2011) Sedimentation effects on the benthos of streams and estuaries: A cross-ecosystem comparison. Marine and Freshwater Research, 62:1201–1213.

Roberts, C D; Stewart, A L (2001) Ross Sea fishes: a collection-based biodiversity research programme. Seafood New Zealand, Dec. 9(11): 79–84.

Robinson, K V; Pinkerton, M H; Hall, J A; Hosie, G W (in prep.) Continuous Plankton Recorder Time Series. New Zealand Aquatic Environment and Biodiversity Report. 76 p.

Robinson, K.V.; M.H. Pinkerton; J.A. Hall; G.W. Hosie (2014). Continuous Plankton Recorder sampling between New Zealand and the Ross Sea, 2006–2013. New Zealand Aquatic Environment and Biodiversity Report No. 128. ISSN 1179-6480 (online), ISBN 978-0-478-43226-8 (online). Pp 74.

Rodil, I F; Lohrer, A M; Chiaroni, L D; Hewitt, J E; Thrush, S (2011) Disturbance of sandflats by thin deposits of terrigenous sediment: consequences for primary production and nutrient release. Ecological Applications, 21:416–426.

Rodríguez, L O; (Editor.) (2000). Implementing the GTI: Recommendations from DIVERSITAS Core Programme Element 3, Including an Assessment of Present Knowledge of Key Species Groups. 22 p.

Rogers, A D; Laffoley, D d'A (2011) International Earth system expert workshop on ocean Stresses and impacts. Summary report. IPSO Oxford, 18 p.

Rowden, A A; Berkenbusch, K; Brewin, P E; Dalen, J; Neill, K F; Nelson, W A; Oliver, M D; Probert, P K; Schwarz, A-M; Sui, P H; Sutherland, D (2012) A review of the marine soft-sediment assemblages of New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 96. 165 p.

Rowden, A A; Clark, M R (2010) Benthic biodiversity of seven seamounts on the southern end of the Kermadec volcanic arc, northeast New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 62. 31 p.

Rowden, A A; Clark, M R; O'Shea, S (2004) Benthic biodiversity of seamounts on the Northland Plateau. Marine Biodiversity Biosecurity Report No. 5. 21 p.

Rowden, A A; Clark, M R; O'Shea, S; McKnight, D G (2003) Benthic biodiversity of seamounts on the southern Kermadec volcanic arc. Marine Biodiversity Biosecurity Report No. 3. 23 p.

Rowden, A A; Clark, M R; Wright, I C (2005) Physical characterisation and a biologically focused classification of "seamounts" in the New Zealand region. New Zealand Journal of Marine and Freshwater Research 39: 1039–1059.

Rowden, A A; Kroger, K; Clark, M (2013) Biodiversity of macroinvertabrates and fish assemblages of the Balleny Islands seamounts. New Zealand Aquatic Environment and Biodiversity Report 115.

Rowden, A A; Oliver, M; Clark, M R; Mackay, K (2008) New Zealand's "SEAMOUNT" database: recent updates and its potential use for ecological risk assessment. New Zealand Aquatic Environment and Biodiversity Report No. 27. 49 p.

Rowden, A A; O'Shea, S; Clark, M R (2002) Benthic biodiversity of seamounts on the northwest Chatham Rise. Marine Biodiversity Biosecurity Report 2:1–21.

Rowden, A.; Leduc, D.; Torres, L.; Bowden, D.; Hart, A.; Chin, C.; Davey, N.; Nodder, S.; Pallentin, A.; Mackay, K.; Northcote, L.; Sturman, J. (2014). Benthic epifauna communities of the central Chatham Rise crest. NIWA Client Report WLG2014-9. 113 p.

Rowden, A.A., Leduc, D., Torres, L., Bowden, D., Hart, A., Chin, C., Davey, N., Wright, J., Carter, M., Crocker, B., Halliday, J., Loerz, A-N., Read, G., Mills, S., Anderson, O., Neill, K., Kelly, M., Tracey, D., Kaiser, S., Gordon, D., Wilkins, S., Horn, P., Pallentin, A., Nodder, S., Mackay, K., Northcote, L. (2013) Benthic communities of MPL area 50270 on the Chatham Rise. NIWA Client Report WLG2012-25. 102 p.

Russell, L K; Hepburn, C D; Hurd, C L; Stuart, M D (2008) The expanding range of *Undaria pinnatifida* in southern New Zealand: distribution, dispersal mechanisms and the invasion of wave-exposed environments. Biological Invasions 10:103–115.

Safi, K; Robinson, K; Hall, J; Schwarz, J; Maas, E (2012) Ross Sea deep-ocean and epipelagic microzooplankton during the summer-autumn transition period. Aquatic Microbial Ecology 67(2): 123–137.

Savage, C (2009) Development of bioindicators for the assimilation of terrestrial nutrient inputs in coastal ecosystems as a tool for watershed management. New Zealand Aquatic Environment and Biodiversity Report No. 30. 35 p.

Savage, C; Thrush, S F; Lohrer, A M; Hewitt, J E (2012) Ecosystem Services Transcend Boundaries: Estuaries Provide Resource Subsidies and Influence Functional Diversity in Coastal Benthic Communities. PLoS ONE 7(8): e42708. doi:10.1371/journal.pone.0042708

Schiaparelli, S; Alvaro, M C; Bohn, J; Albertelli, G (2010) 'Hitchhiker' polynoid polychaetes in cold deep waters and their potential influence on benthic soft bottom food webs. Antarctic Science 22:399–407.

Schiel, D R (2011) Biogeographic patterns and long-term changes on New Zealand coastal reefs: Non-trophic cascades from diffuse and local impacts. Journal of Experimental Marine Biology and Ecology 400: 33–51. http://www.esajournals.org/doi/abs/10.1890/03-3107

Schwarz, A; Taylor, R; Hewitt, J; Phillips, N; Shima, J; Cole, R; Budd, R (2006) Impacts of terrestrial runoff on the biodiversity of rocky reefs. New Zealand Aquatic Environment and Biodiversity Report No 7. 109 p.

Schwarz, A-M; Hawes, I; Andrew, N; Mercer, S; Cummings, V; Thrush, S (2005) Primary production potential of non-geniculate coralline algae at Cape Evans, Ross Sea, Antarctica. Marine Ecology Progress Series 294: 131–140.

Schwarz, A-M; Hawes, I; Andrew, N; Norkko, A; Cummings, V; Thrush, S (2003) Macroalgal photosynthesis near the southern global limit for growth; Cape Evans, Ross Sea, Antarctica. Polar Biology 26: 789–799.

Sewell, M A (2005) Examination of the meroplankton community in the southwestern Ross Sea, Antarctica, using a collapsible plankton net. Polar Biology 28:119–131.

Sewell, M A (2006) The meroplankton community of the northern Ross Sea: a preliminary comparison with the McMurdo Sound region. Antarctic Science 18:595–602.

Sewell, M A; Lavery, S; Baker, C S (2006) Whose larva is that? Molecular identification of planktonic larvae of the Ross Sea. New Zealand Aquatic Environment and Biodiversity Report No. 3. 57 p.

Sharp, B R; Parker, S J; Pinkerton, M H; (lead authors); also Breen, B B; Cummings, V; Dunn, A; Grant, S M; Hanchet, S M; Keys, H J R; Lockhart, S J; Lyver, P O'B; O'Driscoll, R L; Williams, M J M; Wilson P R (2010) Bioregionalisation and Spatial Ecosystem Processes in the Ross Sea Region. CCAMLR document WG-EMM-10/30, Hobart, Australia.

Smith, A M (2009) Bryozoans as southern sentinels of ocean acidification: a major role for a minor phylum. Marine and Freshwater Research 60:475–482.

Smith, A M; Gordon, D (2011) Bryozoans of southern New Zealand Field Identification Guide. New Zealand Aquatic Environment and Biodiversity Report 75. 64 p.

Smith, F (2006) Balleny Islands Ecology Research Voyage Report, R.V. Tiama. Unpublished report for Ministry of Fisheries project ZBD2005/01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Smith, I W G (2005) Retreat and resilience: Fur seals and human settlement in New Zealand, pp 6–18 In: Monks, G G (ed) The Exploitation and Cultural Importance of Marine Mammals. Oxford, Oxbow Books.

Smith, I W G (2011) Estimating the magnitude of pre-European Maori marine harvest in two New Zealand study areas. New Zealand Aquatic Environment and Biodiversity Report, No. 82, 72 p.

Smith, P J; Steinke, D; McMillan, P J; McVeagh, S M; Struthers, C D (2008) DNA database for commercial marine fish. New Zealand Aquatic Environment and Biodiversity Report No. 22. 62 p.

Smith, P J; Steinke, D; McMillan, P J; Stewart, A L; McVeagh, S M; Diaz De Astarloa, J M; Welsford, D; Ward, R D (2011a) DNA barcoding highlights a cryptic species of grenadier (genus *Macrourus*) in the Southern Ocean. Journal of Fish Biology, 78(1):355–365.

Smith, P J; Steinke, D; McMillan, P J; Stewart, A L; Ward, R D (2011b) DNA barcoding of morids (Actinopterygii, Moridae) reveals deep divergence in the anti tropical *Halargyreus johnsoni* but little distinction between *Antimora rostrata* and *A. microlepis*. Mitochondrial DNA, (doi:10.3109/19401736.2010.532329).

Snelder, T; Leathwick, J; Dey, K; Rowden, A; Weatherhead, M (2006) Development of an ecological marine classification in the New Zealand region. Environmental Management 39:12–29.

Sogin, M L; Morrison, H G, Huber, J A, Welch, D M, Huse, S M, Neal, P R, Arrieta, J M, Herndl G J (2006) Microbial diversity in the deep sea and the underexplored "rare biosphere". Proceedings Natural Academy Science U S A. 103(32): 12 115–12 120. www.ncbi.nlm.nih.gov/pmc/articles/PMC1524930/

Statistics New Zealand, Ministry for the Environment, Department of Conservation (2013).Environment domain plan 2013: Initiatives to address our environmental information needs. Available from www.stats.govt.nz.

Stein, D (2012) Snailfishes (Family Liparidae) of the Ross Sea, Antarctica, and closely adjacent waters. Zootaxa 3285:1–120.

Stevens, D W; Dunn, M R (2011) Different food preferences in four sympatric deep-sea Macrourid fishes. Marine Biology 158: 59–72. DOI 10.1007/s00227-010-1542-1

Stevens, D W; Hurst, R J; Bagley, N W (2011) Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000. New Zealand Aquatic Environment and Biodiversity Report No 85.

Sutherland, D L (2008) Surface-associated diatoms from marine habitats at Cape Evans, Antarctica, including the first record of living *Eunotogramma marginopunctatum*. Polar Biology 31:879–888 DOI 10.1007/s00300-008-0426-z.

Tracey, D; Mackay, E.; Gordon, D.; Cairns, S.; Alderslade, P.; Sanchez, J.; Williams, G. 2014. Coral Identification Guide – 2nd Version. Department of Conservation Report, Wellington. 16 p

Thrush, S F; Chiantore, M; Asnagi, V; Hewitt, J; Fiorentino, D; Cattaneo-Vietti, R (2011) Habitat-diversity relationships in rocky shore algal turf infaunal communities Marine Ecology Progress Series, 424:119–132.

Thrush, S F; Cummings, V J (2011) Massive icebergs, alteration in primary food resources and change in benthic communities at Cape Evans, Antarctica. Marine Ecology 32 (3): 289–299. doi: 10.1111/j.1439-0485.2011.00462.x

Thrush, S F; Dayton, P (2010) What can ecology contribute to Ecosystem-based Management of marine fisheries? Annual Reviews in Marine Science, 2:419–441.

Thrush, S F; Dayton, P K (2002) Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity. Annual Review of Ecology and Systematics 33:449–473.

Thrush, S F; Dayton, P K; Cattaneo-Vietti, R; Chiantore, M; Cummings, V J; Andrew, N L; Hawes, I; Kim, S; Kvitek, R; Schwarz, A -M (2006) Broad-scale factors influencing the biodiversity of coastal benthic communities of the Ross Sea. Deep Sea Research II 53: 959–971.

Thrush, S F; Hewitt, J E; Cummings, V J; Green, M O; Funnell, G A; Wilkinson, M R (2000) The generality of field experiments: interactions between local and broad-scale processes. Ecology 81: 399–415.

Thrush, S F; Hewitt, J E; Lohrer, A M (2012) Interaction networks in coastal soft-sediments highlight the potential for change in ecological resilience. Ecological Applications 22:1213–1223.

Thrush, S F; Hewitt, J E; Lohrer, A M; Chiaroni, L D (2013) When small changes matter: the role of cross-scale interactions between habitat and ecological connectivity in recovery. Ecological Applications 23: 226–238.

Thrush, S F; Hewitt, J; Cummings, V J; Norkko, A; Chiantore, M (2010) β-Diversity and species accumulation in Antarctic coastal benthos: Influence of habitat, distance and productivity on ecological connectivity. PLoS ONE 5:E11899.

Thrush, S F; Lohrer, A M (2012) Why bother going outside: the role of observational studies in understanding biodiversity-ecosystem function relationships, pp 198–212 In: Marine biodiversity futures and ecosystem functioning Frameworks, methodologies and integration, edited by Paterson, D M; Solan, M; Aspenal, R Oxford University Press.

Thrush, S F; Lohrer, D; Savage, C (in prep) Carbonate sediments: the positive and negative effects of land-coast interactions on functional diversity, draft AEBR report held by Ministry for Primary Industries.

Thrush, S F; Pridmore, R D; Bell, R G; Cummings, V J; Dayton, P K; Ford, R; Grant, J; Hewitt, J E; Hines, A H; Hume, T M; Lawrie, S M; Legendre, P; McArdle, B H; Morrisey, D; Schneider, D C; Turner, S J; Walters, R; Whitlatch, R B; Wilkinson, M R (1997) The sandflat habitat: Scaling from experiments to conclusions. Journal of Experimental Marine Biology and Ecology 216: 1–9.

Tittensor, D P; Baco, A R; Brewin, P E; Clark, M R; Consalvey, M; Hall-Spencer, J; Rowden, A A; Schlacher, T; Stocks, K I; Rogers, A D (2009) Predicting global habitat suitability for stony corals on seamounts. Journal of Biogeography, 36: 1111–1128.

Townsend, M; Thrush, S; Carbines, M (2011) Simplifying the complex: an ecosystem principles approach to goods and services management in marine coastal systems. Marine Ecology Progress Series, 434:291–301.

Tracey, D M; Anderson, O F; Clark, M R; Oliver, M D (2005) A guide to common deepsea invertebrates in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 1. 160 p.

Tracey, D M; Anderson, O F; Naylor, J R (2007) A guide to common deepsea invertebrates in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 10. 282 p.

Tracey, D M; Anderson, O F; Naylor, R J (2011a) A guide to common deepsea invertebrates in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report 86. 317 p.

Tracey, D; Baird, S J; Sanders, B M; Smith, M H (2011b) Distribution of protected corals in relation to fishing effort and assessment of accuracy of observer identification. NIWA Client Report No: WLG2011-33 prepared for Department of Conservation, Wellington. 74 p.

Tracey, D; Baird, S J; Sanders, B; Smith, M H (2011c) Identification of Protected Corals: distribution in relation to fishing effort and accuracy of observer identifications (MCSINT 2010/03). Final Report prepared for Marine Conservation Services (MCS), Department of Conservation | Te Papa Atawhai. 74 p.

Tracey, D; Bostock, H; Currie, K; Mikaloff-Fletcher, S; Williams, M; Hadfield, M; Neil, H; Guy, C; Cummings, V (2013) The potential impact of ocean acidification on deep-sea corals and fisheries habitat in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 117. 101 p.

Tracey, D; Carter, M; Parker, S (2010) Evaluation of VME taxa monitoring by scientific observers. Final Research Report for Ministry of Fisheries Research Project ANT2009/01 Objective 8. 17 p. (Unpublished report held by the Ministry for Primary Industries.)

Tracey, D; Rowden, A; Mackay, K; Compton, T (2011d) Habitat-forming coldwater corals show affinity for seamounts in the New Zealand region. Marine Ecology Progress Series 430: 1–22.

Tuck, I.; M.H. Pinkerton; Tracey, D.; Anderson, O.A.; S.M. Chiswell (2014). Ecosystem and Environmental Indicators for Deepwater Fisheries. Final Research Report prepared for MPI (DEE201005). Pp 129.

Tuck, I; Cole, R; Devine, J (2009) Ecosystem indicators for New Zealand fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 42. 188 p.

Tuck, I; Drury, J; Kelly, M; Gerring, P (2010) Designing a programme to monitor the recovery of the benthic community between

North Cape and Cape Reinga. New Zealand Aquatic Environment and Biodiversity Report No. 53. 78 p.

Turner, S J; Thrush, S F; Hewitt, J E; Cummings, V J; Funnell, G A (1999) Fishing impacts and the degradation or loss of habitat structure. Fisheries Management and Ecology 6:401–420.

Varian, S J (2005) A summary of the values of the Balleny Islands, Antarctica. Marine Biodiversity Biosecurity Report No. 6. 13 p.

Williams, A; Schlacher, T A; Rowden, A A; Althaus, F; Clark, M R; Bowden, D A; Stewart, R.; Bax, N J; Consalvey, M; Kloser, R J (2010) Seamount megabenthic assemblages fail to recover from trawling impacts. Marine Ecology 31(suppl. 1): 183–199.

Williams, R; Gould, B; Christian, S (2008) Shipwrecks — an international biosecurity risk? Surveillance 35:4–6.

Wing, S R (2005) Fiordland Biodiversity Research Cruise Final Research Report ZBD2003-04. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Woelkerling, W J; Nelson, W A (2004) A baseline summary and analysis of the taxonomic biodiversity of coralline red algae (Corallinales, Rhodophyta) recorded from the New Zealand region. Cryptogamie Algologie 25: 39–106.

Woodin, S A; Wethey, D S; Hewitt, J E; Thrush, S F (2012) Small scale terrestrial clay deposits on intertidal sandflats: Behavioral changes and productivity reduction. Journal of Experimental Marine Biology and Ecology,413:184–191.

15.7 APPENDIX

TECHNICAL RATIONALE FOR THE GOALS AND TARGETS OF THE STRATEGIC PLAN FOR THE PERIOD 2011-2020. UNEP/CBD/COP/10/9 18 JULY 2010.

Strategic goal A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Strategic actions should be initiated immediately to address, over a longer term, the underlying causes of biodiversity loss. This requires policy coherence and the integration of biodiversity into all national development policies and strategies and economic sectors and at all levels of government. Approaches to achieve this include communication, education and public awareness, appropriate pricing and incentives, and the broader use of planning tools such as strategic environmental assessment. Stakeholders across all sectors of government, society and the economy, including business, will need to be engaged as partners to implement these actions. Consumers and citizens must also be mobilized to contribute to biodiversity conservation and sustainable use, to reduce their ecological footprints and to support action by Governments.

[Note: Targets 1-5 not given here.] Targets 6-11 are directly quoted from the document.

Target 6: By 2020, overfishing is ended, destructive fishing practices are eliminated, and all fisheries are managed sustainably.] or [By 2020, all exploited fish stocks and other living marine and aquatic resources are harvested sustainably [and restored], and the impact of fisheries on threatened species and vulnerable ecosystems are within safe ecological limits.

Overexploitation is the main pressure on marine fisheries globally and the World Bank estimates that overexploitation represents a lost profitability of some $50 billion per year and puts at risk some 27 million jobs and the well-being of more than one billion people. Better fisheries management, which may include a reduction in fishing effort is needed to reduce pressure on ecosystems and to ensure the sustainable use of fish stocks. The specific target should be regarded as a step towards ensuring that all fisheries are sustainable while building upon existing initiatives such as the Code of Conduct for Responsible Fishing. Indicators to measure progress towards this target include the Marine Trophic Index, the proportion of products derived from sustainable sources and trends in abundance and distribution of selected species. Other possible indicators include the proportion of collapsed species, fisheries catch, catch per unit effort, and the proportion of stocks overexploited. Baseline information for several of these indicators is available from the Food and Agriculture Organization of the United Nations.

Target 7: By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

The increasing demand for food, fibre and fuel will lead to increasing losses of biodiversity and ecosystem services if management systems do not become increasingly sustainable with regard to the biodiversity. Criteria for sustainable forest management have been adopted by the forest sector and there are many efforts by Governments, indigenous and local communities, NGOs and the private sector to promote good agricultural, aquaculture and forestry practices. The application of the ecosystem approach would also assist with the implementation of this target. While, as yet, there are no universally agreed sustainability criteria, given the diversity of production systems and environmental conditions, each sector and many initiatives have developed their own criteria which could be used pending the development of a more common approach. Similarly, the use of certification and labelling systems or standards could be promoted as part of this target. Relevant indicators for this target include the area of forest, agricultural and aquaculture ecosystems under sustainable management, the proportion of products derived from sustainable sources and trends in genetic diversity of domesticated animals, cultivated plants and fish species of major socioeconomic importance. Existing sustainability certification schemes could provide baseline information for some ecosystems and sectors. UNEP/CBD/COP/10/9 Page 5 /...

Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

Pollution, including nutrient loading is a major and increasing cause of biodiversity loss and ecosystem dysfunction, particularly in wetland, coastal, marine and dryland areas. Humans have already more than doubled the amount of "reactive nitrogen" in the biosphere, and business-as-usual trends would suggest a further increase of the same magnitude by 2050. The better control of sources of pollution, including efficiency in fertilizer use and the better management of animal wastes, coupled with the use of wetlands as natural water treatment plants where appropriate, can be used to bring nutrient levels below levels that are critical for ecosystem functioning, without curtailing the application of fertilizer in areas where it is necessary to meet soil fertility and food security needs. Similarly, the development and application of national water quality guidelines could help to limit pollution and excess nutrients from entering freshwater and marine ecosystems. Relevant indicators include nitrogen deposition and water quality in freshwater ecosystems. Other possible indicators could be the ecological footprint and related concepts, total nutrient use, nutrient loading in freshwater and marine environments, and the incidence of hypoxic zones and algal blooms. Data which could provide baseline information already exists for several of these indicators, including the global aerial deposition of reactive nitrogen and the incidence of marine dead zones (an example of human-induced ecosystem failure).

Target 9: By 2020, invasive alien species are identified, prioritized and controlled or eradicated and measures are in place to control pathways for the introduction and establishment of invasive alien species.

Invasive alien species are a major threat to biodiversity and ecosystem services, and increasing trade and travel means that this threat is likely to increase unless additional action is taken. Pathways for the introduction of invasive alien species can be managed through improved border controls and quarantine, including through better coordination with national and regional bodies responsible for plant and animal health. While well-developed and, globally-applicable indicators are lacking, some basic methodologies do exist which can serve as a starting point for further monitoring or provide baseline information. Process indicators for this target could include the number of countries with national invasive species policies, strategies and action plans and the number of countries which have ratified international agreements and standards related to the prevention and control of invasive alien species. One outcome-oriented indicator is trends in invasive alien species while other possible indicators could include the status of alien species invasion, and the Red List Index for impacts of invasive alien species.

Target 10: By [2020][2015], to have minimized the multiple pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification, so as to maintain their integrity and functioning.

Given the ecological inertias related to climate change and ocean acidification, it is important to urgently reduce other pressures on vulnerable ecosystems such as coral reefs so as to give vulnerable ecosystems time to cope with the pressures caused by climate change. This can be accomplished by addressing those pressures which are most amenable to rapid positive changes and would include activities such as reducing pollution and overexploitation and harvesting practices which have negative consequences on ecosystems. Indicators for this target include the extent of biomes ecosystems and habitats (% live coral, and coral bleaching), Marine Trophic Index, the incidence of human-induced ecosystem failure, and the health and well-being of communities who depend directly on local ecosystem goods and services, proportion of products derived from sustainable sources. UNEP/CBD/COP/10/9 Page 6 /...

Strategic goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Whilst longer term actions to reduce the underlying causes of biodiversity loss are taking effect, immediate actions, such as protected areas, species recovery programmes, land-use planning approaches, the restoration of degraded ecosystems and other targeted conservation interventions can help conserve biodiversity and critical ecosystems. These might focus on culturally-valued species and key ecosystem services, particularly those of importance to the poor, as well as on threatened species. For example, carefully sited protected areas could prevent the extinction of threatened species by protecting their habitats, allowing for future recovery.

Target 11: By 2020, at least [15%][20%] of terrestrial, inland-water and [X%] of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through comprehensive, ecologically representative and well-connected systems of effectively managed protected areas and other means, and integrated into the wider land- and seascape.

Currently, some 13 per cent of terrestrial areas and 5 per cent of coastal areas are protected, while very little of the open oceans are protected. Therefore reaching the proposed target implies a modest increase in terrestrial protected areas globally, with an increased focus on representativity and management effectiveness, together with major efforts to expand marine protected areas. Protected areas should be integrated into the wider land- and seascape, bearing in mind the importance of complementarity and spatial configuration. In doing so, the ecosystem approach should be applied taking into account ecological connectivity and the concept of ecological networks, including connectivity for migratory species. Protected areas should also be established and managed in close collaboration with, and through participatory and equitable processes that recognize and respect the rights of indigenous and local communities, and vulnerable populations. Other means of protection may also include restrictions on activities that impact on biodiversity, which would allow for the safeguarding of sites in areas beyond national jurisdiction in a manner consistent with the jurisdictional scope of the Convention as contained in Article 4. Relevant indicators to measure progress towards this target are the coverage of sites of biodiversity significance covered by protected areas and the connectivity/fragmentation of ecosystems. Other possible indicators include the overlay of protected areas with ecoregions, and the governance and management effectiveness of protected areas. Good baseline information already exists from sources such as the World Database of Protected Areas the Alliance for Zero Extinction, and the IUCN Red List of Threatened Species and the IUCN World Commission on Protected Areas.

16 APPENDICES

16.1 TERMS OF REFERENCE FOR THE AQUATIC ENVIRONMENT WORKING GROUP FOR 2013 ONWARDS

OVERALL PURPOSE

For all New Zealand fisheries in the New Zealand TS and EEZ as well as other important fisheries in which New Zealand engages:

to assess, based on scientific information, the effects of (and risks posed by) fishing, aquaculture, and enhancement on the aquatic environment, including:

- bycatch and unobserved mortality of protected species (e.g. seabirds and marine mammals), fish, and other marine life, and consequent impacts on populations;
- effects of bottom fisheries on benthic biodiversity, species, and habitat;
- effects on biodiversity, including genetic diversity;
- changes to ecosystem structure and function from fishing, including trophic effects; and
- effects of aquaculture and fishery enhancement on the environment and on fishing.

Where appropriate and feasible, such assessments should explore the implications of the effect, including with respect to government standards, other agreed reference points, or other relevant indicators of population or environmental status. Where possible, projections of future status under alternative management scenarios should be made.

AEWG assesses the effects of fishing or environmental status, and may evaluate the consequences of alternative future management scenarios. AEWG does not make management recommendations or decisions (this responsibility lies with MPI fisheries managers and the Minister responsible for Fisheries).

MPI also convenes a Biodiversity Research Advisory Group (BRAG) which has a similar review function to the AEWG. Projects reviewed by BRAG and AEWG have some commonalities in that they relate to aspects of the marine environment. However, the key focus of projects considered by BRAG is on marine issues related to the functionality of the marine ecosystem and its productivity, whereas projects considered by AEWG are more commonly focused on the direct effects of fishing.

PREPARATORY TASKS

1. Prior to the beginning of AEWG meetings each year, MPI fisheries scientists will produce a list of issues for which new assessments or evaluations are likely to become available prior to the next scheduled sustainability round or decision process. AEWG Chairs will determine the final timetables and agendas.
2. The Ministry's research planning processes should identify most information needs well in advance but, if urgent issues arise, MPI-Fisheries or standards managers will alert MPI-Fisheries science managers and the Principal Advisor Fisheries Science, at least three months prior to the required AEWG meetings to other cases for which assessments or evaluations are urgently needed.

TECHNICAL OBJECTIVES

3. To review any new research information on fisheries impacts, including risks of impacts, and the relative or absolute sensitivity or susceptibility of potentially affected species, populations, habitats, and systems.
4. To estimate appropriate reference points for determining population, system, or environmental status, noting any draft or published Standards.
5. To conduct environmental assessments or evaluations for selected species, populations, habitats, or systems in order to determine their status relative to appropriate reference points and Standards, where such exist.
6. In addition to determining the status of the species, populations, habitats, and systems relative to reference points, and particularly where the status is unknown, AEWG should

explore the potential for using existing data and analyses to draw conclusions about likely future trends in fishing effects or status if current fishing methods, effort, catches, and catch limits are maintained, or if fishers or fisheries managers are considering modifying them in other ways.

7. Where appropriate and practical, to conduct or request projections of likely future status using alternative management actions, based on input from AEWG, fisheries plan advisers and fisheries and standards managers, noting any draft or published Standards.

8. For species or populations deemed to be depleted or endangered, to develop ideas for alternative rebuilding scenarios to levels that are likely to ensure long-term viability based on input from AEWG, fisheries managers, noting any draft or published Standards.

9. For species, populations, habitats, or systems for which new assessments are not conducted in the current year, to review and update any existing Fisheries Assessment Plenary report text in order to determine whether the latest reported status summary is still relevant; else to revise the evaluations based on new data or analyses, or other relevant information.

WORKING GROUP INPUT TO ANNUAL AQUATIC ENVIRONMENT AND BIODIVERSITY ANNUAL REVIEW

10. To include in contributions to the Aquatic Environment and Biodiversity Annual Review (AEBAR) summaries of information on selected issues that may relate to species, populations, habitats, or systems that may be affected by fishing. These contributions are analogous to Working Group reports from the Fisheries Assessment Working Groups.

11. To provide information and scientific advice on management considerations (e.g. area boundaries, by-catch issues, effects of fishing on habitat, other sources of mortality, and input controls such as mesh sizes and minimum legal sizes) that may be relevant for setting sustainability measures.

12. To summarise the assessment methods and results, along with estimates of relevant standards, references points, or other metrics that may be used as benchmarks or to identify risks to the aquatic environment.

13. It is desirable that full agreement among technical experts is achieved on the text of contributions to the AEBAR. If full agreement among technical experts cannot be reached, the Chair will determine how this will be depicted in the AEBAR, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

14. To advise the Principal Advisor Fisheries Science, about issues of particular importance that may require review by a plenary meeting or summarising in the AEBAR, and issues that are not believed to warrant such review. The general criterion for determining which issues should be discussed by a wider group or summarised in the AEBAR is that new data or analyses have become available that alter the previous assessment of an issue, particularly assessments of population status or projection results. Such information could include:

- New or revised estimates of environmental reference points, recent or current population status, trend, or projections;
- The development of a major trend in bycatch rates or amount;
- Any new studies or data that extend understanding of population, system, or environmental susceptibility to an effect or its recoverability, fishing patterns, or mitigation measures that have a substantial implications for a population, system, or environment or identify risks associated with fishing activity; and
- Consistent performance outside accepted reference points or Standards.

MEMBERSHIP AND PROTOCOLS FOR ALL SCIENCE WORKING GROUPS (PARAGRAPH NUMBERS CONSISTENT WITH THOSE IN TERMS OF REFERENCE FOR FISHERIES ASSESSMENT WORKING GROUPS)

WORKING GROUP CHAIRS

17. The Ministry will select and appoint the Chairs for Working Groups. The Chair will be an MPI fisheries scientist who is an active participant in the Working Group, providing technical input, rather than simply being a facilitator. Working Group Chairs will be responsible for:

- ensuring that Working Group participants are aware of the Terms of Reference for the Working Group, and that the Terms of Reference are adhered to by all participants;
- setting the rules of engagement, facilitating constructive questioning, and focussing on relevant issues;
- ensuring that all peer review processes are conducted in accordance with the Research and Science Information Standard for New Zealand Fisheries[167] (the Research Standard), and that research and science information is reviewed by the Working Group against the *P R I O R* principles for science information quality (page 6) and the criteria for peer review (pages 12-16) in the Standard;
- requesting and documenting the affiliations of participants at each Working Group meeting that have the potential to be, or to be perceived to be, a conflict of interest of relevance to the research under review (refer to page 15 of the Research Standard). Chairs are responsible for managing conflicts of interest, and ensuring that fisheries management implications do not jeopardise the objectivity of the review or result in biased interpretation of results;
- ensuring that the quality of information that is intended or likely to inform fisheries management decisions is ranked in accordance with the information ranking guidelines in the Research Standard (page 21-23), and that resulting information quality ranks are appropriately documented in Working Group reports and, where appropriate, in Status of Stock summary tables;
- striving for consensus while ensuring the transparency and integrity of research analyses, results, conclusions and final reports; and
- reporting on Working Group recommendations, conclusions and action items; and ensuring follow-up and communication with the MPI Principal Advisor Fisheries Science, relevant MPI fisheries management staff, and other key stakeholders.

WORKING GROUP MEMBERS

18. Working Groups will consist of the following participants:

- MPI fisheries science chair – required;
- Research providers – required (may be the primary researcher, or a designated substitute capable of presenting and discussing the agenda item);
- Other scientists not conducting analytical assessments to act in a peer review capacity;
- Representatives of relevant MPI fisheries management teams; and
- Any interested party who agrees to the standards of participation below.

19. Working Group participants must commit to:

- participating in the discussion;
- resolving issues;
- following up on agreements and tasks;

[167] Link to the Research Standard: http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm

- maintaining confidentiality of Working Group discussions and deliberations (unless otherwise agreed in advance, and subject to the constraints of the Official Information Act);
- adopting a constructive approach;
- avoiding repetition of earlier deliberations, particularly where agreement has already been reached;
- facilitating an atmosphere of honesty, openness and trust;
- respecting the role of the Chair; and
- listening to the views of others, and treating them with respect.

20. Participants in Working Group meetings will be expected to declare their sector affiliations and contractual relationships to the research under review, and to declare any substantial conflicts of interest related to any particular issue or scientific conclusion.

21. Working Group participants are expected to adhere to the requirements of independence, impartiality and objectivity listed under the Peer Review Criteria in the Research Standard (pages 12-16). It is understood that Working Group participants will often be representing particular sectors and interest groups, and will be expressing the views of those groups. However, when reviewing the quality of science information, representatives are expected to step aside from their sector affiliations, and to ensure that individual and sector views do not result in bias in the science information and conclusions.

WORKING GROUP PAPERS

23. Working group papers will be posted on the MPI-Fisheries website prior to meetings if they are available. As a general guide, Powerpoint presentations and draft or discussion papers should be available at least 2 working days before a meeting, and near-final papers should be available at least 5 working days before a meeting if the Working Group is expected to agree to the paper. However, it is also likely that many papers will be tabled during the meeting due to time constraints. If a paper is not available for sufficient time before the meeting, the Chair may provide for additional time for written comments from Working Group members.

24. Working Group papers are "works in progress" whose role is to facilitate the discussion of the Working Groups. They often contain preliminary results that are receiving peer review for the first time and, as such, may contain errors or preliminary analyses that will be superseded by more rigorous work. For these reasons, no-one may release the papers or any information contained in these papers to external parties. In general, Working Group papers should never be cited. Exceptions may be made in rare instances by obtaining permission in writing from the Principal Advisor Fisheries Science, and the authors of the paper.

25. Participants who use Working Group papers inappropriately, or who do not adhere to the standards of participation, may be requested by the Chair to leave a particular meeting or, in more serious instances, to refrain from attending one or more future meetings.

WORKING GROUP MEETINGS

26. Meetings will take place as required, generally January-April and July-November for FAWGs and throughout the year for other working groups (AEWG, BRAG, Marine Amateur Fisheries and Antarctic Working Groups).

27. A quorum will be reached when the Chair, the designated presenter, and three or more other technical experts are present. In the absence of a quorum, the Chair may decide to proceed as a sub-group, with outcomes being taken forward to the next meeting at which a quorum is formed.

28. The Chair is responsible for deciding, with input from the entire Working Group, but focussing primarily on the technical discussion and the views of technical expert members:

- The quality and acceptability of the information and analyses under review;
- The way forward to address any deficiencies;
- The need for any additional analyses;
- Contents of Working Group reports;
- Choice of base case models and sensitivity analyses to be presented; and
- The status of the stocks, or the status/performance in relation to any relevant environmental standards or targets.

29. The Chair is responsible for facilitating a consultative and collaborative discussion.

30. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.

31. A record of recommendations, conclusions and action items will be posted on the MPI-Fisheries website after each meeting has taken place.

32. Data upon which analyses presented to the Working Groups are based must be provided to MPI in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MPI; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members).

33. The outcome of each Working Group round will be evaluated, with a view to identifying opportunities to improve the Working Group process. The Terms of Reference may be updated as part of this review.

34. MPI fisheries scientists and science officers will provide administrative support to the Working Groups.

Information Quality Ranking

22. Science Working Groups are required to rank the quality of research and science information that is intended or likely to inform fisheries management decisions, in accordance with the science information quality ranking guidelines in the Research Standard (pages 21-23). Information quality rankings should be documented in Working Group reports and, where appropriate, in Status of Stock summary tables.

- Working Groups are not required to rank all research projects and analyses, but key pieces of information that are expected or likely to inform fisheries management decisions should receive a quality ranking;
- Explanations substantiating the quality rankings will be included in Working Group reports. In particular, the quality shortcomings and concerns for moderate/mixed and low quality information must be documented; and
- The Chair, working with participants, will determine which pieces of information require a quality ranking. Not all information resulting from a particular research project would be expected to achieve the same quality rank, and different quality ranks may be assigned to different components, conclusions or pieces of information resulting from a particular piece of research.

RECORD-KEEPING

35. The overall responsibility for record-keeping rests with the Chair of the Working Group, and includes:

- keeping notes on recommendations, conclusions and follow-up actions for all Working Group meetings, and to ensure that these are available to all members of the Working Group and the Principal Advisor Fisheries Science in a timely manner. If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes; and
- compiling a list of generic assessment issues and specific research needs for

each Fishstock or species or environmental issue under the purview of the Working Group, for use in subsequent research planning processes.

16.2 AEWG MEMBERSHIP 2013–14

CONVENORS: Rich Ford, Martin Cryer, Nathan Walker

MEMBERS: Blake Abernethy, Ed Abraham, Owen Anderson, Ian Angus, William Arlidge, Louise Askin, Karen Baird, Suze Baird, Barry Baker, Sira Ballara, Andrew Baxter, Brett Beamsley, Andrew Bell, Michelle Beritzhoff-Law, Katrin Berkenbusch, Tiffany Bock, Lesley Bolton-Ritchie, Laura Boren, Christine Bowden, Paul Breen, Stuart Brodie, Niall Broekhuizen, Bruno Brosnan, Martin Cawthorn, Alastair Childs, Steve Chiswell, David Clark, Malcolm Clark, Tom Clark, Rebecca Clarkson, Katie Clemens, Deanna Clement, Chris Cornelisen, Paul Crozier, Rohan Currey, Steve Dawson, Igor Debski, Ian Doonan, Matt Dunn, Adele Dutilloy, Charlie Edwards, Jack Fenaughty, Malcolm Francis, Charmaine Gallagher, Sarah Gardiner, Hilke Giles, Mark Gillard, Paul Gillespie, Neil Hartstein, Jeremy Helson, Judi Hewitt, Julie Hills, Deborah Hoffstra, Stephanie Hopkins, Rosie Hurst, Aaron Irving, Colin Johnston, Nigel Keeley, Dan Kluza, Ben Knight, Anna Kraack, Laws Lawson, Mary Livingston, Carolyn Lundquist, Dave Lundquist, Pamela Mace, Darryl MacKenzie, Lucy Manning, Rob Mattlin, Vidette McGregor, David Middleton, Rosemary Millar, Jodi Milne, Michael Neilsen, Tracey Osborne, Milena Palka, Matt Pinkerton, Irene Pohl, Marine Pomarede, Steve Pullan, Kris Ramm, Will Rayment, Vicky Reeve, Yvan Richard, Graham Rickard, Paul Sagar, Carol Scott, Liz Slooten, Tony Stafford, Kevin Stokes, Katrina Subedar, Alex Thompson, Findlay Thompson, Geoff Tingley, Di Tracey, Ian Tuck, Ben Tuckey, Nathan Walker, Bill Wallace, Barry Weeber, Richard Wells, John Wilmer, Hamish Wilson, John Wilson, Brent Wood.

16.3 TERMS OF REFERENCE FOR THE BIODIVERSITY RESEARCH ADVISORY GROUP (BRAG) 2013 ONWARDS

OVERALL PURPOSE

Since 2000, the objectives of the Biodiversity Research Programme have been drawn directly from MFish commitments to Theme 3 of the New Zealand Biodiversity Strategy. Within this framework, the Biodiversity Medium Term Research Plan has been adapted over time as new issues emerge, to build on synergies with other research programmes and work where biodiversity is under greatest threat from fishing or other anthropogenic activity.

Within the constraints of the overall purpose of the Programme,

> "To improve our understanding of New Zealand marine ecosystems in terms of species diversity, marine habitat diversity, and the processes that lead to healthy ecosystem functioning, and the role that biodiversity has for such key processes[168]"

and the NZBS definition of biodiversity (the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystem) the science currently commissioned broadly aims to:

- Describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed;
- determine the functional role of different organisms or groups of organisms in marine ecosystems, and assess the role of marine biodiversity in mitigating the impacts of anthropogenic disturbance on healthy ecosystem functioning;
- identify which components of biodiversity must be protected to ensure the sustainability of a healthy

[168] See MFish Biodiversity Research Programme 2010: Part 1. Context and Purpose

marine ecosystem as well as to meet societal values on biodiversity.

MPI also convenes an Aquatic Environment Working Group (AEWG) which has a similar review function to the BRAG. Projects reviewed by BRAG and AEWG have some commonalities in that they relate to aspects of the marine environment. However, the key focus of projects considered by BRAG is on marine issues related to the functionality of the marine ecosystem and its productivity, whereas projects considered by AEWG are more commonly focused on the direct effects of fishing.

BRAG may identify natural resource management issues that extend beyond fisheries management and make recommendations on priority areas of research that will inform MAF or other government departments of emerging science results that require the attention of managers, policymakers and decision-makers in the marine sector. BRAG does not make management recommendations or decisions (this responsibility lies with the MAF Fisheries Management Group and the Minister of Primary Industry).

PREPARATORY TASKS

1. Prior to the beginning of BRAG meetings each year, MPI fisheries scientists will produce a list of issues for which new research projects are likely to required in the forthcoming financial year. The BRAG Chair will determine the final timetables and agendas.
2. The Ministry's research planning processes should identify most information needs well in advance but, if urgent issues arise, MPI fisheries managers will alert the Aquatic Environment and Biodiversity Science Manager and the Principal Advisor Fisheries Science at least three months prior to the required meetings where possible.

BRAG TECHNICAL OBJECTIVES

3. To review, discuss and convey views on the results of marine biodiversity research projects contracted by MPI (formerly Ministry of Fisheries).

It is the responsibility of the BRAG to review, discuss, and convey views on the results of marine biodiversity research projects contracted by MPI and the former Ministry of Fisheries. The review process is an evaluation of how existing research results can be built upon to address emerging research issues and needs. It is essentially an evaluation of "what we already know" and how this can be used to obtain "what we need to know". This information should be used by the BRAG to identify gaps in our knowledge and for developing research plans to address these gaps.

4. Discuss, evaluate, make recommendations and convey views on a 3 to 5 year Medium Term Research Plan.

It is the responsibility of BRAG participants to discuss, evaluate, make recommendations and convey views on a 3 to 5 year Medium Term Research Plan for its particular research area as required. Individual related projects on a species or fishery or research topic need to be integrated into Medium Term Research Plans. The Medium Term Research Plans should encompass research needs and directions for at least the next 3 to 5 years.

The Biodiversity Medium Term Research Plan is aligned to relevant strategic and policy directions such as the "MPI Statement of Intent" and any Strategic Research Plan (Fisheries 2030, Deepwater 10 year research plan) and fisheries plans developed for the appropriate species/fishery or research area, including biodiversity.

The recommendations on project proposals for the next financial year will be submitted via the Chair of BRAG to the Principal Science Advisor Fisheries (MAF).

5. The Biodiversity Research Programme includes research in New Zealand's TS, EEZ, Extended Continental Shelf, the South Pacific Region and the Ross Sea region and has seven scientific work streams as follows:
    1. To develop ecosystem-scale understanding of biodiversity in the New Zealand marine environment
    2. To classify and characterise the biodiversity, including the description and documentation of biota, associated with nearshore and offshore marine habitats in New Zealand

3. To investigate the role of biodiversity in the functional ecology of nearshore and offshore marine communities.
4. To assess developments in all aspects of biodiversity, including genetic marine biodiversity and identify key topics for research
5. To determine the effects of climate change and increased ocean acidification on marine biodiversity, as well as effects of incursions of non-indigenous species, and other threats and impacts.
6. To develop appropriate diversity metrics and other indicators of biodiversity that can be used to monitor change
7. To identify threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation

BRAG INPUT TO MPI "AQUATIC ENVIRONMENT AND BIODIVERSITY ANNUAL REVIEW"

6. To contribute to and summarise progress on biodiversity research in the Aquatic Environment and Biodiversity Annual Review. This contribution is analogous to Working Group Reports from the Fishery Assessment Working Groups.
7. To summarise the assessment methods and results, along with estimates of relevant standards, references points, or other metrics that may be relevant to biodiversity objectives by MPI, the Biodiversity Strategy and international obligations.
8. It is desirable that full agreement among technical experts is achieved on the text of these contributions. If full agreement among technical experts cannot be reached, the Chair will determine how this will be depicted in the Aquatic Environment and Biodiversity Annual Review, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.
9. To advise the Principal Science Advisor Fisheries (MPI), about issues of particular importance that may require review by a plenary meeting or summarising in the Aquatic Environment and Biodiversity Annual Review. The general criterion for determining which issues should be discussed by a wider group include:

- Emerging issues, recent or current biodiversity status assessments, trends, or projections
- The development of a major trend in the marine environment that will impact on marine productivity or ecosystem resilience to stressors
- Any new studies or data that impact on international obligations

MEMBERSHIP AND PROTOCOLS FOR ALL SCIENCE WORKING GROUPS (NOTE: PARAGRAPH NUMBERS CONSISTENT WITH THOSE IN TERMS OF REFERENCE FOR FISHERIES ASSESSMENT WORKING GROUPS)

WORKING GROUP CHAIRS

17. The Ministry will select and appoint the Chairs for Working Groups. The Chair will be an MPI fisheries scientist who is an active participant in the Working Group, providing technical input, rather than simply being a facilitator. Working Group Chairs will be responsible for:

- ensuring that Working Group participants are aware of the Terms of Reference for the Working Group, and that the Terms of Reference are adhered to by all participants;
- setting the rules of engagement, facilitating constructive questioning, and focussing on relevant issues;
- ensuring that all peer review processes are conducted in accordance with the Research and Science Information Standard for New Zealand Fisheries[169] (the Research Standard), and that

[169] Link to the Research Standard: http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm

research and science information is reviewed by the Working Group against the *P R I O R* principles for science information quality (page 6) and the criteria for peer review (pages 12-16) in the Standard;

- requesting and documenting the affiliations of participants at each Working Group meeting that have the potential to be, or to be perceived to be, a conflict of interest of relevance to the research under review (refer to page 15 of the Research Standard). Chairs are responsible for managing conflicts of interest, and ensuring that fisheries management implications do not jeopardise the objectivity of the review or result in biased interpretation of results;
- ensuring that the quality of information that is intended or likely to inform fisheries management decisions is ranked in accordance with the information ranking guidelines in the Research Standard (page 21-23), and that resulting information quality ranks are appropriately documented in Working Group reports and, where appropriate, in Status of Stock summary tables;
- striving for consensus while ensuring the transparency and integrity of research analyses, results, conclusions and final reports; and
- reporting on Working Group recommendations, conclusions and action items; and ensuring follow-up and communication with the MPI Principal Advisor Fisheries Science, relevant MPI fisheries management staff, and other key stakeholders.

WORKING GROUP MEMBERS

18. Working Groups will consist of the following participants:

- MPI fisheries science chair – required;
- Research providers – required (may be the primary researcher, or a designated substitute capable of presenting and discussing the agenda item);
- Other scientists not conducting analytical assessments to act in a peer review capacity;
- Representatives of relevant MPI fisheries management teams; and
- Any interested party who agrees to the standards of participation below.

19. Working Group participants must commit to:

- participating in the discussion;
- resolving issues;
- following up on agreements and tasks;
- maintaining confidentiality of Working Group discussions and deliberations (unless otherwise agreed in advance, and subject to the constraints of the Official Information Act);
- adopting a constructive approach;
- avoiding repetition of earlier deliberations, particularly where agreement has already been reached;
- facilitating an atmosphere of honesty, openness and trust;
- respecting the role of the Chair; and
- listening to the views of others, and treating them with respect.

20. Participants in Working Group meetings will be expected to declare their sector affiliations and contractual relationships to the research under review, and to declare any substantial conflicts of interest related to any particular issue or scientific conclusion.

21. Working Group participants are expected to adhere to the requirements of independence, impartiality and objectivity listed under the Peer Review Criteria in the Research Standard (pages 12-16). It is understood that Working Group participants will often be representing particular sectors and interest groups, and will be expressing the views of those groups. However, when reviewing the quality of science information, representatives are expected to step aside

from their sector affiliations, and to ensure that individual and sector views do not result in bias in the science information and conclusions.

WORKING GROUP PAPERS

23. Working group papers will be posted on the MPI-Fisheries website prior to meetings if they are available. As a general guide, Powerpoint presentations and draft or discussion papers should be available at least 2 working days before a meeting, and near-final papers should be available at least 5 working days before a meeting if the Working Group is expected to agree to the paper. However, it is also likely that many papers will be tabled during the meeting due to time constraints. If a paper is not available for sufficient time before the meeting, the Chair may provide for additional time for written comments from Working Group members.

24. Working Group papers are "works in progress" whose role is to facilitate the discussion of the Working Groups. They often contain preliminary results that are receiving peer review for the first time and, as such, may contain errors or preliminary analyses that will be superseded by more rigorous work. For these reasons, no-one may release the papers or any information contained in these papers to external parties. In general, Working Group papers should never be cited. Exceptions may be made in rare instances by obtaining permission in writing from the Principal Advisor Fisheries Science, and the authors of the paper.

25. Participants who use Working Group papers inappropriately, or who do not adhere to the standards of participation, may be requested by the Chair to leave a particular meeting or, in more serious instances, to refrain from attending one or more future meetings.

WORKING GROUP MEETINGS

26. Meetings will take place as required, generally January-April and July-November for FAWGs and throughout the year for other working groups (AEWG, BRAG, Marine Amateur Fisheries and Antarctic Working Groups).

27. A quorum will be reached when the Chair, the designated presenter, and three or more other technical experts are present. In the absence of a quorum, the Chair may decide to proceed as a sub-group, with outcomes being taken forward to the next meeting at which a quorum is formed.

28. The Chair is responsible for deciding, with input from the entire Working Group, but focussing primarily on the technical discussion and the views of technical expert members:

- The quality and acceptability of the information and analyses under review;
- The way forward to address any deficiencies;
- The need for any additional analyses;
- Contents of Working Group reports;
- Choice of base case models and sensitivity analyses to be presented; and
- The status of the stocks, or the status/performance in relation to any relevant environmental standards or targets.

29. The Chair is responsible for facilitating a consultative and collaborative discussion.

30. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.

31. A record of recommendations, conclusions and action items will be posted on the MPI-Fisheries website after each meeting has taken place.

32. Data upon which analyses presented to the Working Groups are based must be provided to MPI in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MPI; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members).

33. The outcome of each Working Group round will be evaluated, with a view to identifying

opportunities to improve the Working Group process. The Terms of Reference may be updated as part of this review.

34. MPI fisheries scientists and science officers will provide administrative support to the Working Groups.

RECORD-KEEPING

35. The overall responsibility for record-keeping rests with the Chair of the Working Group, and includes:

- keeping notes on recommendations, conclusions and follow-up actions for all Working Group meetings, and to ensure that these are available to all members of the Working Group and the Principal Advisor Fisheries Science in a timely manner. If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes; and
- compiling a list of generic assessment issues and specific research needs for each Fishstock or species or environmental issue under the purview of the Working Group, for use in subsequent research planning processes.

16.4 BRAG ATTENDANCE 2013

CONVENOR: Mary Livingston (MPI chair),

MEMBERS: Malcolm Clark, Mark Morrison, Anne-Nina Loerz, Dennis Gordon, Wendy Nelson, Cliff Law, Di Tracey, David Bowden, Matt Pinkerton, Ashley Rowden, Carolyn Lundquist, Malcolm Francis, Darren Parsons, Judi Hewitt, Drew Lohrer, Alison MacDiarmid, Julie Hall, Karen Robinson, Wendy Nelson, Emma Jones, Vonda Cummings, Di Tracey, Alistair Dunn, Barb Hayden, Scott Nodder, Sara Mikaloff-Fletcher (all NIWA); David Middleton (Trident Services NZ); Martin Cryer, Rob Tinkler, Rich Ford, Rohan Currey (MPI); Mark Costello, Shane Lavery (Auckland University); Lyndsey Holland, Jo Hamilton, Jonathan Gardner (Victoria University of Wellington); Paul Breen (RLIC); William Arlidge, Shane Geange (DOC); Aaron Irving (Deepwater Group)

16.5 GENERIC TERMS OF REFERENCE FOR RESEARCH ADVISORY GROUPS (SEPT 2010)

OVERALL PURPOSE

1. The purpose of the Research Advisory Groups (RAGs) is to develop research proposals to meet management information needs and support standards development.

CONTEXT

2. To assist RAG members with their work this section outlines the wider process that RAGs will operate within.

Fisheries Plans will guide the management of fisheries

3. From 1 July 2011 the Ministry of Fisheries (MFish) will be using Fisheries Plans in the following five areas to guide the management of fisheries:

    - Deepwater
    - Highly Migratory Species
    - Inshore – Finfish
    - Inshore – Freshwater
    - Inshore – Shellfish

4. In each of those five areas there will be:

    - A Fisheries Plan that sets out management objectives over a 5 year period.
    - An Annual Operational Plan that sets out what will be done in a financial year to help meet those objectives, including in the areas of science research, compliance and observer coverage (i.e., the Annual Operational Plan will be where priorities are set each year). Note that external stakeholders will have an opportunity to provide comment on prioritisation through draft Annual Operational Plans.
    - An Annual Review Report that will assess progress made against the management objectives, and help identify gaps to be considered in setting the next set of priorities.

RAGs will largely be aligned to the Fisheries Plan areas

5. There will be a RAG for each of the five Fisheries Plan areas above.
6. In addition there will be a RAG for Aquatic Environment (Standards), for research needed to support standards development, and another for Antarctic research. (Note that biodiversity research is dealt with through a separate process that has more of a cross-agency focus.)

RAGs will develop research proposals to be considered as part of a subsequent prioritisation process

7. As part of the process for developing the Annual Operational Plans, the identification and prioritisation of science research will broadly occur as follows:

    i. MFish fisheries managers will identify the fisheries management objectives and information needs that they want the relevant RAG to consider. This will be done in conjunction with MFish scientists, and will draw on the following:

        - The relevant Annual Review Report discussed above
        - Existing research plans
        - Science Assessment Working Groups' feedback arising from research that has been evaluated previously
        - Ad-hoc issues as they arise
        - Initial indications of the available budget

    ii. The RAGs will then develop proposals for scientific research to meet those management and information needs.

    iii. MFish fisheries managers will then run a process for prioritising the research proposals that have been developed and updating multi-year research plans, in conjunction with MFish scientists. This will be part of the wider process for developing Annual Operational Plans.

8. In the Aquatic Environment (Standards) and Antarctic areas a similar process will be followed to that above, involving relevant MFish managers.
9. In practice, these processes are likely to iterate between the above steps, e.g., when prioritising research proposals fisheries managers may identify additional questions that they want a RAG to consider.
10. RAGs will only be convened when necessary. If, for example, all of the research for the coming year under review has previously been approved as part of a multi-year funding package for an area, and no additional management needs have emerged, the relevant RAG will not be convened.
11. During 2010-11 RAGs will be used, as required, in all areas except Inshore, given that the three Inshore Fisheries Plans are still being developed through the year. For the Inshore areas a transitional process will be used, with RAGs commencing during 2011-12.

RESEARCH PROPOSALS

12. RAGs will provide recommendations to fisheries managers on research to meet management needs. This section provides more detail on the research proposals that the RAGs will produce.
13. The RAGs will produce an initial set of project proposals to meet the management and information needs provided to the RAG, for consideration in the subsequent prioritisation process.
14. The proposals may be in the form of multi-year projects where appropriate.
15. While the prioritisation of research is outside the scope of the work of the RAGs, the proposals will include information on potential cost and feasibility to guide decisions on prioritisation. Cost estimates should be specified as ranges so as to not unduly influence subsequent research provider costings.
16. Where the RAG identifies more than one desirable option for scientific research to meet management and information needs, the RAG's proposals will cover those options, their relative pros and cons, their respective potential costs, and the RAG's recommendation as to the preferred option.
17. Once prioritisation decisions have been made on the initial set of research proposals, the RAG may be asked to produce more fully developed project proposals for inclusion in the relevant Annual Operational Plan, and for the purposes of cost recovery consultation and tendering.

MEMBERSHIP

18. Membership of RAGs is expertise-based.
19. Membership will be by invitation from MFish only.
20. A RAG will consist of a core group of one MFish scientist and one manager from the relevant Fisheries Plan or Standards team, with the option to "call in" relevant technical expertise (internal and/or external) as needed.
21. External participants will be paid for their time. This will include preparing for and attending RAG meetings, and any time spent writing proposals.

PROTOCOLS

22. All RAG members will commit to:

- participating in the discussion in an objective and unbiased manner;
- resolving issues;
- following up on agreements and tasks;
- adopting a constructive approach;
- facilitating an atmosphere of honesty, openness and trust;
- having respect for the role of the Chair; and
- listening to the views of others, and treating them with respect.

23. RAG meetings will be run formally with agendas pre-circulated and formal records kept of recommendations, conclusions and action items.

24. Participants who do not adhere to the standards of participation may be requested by the Chair to leave a particular meeting or, in more serious instances, will be excluded from the RAG.

Chairpersons

25. The Chair of each RAG will be a MFish scientist with appropriate expertise.

26. The Chair commits to undertaking the following roles:

- The Chair is an active participant in RAGs, who also provides technical input, rather than simply being a facilitator.
- The Chair is responsible for: setting the rules of engagement; promoting full participation by all members; facilitating constructive questioning; focussing on relevant issues; reporting on RAG recommendations, conclusions and action items, and ensuring follow-up; and communicating with relevant MFish managers.

27. The Chair is responsible for facilitating consultative and collaborative discussions.

Decision-making

28. The Chair is responsible for working towards an agreed view of the RAG members on their recommendations to the fisheries manager, but where that proves not to be possible then the Chair is responsible for determining the final recommendation. Minority views should be clearly represented in proposals in those cases.

29. A record of recommendations, conclusions and action items will be circulated by e-mail after each meeting by the Chair.

30. Each RAG round will be evaluated by MFish, with a view to identifying opportunities to improve the process. The Terms of Reference may be updated as part of this review.

Non-disclosure agreements

31. Participants may be asked to sign a Non-Disclosure Agreement relating to documents that disclose cost details.

Conflicts of Interest

32. New Zealand is a small country and fisheries research is a relatively limited market, even internationally. People with the necessary skills and knowledge to participate in this advisory process may also have close working relationships with industry, research providers and other stakeholders. This will apply to nearly all external members of a RAG.

33. Participants will be asked to declare any “actual, perceived or likely conflicts of interest” before involvement in a RAG is approved, and any new conflicts that arise during the process should be declared immediately. These will be clearly documented by the Chair.

34. Management of conflicts of interest will be determined by the Chair in consultation with Fisheries Managers, and approved by the Deputy Chief Executive, Fisheries Management prior to meetings commencing.

Frequency of Meetings

35. Relevant MFish managers, in consultation with the Chair of the RAG, will decide on the frequency and timing of RAG meetings.

Documents and record-keeping

36. Unless signalled by the Chair, all RAG documents (papers, agendas, formal records of recommendations, conclusions and action items) will be available to all interested parties through the Ministry of fisheries website (www.fish.govt.nz), except where confidentiality is required for reasons of commercial sensitivity (e.g. cost estimates).

37. RAG documents will be distributed securely.

38. Participants who use RAG papers inappropriately may not be invited to subsequent RAG meetings.

39. The overall responsibility for record-keeping rests with the Chair and includes:

- Records of recommendations, conclusions and follow-up actions for all RAG meetings and to ensure that these are available in a timely manner.
- If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

16.6 FISHERIES 2030

USE OUTCOME – Fisheries resources are used in a manner that provides the greatest overall economic, social, and cultural benefit. This means having:

- An internationally competitive and profitable seafood industry that makes a significant contribution to our economy
- High-quality amateur fisheries that contribute to the social, cultural, and economic well-being of all New Zealanders
- Thriving customary fisheries, managed in accordance with kaitiakitanga, supporting the cultural well-being of iwi and hapū
- Healthy fisheries resources in their aquatic environment that reflect and provide for intrinsic and amenity value.

GOVERNANCE CONDITIONS – Fundamental to achieving our goal is the recognition that our approach must be based on sound governance. This means having arrangements that lead to:

- The Treaty partnership being realised through the Crown and Māori clearly defining their respective rights and responsibilities in terms of governance and management of fisheries resources
- The public having confidence and trust in the effectiveness and integrity of the fisheries and aquaculture management regimes
- All stakeholders having rights and responsibilities related to the use and management of fisheries resources that are understood and for which people can be held individually and collectively accountable
- Having an enabling framework that allows stakeholders to create optimal economic, social, and cultural value from their rights and interests
- An accountable, responsive, dynamic, and transparent system of management.

Fisheries 2030 draws on a number of values and principles. These seek to outline the behaviour and approach that should be used to undertake the actions, make decisions, and achieve the goal for New Zealand fisheries.

VALUES

- Tikanga: the Mäori way of doing things; correct procedure, custom, habit, lore, method, manner, rule, way, code, meaning, reason, plan, practice, convention. It is derived from the word tika meaning ‘right’ or ‘correct’.
- Kaitiakitanga: The root word in kaitiakitanga is tiaki, which includes aspects of guardianship, care, and wise management. Kaitiakitanga is the broad notion applied in different situations.
- Kotahitanga: Collective action and unity.
- Manaakitanga: Manaakitanga implies a duty to care for others, in the knowledge that at some time others will care for you. This can also be translated in modern Treaty terms as “create no further grievances in the settlement of current claims”.
- Integrity: Be honest and straightforward in our dealings with one another. If we agree to do something we will carry it out.
- Respect: Treat each other with courtesy. We will respect each other’s right to have different values and hold different opinions.
- Constructive relationship: Strive to build and maintain constructive ways of working with each other, which can endure.
- Achieving results: Focus on producing a solution rather than just discussing the problem.

PRINCIPLES

- Ecosystem-based approach: We apply an ecosystem-based approach to fisheries management decision-making.

- Conserve biodiversity: Use should not compromise the existence of the full range of genetic diversity within and between species.
- Environmental bottom lines: Biological standards define the limits of extraction and impact on the aquatic environment.
- Precautionary approach: Particular care will be taken to ensure environmental sustainability where information is uncertain, unreliable, or inadequate.
- Address externalities: Those accessing resources and space should address the impacts their activities have on the environment and other users.
- Meet Settlement obligations: Act in ways that are consistent with the Treaty of Waitangi principles and deliver settlement obligations.
- Responsible international citizen: Manage in the context of international rights, obligations, and our strategic interests.
- Inter-generational equity: Current use is achieved in a manner that does not unduly compromise the opportunities for future generations.
- Best available information: Decisions need to be based on the best available and credible biological, economic, social, and cultural information from a range of sources.
- Respect rights and interests: Policies should be formulated and implemented to respect established rights and interests.
- Effective management and services: Use least-cost policy tools to achieve objectives where intervention is necessary and ensure services are delivered efficiently.
- Recover management costs for the reasonable expenses of efficiently provided management and services, from those who benefit from use, and those who cause the risk or adverse effect.
- Dynamic efficiency: Frameworks should be established to allow resources to be allocated to those who value them most.

Fisheries 2030 includes a "plan of action" for the five years from 2009, including: improving the management framework; supporting aquaculture and international objectives; ensuring sustainability of fish stocks; improving fisheries information; building sector leadership and capacity; meeting obligations to Māori; and enabling collective management responsibility. The key components guiding this document are ensuring sustainability of fish stocks and improving fisheries information:

ENSURING SUSTAINABILITY OF FISH STOCKS

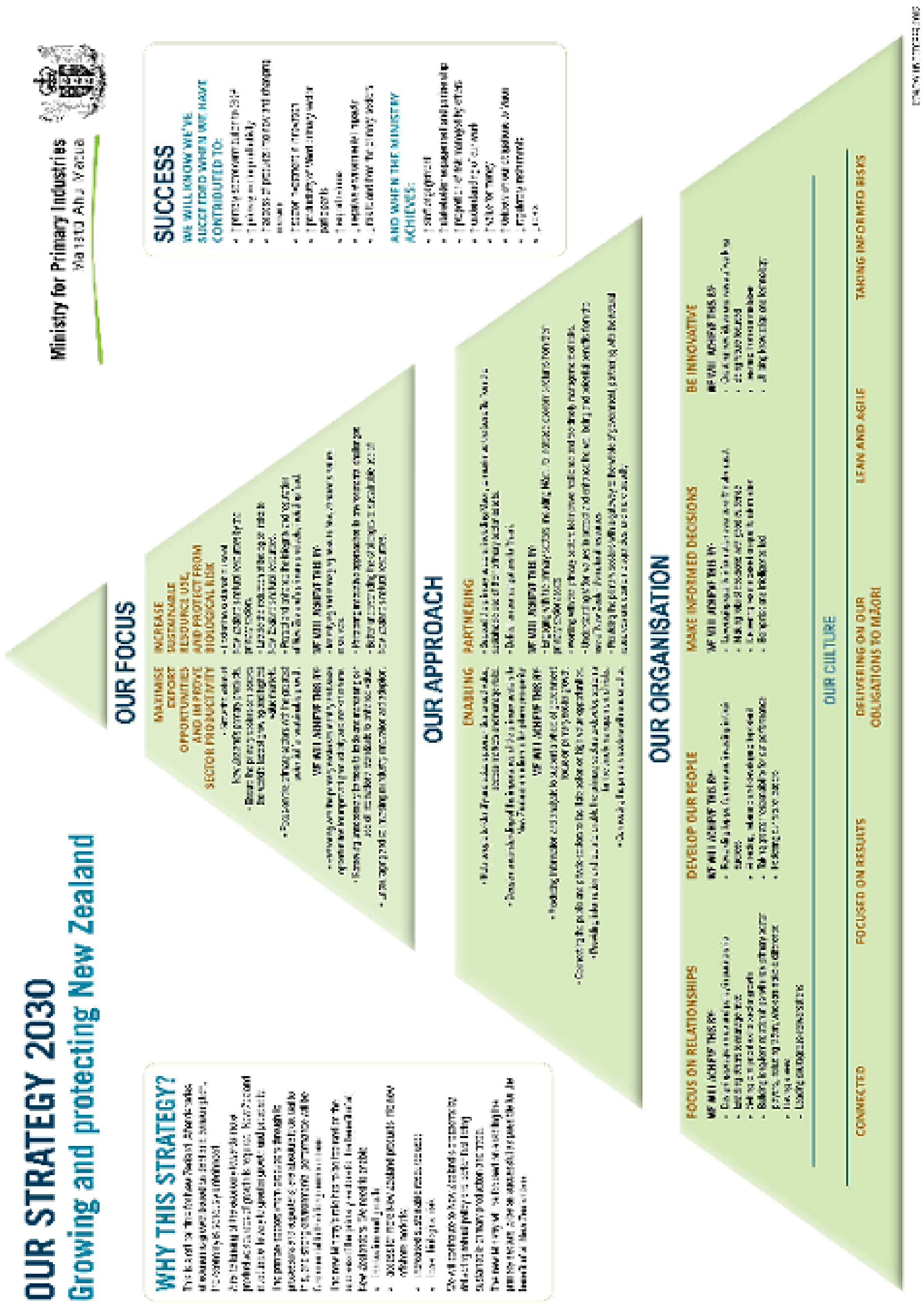
- Setting and implementing fisheries harvest strategy standards
- Setting and monitoring environmental standards, including for threatened and protected species and seabed impacts
- Enhancing the framework for fisheries management planning, including the use of decision rules to adjust harvest levels over time

IMPROVING FISHERIES INFORMATION

- Determining best options for information collection on catch from amateur fisheries, including the implementation of charter boat reporting
- Improving our knowledge of fish stocks and the environmental impacts of fishing through long-term research plans
- Gaining access to increased research and development funding

16.7 OUR STRATEGY 2030: GROWING AND PROTECTING NEW ZEALAND

Also available at: http://www.mpi.govt.nz/Portals/0/Documents/about-maf/strategy.pdf



16.8 OTHER STRATEGIC POLICY DOCUMENTS

16.8.1 BIODIVERSITY STRATEGY

New Zealand's Biodiversity Strategy was launched in 2000 in response to the decline of New Zealand's indigenous biodiversity — described in the State of New Zealand's Environment report as our "most pervasive environmental issue". It can be found on the government's biodiversity website at:

(http://www.biodiversity.govt.nz/picture/doing/nzbs/contents.html)

The Strategy also reflects New Zealand's commitment, through ratification of the international Convention on Biological Diversity, to help stem the loss of biodiversity worldwide. Strategic Priority 7 of the strategy was "To manage the marine environment to sustain biodiversity". Fishing practices, the effects of activities on land, and biosecurity threats are identified as constituting the areas of greatest risk to marine biodiversity. Pertinent objectives and summarised actions from the strategy are as follows:

Objective 3.1: Improving our knowledge of coastal and marine ecosystems (Substantially increase our knowledge of coastal and marine ecosystems and the effects of human activities on them, especially assessing the importance of, and threats facing, marine biodiversity, and establishing environmental monitoring capabilities to assess the effectiveness of measures to avoid, remedy or mitigate impacts on marine biodiversity).

Objective 3.4: Sustainable marine resource use practices (Protect biodiversity in coastal and marine waters from the adverse effects of fishing and other coastal and marine resource uses, especially maintaining harvested species at sustainable levels, integrating marine biodiversity protection into an ecosystem approach, applying a precautionary approach, identifying marine species and habitats most sensitive to disturbance, and integrating environmental impact assessments into fisheries management decision making.)

Objective 3.6: Protecting marine habitats and ecosystems (Protect a full range of natural marine habitats and ecosystems to effectively conserve marine biodiversity, using a range of appropriate mechanisms, including legal protection, especially establishing a network of areas that protect marine biodiversity.)

Objective 3.7: Threatened marine and coastal species management (Protect and enhance populations of marine and coastal species threatened with extinction, and prevent additional species and ecological communities from becoming threatened.)

In addition to its annual reviews (http://www.biodiversity.govt.nz/news/publications/index.html), the Biodiversity Strategy was reviewed by Green and Clarkson at the end of its 5-year term. This review was published in 2006 (http://www.biodiversity.govt.nz/pdfs/nzbs-5-year-review-synthesis-report.pdf). Most relevant to this synopsis were their findings on Objective 3.4 (Sustainable marine resource use) where they cited "Moderate progress". *"The policy move towards adopting a more ecosystem approach to fisheries management should be encouraged and strengthened. We acknowledge, however, the difficulties associated with obtaining the necessary information to make this approach effective. There are links to Objective 3.1 and the need for a more coordinated approach to identifying priority areas for marine research."*

16.8.2 BIOSECURITY STRATEGY

In its 2003 Biosecurity Strategy, The Ministry of Agriculture and Forestry's Biosecurity NZ defined biosecurity as "the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health". New Zealand is highly dependent on effective biosecurity measures because our indigenous flora, fauna, biodiversity, and, consequently, our primary production industries, including fisheries are uniquely at risk from invasive species. Information can be found on the Biosecurity New Zealand website at: (http://www.biosecurity.govt.nz/biosec/sys/strategy/biostrategy/biostrategynz (noting that MAF-BNZ is part of the Ministry of Agriculture and Forestry and will be merged with the Ministry of Fisheries in 2011 so this URL may change). A complementary Biosecurity Science Strategy for New Zealand was developed in 2007 to address the science expectations of the Biosecurity Strategy. The science strategy identified the need to:

- prioritise science needs;

- minimise biosecurity risks at the earliest stage possible by increasing focus on research that is strategic and proactive;
- improve planning, integration and communication in the delivery of science;
- ensure research outputs can be used effectively to improve biosecurity operations and decision making.

16.8.3 MARINE PROTECTED AREAS POLICY

The Marine Protected Areas (MPA) Policy and Implementation Plan was released for consultation in December 2005 jointly by the Ministry of Fisheries and Department of Conservation. It confirmed Government's commitment to ensuring that New Zealand's marine biodiversity was protected, and established MPA Policy as a key component of that commitment. The MPA Policy objective is to protect marine biodiversity by establishing a network of Marine Protected Areas that is comprehensive and representative of New Zealand's marine habitats and ecosystems. The Policy involved a four-stage approach to implementation:

Stage 1: Development of the approach to classification, formulation of a standard of protection, and mapping of existing protected areas and/or mechanisms. Scientific workshops will be used to assist with the process, and the results will be put on the website for comment

Stage 2: Development of the MPA inventory, identification of gaps in the MPA network, and prioritisation of new MPAs

Stage 3: Establishment of new MPAs to meet gaps in the network. This will be undertaken at a regional level and a national process will be followed for offshore MPAs

Stage 4: Evaluation and monitoring.

Stage 1 and the inventory specified for Stage 2 are complete and regional forums were established for the Subantarctic and West Coast bioregions.

The link for the stage 2 report is at:

http://www.doc.govt.nz/publications/conservation/marine-and-coastal/marine-protected-areas/coastal-marine-habitats-and-marine-protected-areas-in-the-new-zealand-territorial-sea-a-broad-scale-gap-analysis/

In June 2009, these planning forums released consultation documents on implementation of the MPA Policy in their bioregions:

Consultation Document - Implementation of the Marine Protected Areas Policy in the Territorial Seas of the Subantarctic Biogeographic Region of New Zealand:

http://www.biodiversity.govt.nz/pdfs/seas/subantarctics-mpa-policy-consultation-document.pdf

Proposed Marine Protected Areas for the South Island's West Coast Te Tai o Poutini: A public consultation document:

http://www.westmarine.org.nz/documents/ProposedMPAsWestCoastSubmissiondocumentwebresv2.pdf

The MPA Classification, Protection Standard, Implementation Guidelines, together with a summary of subsequent consultation processes around implementing the policy can be found on the Government Biodiversity website at:

http://www.biodiversity.govt.nz/seas/biodiversity/protected/mpa_consultation.html

16.8.4 REVISED COASTAL POLICY STATEMENT

The revised New Zealand Coastal Policy Statement (NZCPS) came into force in December 2010, replacing the original 1994 NZCPS. The statement is to be applied, as required by the Resource Management Act 1991 (RMA), by persons exercising functions and powers under that Act. The documentation can be read on the Department of Conservation's website at:

http://www.doc.govt.nz/publications/conservation/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/

The NZCPS does not directly apply to fisheries management decision-making, although the Minister of Fisheries is required to have regard to the Statement when making decisions on sustainability measures under section 11 of the Fisheries Act. In addition, this synopsis include chapters on land use issues and habitats of particular significance for fisheries management for which the main threats are managed under the RMA (e.g., land use practices could increase sedimentation and affect the estuarine nursery grounds of important fishstocks). In other areas, management of effects under the RMA can complement management of the effects of fishing (e.g., complementary management of the habitat and bycatch of a protected species). The following objectives and policies are considered relevant (numbering as per NZCPS, text in parentheses summarises subheadings in the Statement of most relevance to fisheries values):

Objective 1: To safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries, dunes and land (especially by maintaining or enhancing natural biological and physical processes in the coastal environment).

Objective 6: To enable people and communities to provide for their social, economic, and cultural wellbeing and their health and safety, through subdivision, use, and development (especially by recognising that the protection of habitats of living marine resources contributes to social, economic and cultural wellbeing and that the potential to utilise coastal marine natural resources should not be compromised by activities on land).

Policy 5: Land or waters managed or held under other Acts (especially to consider effects on coastal areas held or managed under other Acts with conservation or protection purposes and to avoid, remedy or mitigate adverse effects of activities in relation to those purposes).

Policy 8: Aquaculture: Recognise the significant existing and potential contribution of aquaculture to the social, economic and cultural well-being of people and communities (especially by taking account of the social and economic benefits of aquaculture, recognising the need for high water quality, and including provision for aquaculture in the coastal environment).

Policy 11: Indigenous biodiversity: To protect indigenous biological diversity in the coastal environment (especially by avoiding, remedying or mitigating adverse effects on: habitats that are important during the vulnerable life stages of indigenous species; ecosystems and habitats that are particularly vulnerable to modification; and habitats of indigenous species that are important for recreational, commercial, traditional or cultural purposes).

Policy: 21 Enhancement of water quality: Where the quality of water in the coastal environment has deteriorated so that it is having a significant adverse effect on ecosystems, natural habitats, or water based recreational activities, or is restricting existing uses, such as aquaculture, shellfish gathering, and cultural activities, give priority to improving that quality.

Policy 22: Sedimentation (especially with respect to impacts on the coastal environment).

Policy 23: Discharge of contaminants (especially with respect to impacts on ecosystems and habitats).

16.8.5 MANAGEMENT OF ACTIVITIES IN THE EEZ

Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. The Act manages the environmental effects of activities in New Zealand's oceans. The legislation aims to protect our oceans from the potential environmental risks of activities like petroleum exploration activities, seabed mining, marine energy generation and carbon capture developments.

The Resource Management Act regulates natural resource management activities on land and in the territorial sea out to 12 nautical miles. Fishing and shipping are also regulated by other Acts. The EEZ Act does not override these other controls that already exist in the EEZ. Beyond 12 nautical miles New Zealand has historically had no means to assess and regulate the environmental effects of many other activities. The EEZ Act fills that regulatory gap and manages the previously unregulated adverse environmental effects of activities in the EEZ and continental shelf. Before the EEZ Act was passed there was a gap in our domestic legislation.

The EEZ Act sets up a framework for managing the effects of activities in the EEZ and continental shelf. The text of the Act can be found on the New Zealand Legislation website.

The EEZ legislation to manage effects other than those caused by fishing do not directly apply to fisheries management decision-making under the Fisheries Act. However, there are issues around the management of cumulative effects (e.g., of more than one activity on benthic communities) and around effects of any proposed new activities in the EEZ on fishing activity already occurring. Some projects already completed or currently underway are likely to be useful for these processes (e.g., detailed maps of fishing effort produced under ENV2001/07 and BEN2006/01 and enhancements of the Marine Environment Classification produced under ZBD2005-02 for demersal fishes and BEN2006/01A for benthic invertebrates).

16.8.6 NATIONAL PLAN OF ACTION TO REDUCE THE INCIDENTAL CATCH OF SEABIRDS IN NEW ZEALAND FISHERIES

New Zealand released its first National Plan of Action (NPOA) to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries in April 2004. That document is available online at:

http://www.doc.govt.nz/documents/conservation/native-animals/birds/npoa.pdf

or

http://www.fish.govt.nz/NR/rdonlyres/5618E7BB-CE01-4865-9E99-1B891F95FB2A/0/NZNPOASeabirds2004.pdf

A completely revised and refreshed NPOA-Seabirds was released in March 2013. A resources page was added to the MPI (Fisheries) website to provide access to this plan, its supporting risk assessment documents, a web-based reporting system for protected species captures, and information on MPI's fisheries planning processes that will be the vehicle for implementation:

http://www.fish.govt.nz/en-nz/Environmental/Seabirds/default.htm

The 2013 NPOA-Seabirds can be found at:

http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1760

The 2013 NPOA covers all New Zealand fisheries and has a long-term objective that *"New Zealand seabirds thrive without pressure from fishing related mortalities, New Zealand fishers avoid or mitigate against seabird captures and New Zealand fisheries are globally recognised as seabird friendly."*

There are high-level subsidiary objectives related to practical aspects, biological risk, research and development, and international issues.

i. Practical objective: All New Zealand fishers implement current best practice mitigation measures relevant to their fishery and aim through continuous improvement to reduce and where practicable eliminate the incidental mortality of seabirds.
ii. Biological risk objective: Incidental mortality of seabirds in New Zealand fisheries is at or below a level that allows for the maintenance at a favourable conservation status or recovery to a more favourable conservation status for all New Zealand seabird populations.
iii. Research and Development objectives:
    a. the testing and refinement of existing mitigation measures and the development of new mitigation measures results in more practical and effective mitigation options that fishers readily employ;
    b. research and development of new observation and monitoring methods results in improved cost effective assurance that mitigation methods are being deployed effectively; and
    c. research outputs relating to seabird biology, demography and ecology provide a robust basis for understanding and mitigating seabird incidental mortality.
iv. International objective: In areas beyond the waters under New Zealand jurisdiction, fishing fleets that overlap with New Zealand breeding seabirds use internationally accepted current best practice mitigation measures relevant to their fishery.

16.8.7 NEW ZEALAND NATIONAL PLAN OF ACTION FOR THE CONSERVATION AND MANAGEMENT OF SHARKS

The New Zealand National Plan of Action (NPOA) for the Conservation and Management of Sharks (2013) was approved by the Minister of Fisheries on 9 January 2014. The purpose of the NPOA-Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. It also contains a set of actions in order to meet this purpose. The document is available online at:

http://www.fish.govt.nz/en-nz/Environmental/Sharks/default.htm.

16.8.8 NATIONAL SCIENCE CHALLENGES

The National Science Challenges were conceived to tackle some of the biggest science-based issues and opportunities facing New Zealand. They were designed to take a more strategic approach to the government's science investment by targeting a series of goals, which, if achieved, would have major and enduring benefits for New Zealand. The Challenges provide an opportunity to align and focus New Zealand's research on large and complex issues by drawing scientists together from different institutions and across disciplines to achieve a common goal through collaboration.

Many of the issues facing New Zealand require new knowledge obtained through science and research. The Government has launched the Challenges to provide a means to address the most pressing of these complex issues. The Challenges will seek answers to questions of national significance to New Zealand by focusing effort and providing additional focus on key areas. The Challenges provide an opportunity to identify which issues are most important to New Zealand and will allow Government to take a targeted, cross-government approach to addressing them.

Each Challenge includes both new funding and funds that will become available as current MBIE research contracts mature. Relevant CRI core funding will also be invested in Challenges, where CRIs are part of a Challenge collaboration. The new Challenge money comprises $73.5 million over four years in Budget 2013, in addition to the $60 million allocated in Budget 2012, and $30.5 million per year thereafter.

The eleven research areas identified for National Science Challenge funding (asterisks mark those Challenges potentially relevant to fisheries and the marine environment) were:

1. High Value Nutrition
2. The Deep South *
3. New Zealand's Biological Heritage *
4. Sustainable Seas *
5. A Better Start
6. Resilience to Nature's Challenges *
7. Science for Technological Innovation
8. Ageing Well
9. Healthier Lives
10. Our Land and Water *
11. Building Better Homes, Towns and Cities

See also: http://www.msi.govt.nz/update-me/major-projects/national-science-challenges/.

The Ministry for Business, Innovation and Employment administers the Challenges and issued Requests for Proposals for four of the Challenges in October 2013 and for the remainder in February 2014. Given that the Challenges represent a radically different approach to research in New Zealand, and required substantial collaboration between science organisations, it is perhaps not surprising that designing and contracting the work has taken some time. The following Challenges of relevance to fisheries and marine systems have been launched (as at December 2014, listed in order of their launch):

The Deep South — Te Kōmata o Te Tonga — was launched on 5 August 2014 with a headline of *Understanding the role of the Antarctic and the Southern Ocean in determining our climate and our future environment*. The mission of this Challenge is to transform the way New Zealanders adapt, manage risk, and thrive in a changing climate. Working with communities and industry we will bring together new research approaches to determine the impacts of a changing climate on our climate-sensitive economic sectors, infrastructure and natural resources to guide planning and policy. This will be underpinned by improved knowledge and observations of climate processes in the Southern Ocean and Antarctica - our Deep South - and will include development of a world-class earth systems model to predict Aotearoa/New Zealand's climate. Further information can be found at: http://www.deepsouthchallenge.co.nz/.

New Zealand's Biological Heritage — Ngā Koiora Tuku Iho — was launched on 29 August 2014 with a headline of *Protecting and managing our biodiversity, improving our biosecurity, and enhancing our resilience to harmful organisms*. This Challenge does not consider marine systems as such, but includes estuarine systems and close liaison between this Challenge and Sustainable Seas will be necessary to ensure important biological systems and processes are covered. Further information can be found at: http://www.biologicalheritage.org.nz/.

Sustainable Seas — Ko ngā moana whakauka — was launched on 4 September 2014 with a headline of *Enhance utilisation of our marine resources within environmental and biological constraints*. The aim of this Challenge is to enhance use of New Zealand's vast marine resources, while ensuring that our marine environment is understood, cared for, and used wisely for the benefit of all, now and in the future. This requires a new way of managing the many uses of our marine resources that combines the aspirations and experience of Māori, communities, and industry with the evidence of scientific research to transform New Zealand into a world-leader in sustainable marine economic development. Thus, this is the Challenge most closely associated with fisheries management. Further information can be found at: http://sustainableseaschallenge.co.nz/.

16.9 APPENDIX OF AQUATIC ENVIRONMENT AND BIODIVERSITY FUNDED AND RELATED PROJECTS

The following listing of projects are those relevant to aquatic environment research that have been through research planning and subsequently been funded by the Ministry of Fisheries (MFish), the Ministry for Primary Industries (MPI) or the fishing industry. These projects have been ordered by the research themes:

1. Protected species (PRO)
2. Non-protected bycatch (NPB)
3. Benthic impacts (BEN)
4. Ecosystem effects (ECO)
5. Biodiversity (BIO)

Within these themes projects are ordered chronologically (from the most recent to the oldest). A list of references cited within the table is included at the end of this appendix.

Each project or row of the table is described by a project number (used by MFish/MPI), a project title, specific objectives (where there are many objectives and some are clearly not relevant to aquatic environment research they may not be listed), project status and any relevant citations from the project.

Citations listed below can be accessed differently depending upon the type of output. Finalised FARs (Fisheries Assessment Reports) and AEBRs (Aquatic Environment and Biodiversity Reports), historical FARDs (Fisheries Assessment Research Documents) and MMBRs (Marine Biodiversity and Biosecurity Reports), and some FRRs (final Research Reports) can be found at: http://fs.fish.govt.nz/Page.aspx?pk=61&tk=209. Increasingly, reports will be available from the MPI website at: http://www.mpi.govt.nz/news-resources/publications. For unpublished documents or those not available on either of these websites please contact Science.Officer@mpi.govt.nz. Every attempt has been made to make this table comprehensive and correct, but if any errors are found please send suggested corrections or additions through to Science.Officer@mpi.govt.nz

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2014-06	Update of level-2 seabird risk assessment	1. To update the level-2 seabird risk assessment using all new information on bird population size, productivity, and distribution, and all relevant fishing effort and observer data for the 2009/10 to 2013/14 fishing years. 2. To identify key drivers of uncertainty and opportunities to reduce uncertainty in the risk ratios for species at high or very high risk. 3. To participate in, and provide data for, a workshop to review the findings relative to other available data and results. 4. To update the level-2 seabird risk assessment using all new information on bird population size, productivity, and distribution, and all relevant fishing effort and observer data for the 2010/11 to 2014/15 fishing years. 5. To identify key drivers of uncertainty and opportunities to reduce uncertainty in the risk ratios for species at high or very high risk.	Will be commissioned early in 2015	
PRO	ENV2014-01	NPOA-sharks: comprehensive risk assessment	Yet to be decided.	In development	
PRO	PRO2014-03	Research in response to advice from the Maui's dolphin research advisory group	1. To be developed through the MRAG process	In development	
PRO	PRO2014-02	Risk assessment modelling for fishing-related mortality of sea lions to underpin the TMP	1. To review existing models of New Zealand sea lions that have been used to estimate key demographic rates and their variability 2. Based on the results of Objective 1, develop an operating model of the Auckland Island population of New Zealand sea lions suitable for use in management strategy evaluation 3. To use a management strategy evaluation to assess the risk posed by commercial fishing to New Zealand sea lions, including assessing the likely performance of candidate management approaches against current or agreed performance criteria 4. To extend the modelling to other populations and risks as information permits	Ongoing analysis	
PRO	PRO2014-05	Reducing uncertainty in biological components of the risk assessments for at-risk seabird species	1. Species, population, and information requirements to be determined based on the prioritisation procedures in the NPOA-seabirds and the table of priorities from the outputs of the review workshop	Partially contracted as a contribution to work on black petrel	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2014-01	Improving information on the distribution of key protected species	1. To produce an agreed list of seabird and marine mammal species for inclusion and compile all available spatial data for these species. 2. To model and map the distribution of the species identified in objective 1 from available spatial data, reflecting any temporal changes (seasonality or trends). 3. To refine the results of the mapping for priority species by developing and implementing predictive habitat distribution models.	Uncertain	
PRO	ENV2014-02	NPOA-sharks: age and growth of selected at-risk species	1. To estimate basic biological parameters for high risk, high uncertainty chondrichthyans.	Approved but not contracted	
PRO	ENV2014-09	Spatial decision support tools for multi-use and cumulative effects	1. To be developed, depending on the delivery mechanism and focus finalised for this work.	Uncertain	
PRO	SEA2012-22	Surface long line mitigation trials	1. Surface long line mitigation trials	Completed	
PRO	SEA2013-06	Black Petrel Distribution Modelling	1. To use the best available information to develop a spatial and seasonal distribution of black petrel, in New Zealand waters.	Completed	
PRO	SEA2013-14	Re-Run of Level-2 Seabird Risk Assessment 2014	1. To provide an update of the Seabird Risk Assessment, including observer and fisheries data to the end of the 2012/13 fishing year.	Completed	Richard & Abraham Submitted
PRO	SEA2013-08	Data preparation for protected species bycatch estimation	1. Groom catch effort, observer, and protected species capture data 2. Provide web-based interface to allow exploration, display, and reporting on the data	Completed: preparation for PRO2013-01	
PRO	PRO2013-01	Protected species capture estimation	1. To estimate capture rates and total captures of seabirds, marine mammals, turtles, and protected fish species by method, area, and target fishery, and where possible, by species for the fishing years 2012/13, 2013/14 and 2014/15. 2. To estimate factors associated with the capture of seabirds and marine mammals. 3. To estimate, where possible, the nature and rate of warp strike incidents and total number of seabirds affected.	Ongoing analysis	
PRO	SEA2013-06	Black petrel distribution modelling	1. Generate fine-scale spatial distribution data layers that vary on seasonal basis to reflect known or presumed seasonal movements and habitat utilization patterns for black petrel. 2. Generate seasonally disaggregated maps and numerical estimates of overlap between species distributions and fishing effort.	Completed	Abraham & Richard In Press

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2013-06	Abundance and distribution of WCSI Hector's dolphins	1. To develop and refine designs and methods for summer and winter aerial surveys for Hector's dolphins along the WCSI consistent with the recent ECSI surveys. 2. To estimate the abundance of Hector's dolphins along the WCSI in summer 2013/14 applying an agreed aerial survey methodology. 3. To estimate the distribution of Hector's dolphins along the WCSI in summer 2013/14 applying an agreed aerial survey methodology. 4. To estimate the abundance of Hector's dolphins along the WCSI in winter 2014 applying an agreed aerial survey methodology. 5. To estimate the distribution of Hector's dolphins along the WCSI in winter 2014 applying an agreed aerial survey methodology.	Ongoing analysis	
PRO	PRO2013-08	Reanalysis of Hector's dolphin line transect aerial survey data	1. To collate sightings and effort data for all Hector's dolphin aerial surveys that applied different approaches to estimating the detection function. 2. To assess the impact of different approaches to estimating the detection function on estimates of abundance and distribution and develop correction factors. 3. To reanalyse all relevant survey data to estimate Hector's dolphin abundance and distribution applying the agreed approach to estimating the detection function	Included in PRO2013-06	
PRO	PRO2013-13	Global seabird risk assessment (for New Zealand species)	1. Evaluate relative exposure to commercial fisheries at a global scale for New Zealand seabird populations applying a seasonally-disaggregated spatial overlap approach (i.e. accessing global seabird spatio-temporal distribution data and compiling comprehensive global fisheries effort databases) for different categories of fishing effort. 2. Apply estimates of population PBR (from the updated NZ-EEZ seabird risk assessment, including uncertainty) and species- or guild-specific estimates of seabird Vulnerability (i.e. as estimated in the updated NZ-EEZ seabird risk assessment, modified to the extent possible by data indicative of relative seabird bycatch rates in comparable fishing effort inside vs. outside the New Zealand EEZ, including uncertainty) to estimate global fisheries risk for New Zealand seabird populations. 3. For each New Zealand seabird population estimate what proportion of global fisheries risk is attributable to mortalities occurring inside vs. outside the NZ-EEZ, and what proportion is likely to be unaccounted for in the analysis (e.g. due to incomplete global fisheries data or risk from IUU fishing). 4. For that portion of species risk outside the NZ-EEZ, summarize the source of that risk to the extent possible, for example by RFMO (or other relevant management agency), and by fishery group, geographic area, season, vessel size, and other relevant categories.	Will be commissioned early in 2015	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2013-17	Repeat quantitative modelling of southern Buller's albatross	1. To update the fully quantitative population model of southern Buller's albatross to assess population trend and key demographic rates for this population. 2. To use the model to predict future trends assuming recent average demographic rates.	Ongoing analysis	
PRO	PRO2013-18	Authoritative Sea Lion Capture List	To produce a definitive data set of New Zealand sea lion captures and to reconcile data from the different sources, and resolve any discrepancies.	Completed	Thompson *et al.* In Press
PRO	No project number	A risk assessment of threats to Maui's dolphins	To evaluate of the risks posed to Maui's dolphin to support the review of the TMP.	Completed	Currey *et al.* 2012
PRO	PRO2012-02	Assessment of the risk to marine mammal populations from New Zealand commercial fisheries	1. To scope the risk assessment, including producing an agreed list of marine mammal populations (in concert with MAF and DOC). 2. To review the literature, compile the required information and evaluate the appropriate level of risk assessment for the marine mammal populations identified in objective 1. 3. To conduct a risk assessment for the marine mammal populations identified in objective 1 using, where possible, a risk index reflecting the ratio of fisheries-related mortality to the level of potential biological removal. 4. To refine the results of the risk assessment for priority marine mammal populations by incorporating spatially and temporally-explicit abundance, distribution and capture information.	Ongoing analysis	Berkenbusch *et al.* 2013
PRO	PRO2012-07	Cryptic mortality of seabirds in trawl and longline fisheries	1. To review available information from international literature and unpublished sources to characterize and inform estimation of cryptic mortality and live releases for at-risk seabirds in New Zealand trawl and longline fisheries 2. To review the extent to which fisheries observer data informing current estimates of seabird captures may be used to also estimate cryptic mortalities in different fishery groups in the seabird risk assessment, and identify key assumptions and associated uncertainty in the estimation of cryptic mortalities. 3. To identify those species and/or fishery groups for which current uncertainty regarding cryptic mortality contributes most strongly to high risk scores for at-risk seabird species, and recommend options to improve estimation of cryptic mortality for those species / fishery group combinations.	Contracted with DOC, Ongoing analysis	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2012-08	Improved estimation of spatio-temporal overlap with fisheries for at-risk seabird species	1. To generate seabird distribution map layers for seabird species which the existing level 1 risk assessment identifies as being at-risk, but for which no level 2 assessment has been completed. 2. To modify seabird distribution layers used in the current level 2 risk assessment, for those species that the L2 assessment identifies as at-risk and for which: i) spatial distributions used in the current L2 assessment are known to be wrong, or ii) improved spatial distribution layers are readily available (e.g. from new satellite telemetry data). 3. To seasonally disaggregate seabird spatial distribution data layers for those at-risk seabird species with a strongly seasonal abundance and/or distribution in the New Zealand EEZ 4. To utilize updated spatial/seasonal seabird distribution layers to generate improved estimates of spatio-temporal overlap with fisheries, for integration into the existing level 2 seabird risk assessment framework.	Approved but not contracted	
PRO	PRO2012-09	Improvements to key information gaps for highest risk seabird populations TBC	1. To improve estimates of the population size of specified seabirds where this will substantially reduce uncertainty in the risk ratio estimated in the Level 2 seabird risk assessment. 2. To improve estimates of the age at first breeding for specified seabird populations where this will substantially reduce uncertainty in the risk ratio estimated in the Level 2 seabird risk assessment. 3. To improve estimates of the average adult survival rate for specified seabird populations where this will substantially reduce uncertainty in the risk ratio estimated in the Level 2 seabird risk assessment.	Approved but not contracted	
PRO	PRO2012-10	Level 3 risk assessment for Antipodean albatross TBC	1. Develop an Antipodean albatross population model 2. Assess the effect of fisheries mortality on population viability 3. As information permits, assess the effect of alternative management strategies	Ongoing analysis	
PRO	SRP2011-03	Probabilistic modelling of sea lion interactions	1. Estimate the probability that a sea lion suffers mild head trauma following a collision with a SLED grid	Completed	Abraham 2011
PRO	SRP2011-04	HSL Modelling	1. Revise Breen-Fu-Gilbert sea lion model	Completed	Breen *et al.* 2010
PRO	ENV2011-01	NPOA-sharks science review	1. To collate and summarise information in support of a review of the National Plan of Action for the Conservation and Management of Sharks (NPOA-sharks). 2. To identify research gaps from objective 1 and suggest cost-effective ways these could be addressed.	Completed	Francis & Lyon 2012; Francis & Lyon 2013

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2010-01	Estimating the nature and extent of incidental captures of seabirds, marine mammals and turtles in New Zealand commercial fisheries	1. To estimate the nature and extent of captures of seabirds, marine mammals and turtles, and the warp strikes of seabirds in New Zealand fisheries for the fishing years 2009/10, 2010/11 and 2011/12.	Ongoing analysis	Thompson *et al.* 2012; 2013; Submitted; Richard & Abraham Submitted
PRO	PRO2010-02	Research into key areas of uncertainty or development of mitigation techniques for the revised NPOA-seabirds	1. To provide the information necessary to underpin the revised NPOA-seabirds or develop mitigation techniques to reduce risk identified via the revised NPOA-seabirds.	Completed	Richard & Abraham 2013a, b, c, Berkenbusch *et al.* 2013
PRO	DEE2010-03	Development of a methodology to estimate cryptic mortalities to ETP species from DW fishing activity	1. To conduct a review of existing national and international techniques to estimate cryptic mortality of endangered, threatened and protected species caused by deepwater fishing activities 2. To develop one or more approaches to estimating cryptic mortality of endangered, threatened and protected species caused by deepwater fishing activities 3. To field test one or more approaches to estimating cryptic mortality of endangered, threatened and protected species caused by deepwater fishing activities	Ongoing analysis	
PRO	No project number	A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ	To describe the conceptual and methodological framework of this risk assessment approach to guide the completion of similar risk assessments elsewhere.	Completed	Sharp *et al.* 2011
PRO	SRP2010-03	Fur Seal interactions with a SED excluder device	1. Fur seal interactions with SED excluder device (Dr J Lyle)	Completed	Lyle 2011

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	SRP2010-05	Fur seal interaction with an SLED excluder device	1 Using a series of 10-15 impact tests at a maximum collision speed of 5 or 6 ms-1, develop a “HIC map” for the SLED grid to enable the consequences of collisions with different parts of the grid by sea lions of different head masses to be predicted (scaling values (for eq 3) will include -1/3, -2/3, and -3/4) 2 Using a small number of collision tests, verify that the HIC for a glancing blow can be predicted with sufficient accuracy by resolving vectors 3 Calculate the maximum possible sensitivity to different boundary conditions using the relative masses of the SLED grid and sea lion heads 4 Clarify in the final research report that undertaking tests in air (as opposed to underwater) should not affect the results	Completed	Ponte et al. 2011
PRO	IPA2009-09	Sea Lion bioenergetics modelling	1. To review and collate data on growth, metabolism, diet and reproductive parameters of NZ sea lions or, if data are inexistent, of other sea lions species 2. To analyse the energy density of various NZ sea lion prey items 3. To incorporate the data acquired in objectives 1. and 2. into a bioenergetics model to estimate the energy and food requirements of NZ sea lions	Completed	Meynier 2010
PRO	IPA2009-16	Preliminary impact assessment of NZ sea lion interaction with SLEDS	1. Preliminary impact assessment of New Zealand sea lion interactions with SLEDs	Completed	Ponte *et al.* 2010
PRO	IPA2009-19/20	Level 2 seabird risk assessment rerun	1. To examine the risk of incidental mortality from commercial fishing for 64 seabird species in New Zealand trawl and longline fisheries	Completed	Richard *et al.* 2011
PRO	No project number	External review of NZ sea lion bycatch necropsy data and methods	The primary purposes of this review were to determine whether, in the opinion of a group of independent experts: - the interpretation of necropsy findings and trauma classification system used by Dr Wendi Roe are valid - sea lions recovered from trawl nets have sustained clinically significant trauma - some or all of the sea lions exiting through SLEDs are likely to survive	Completed	Roe 2010a
PRO	PRO2009-01A	Abundance & distribution of Hector's & Maui's dolphins (5 year project)	1. To estimate the distribution of the South Coast South Island Hector’s dolphin sub-population in both winter and summer. 2. The work for this sub-project was subsequently extended to include data collection necessary to estimate abundance.	Completed	Clement & Mattlin 2010

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2009-01B	Abundance, distribution, and productivity of Hector's (and Maui's) dolphins	1. To estimate the likely precision of abundance estimates from summer aerial surveys for Hector's dolphins along the East Coast South Island (ECSI; from Farewell Spit to Nugget Point) under different levels of sampling intensity and stratification. 2. To estimate the likely precision of abundance estimates and the likely quality of distribution information from winter aerial surveys for Hector's dolphins along the ECSI under different levels of sampling intensity and stratification. 3. To identify and quantify trade-offs between the precision of abundance estimates and the quality of distribution information as well as between overall precision and likely cost (e.g., based on the number of flying hours required). 4. To identify key areas and times for which it would be particularly useful to have information on Hector's dolphin distribution (e.g., where risk may come from overlap with particular fisheries) and quantify trade-offs between the precision of ECSI-wide surveys and collecting such fine-scale information. 5. Assess the extent to which two-phase or adaptive approaches would be useful to improve the surveys' utility for assessing dolphin distribution, particularly the seaward limit.	Completed	MacKenzie *et al.* 2013a; b
PRO	PRO2009-01C	Abundance, distribution and productivity of Hector's (and Maui's) Dolphins	1. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the abundance of Hector's dolphins along the ECSI in summer 2012/13 applying an agreed aerial survey methodology. 2. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the distribution of Hector's dolphins along the ECSI in summer 2012/13 applying an agreed aerial survey methodology. 3. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the abundance of Hector's dolphins along the ECSI in winter 2013 applying an agreed aerial survey methodology. 4. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the distribution of Hector's dolphins along the ECSI in winter 2013 applying an agreed aerial survey methodology.	Completed	MacKenzie & Celment 2014
PRO	PRO2009-04	Development and efficacy of seabird mitigation measures	1. To test the efficacy of a variety of configurations of mitigation techniques at reducing seabird mortality (or appropriate proxies for mortality) in longline fisheries	Completed	No reports specified as required output

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	ENV2008-03	Bycatch of basking sharks in New Zealand fisheries	1. To review the productivity of basking sharks 2. To describe the nature and extent of fishery-induced mortality of basking sharks in New Zealand waters and recommend methods of reducing the overall catch.	Completed	Francis & Smith 2010
PRO	PRO2008-01	Risk assessment of protected species bycatch in NZ fisheries	1. To provide an assessment of the risk posed by different fisheries to the viability of New Zealand protected species, and to assign a risk category to all New Zealand fishing operations.	Completed	Waugh *et al.* 2009
PRO	PRO2008-03	Necropsy of marine mammals captured in New Zealand	1. To necropsy marine mammals captured incidentally to New Zealand fishing operations in the SQU6T fishery during the 2008/09 fishing year to determine life-history characteristics such as sex- reproductive status and the likely cause of mortality- and to determine the species- and sex of captured animals returned for necropsy. 2. To determine- through examination of returned carcasses- the species- sex-reproductive status- and age-class of sea lions and fur seals captured in the SQU6T New Zealand fishery. 3. To detail any injuries and- where possible- the cause of mortality of sea lions and fur seals returned from New Zealand fisheries- and examine relationships between injuries and body condition- breeding status- and other associated demographic characteristics. 4. To review and collate data from previous NZ sea lion autopsy programmes.	Completed	Roe & Meynier 2012; Roe 2010b
PRO	SAP2008-14	Sea lion population modelling, additional	1. To assess the likely performance of different bycatch control rules for the SQU6T fishery. 2. To correct and update the Breen-Fu-Gilbert (2008) sea lion model- including assessment of the performance of 200-series and 300-series management control rules. 3. To document the development of the model- including all four objectives of project IPA2006/09 and objective 1 of this project- in a single report suitable for an international review.	Completed	Breen *et al.* 2010
PRO	Deepwater Group	Necropsy of marine mammals captured in New Zealand fisheries in the 2007-08 fishing year	Necropsy of marine mammals captured in New Zealand fisheries in the 2007-08 fishing year	Completed	Roe 2009a
PRO	IPA2007-09	Protected species risk assessment	To provide an assessment of the risk posed by different fisheries to the viability of NZ protected species- and to assign a risk category to all NZ fishing operations	Completed	Waugh *et al.* 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2007-01	Estimating the nature and extent of incidental captures of seabirds in New Zealand commercial fisheries	1. Estimate capture rates per unit effort and total captures of seabirds for the New Zealand EEZ and in selected fisheries by method, area, target fishery, in relation to mitigation methods in use, and, where possible, by seabird species for the fishing year 2006/07, 2007/08 and 2008/09. 2. Examine the incidence of seabird warp strike in trawl fisheries where these data are available from fisheries observers, and estimate the rate of incidents (birds affected per hour) and total number of seabirds affected by fishery, area and method. Examine the factors (fishery, environmental, seasonal, mitigation, area) that influence the probability of warp-strike occurring.	Completed	Abraham 2010; Abraham & Thompson 2009a; 2010; 2011a; b; Thompson & Abraham 2009a; Abraham et al. 2010b
PRO	PRO2007-02	Estimating the nature and extent of incidental captures of seabirds in New Zealand commercial fisheries	1. Estimate capture rates per unit effort and total captures of seabirds for the New Zealand EEZ and in selected fisheries by method, area, target fishery, in relation to mitigation methods in use, and, where possible, by seabird species for the fishing year 2006/07, 2007/08 and 2008/09. 2. Examine the incidence of seabird warp strike in trawl fisheries where these data are available from fisheries observers, and estimate the rate of incidents (birds affected per hour) and total number of seabirds affected by fishery, area and method. Examine the factors (fishery, environmental, seasonal, mitigation, area) that influence the probability of warp-strike occurring.	Completed	Abraham et al. 2010a; Thompson & Abraham 2009a; 2009b; 2009c; 2010; 2011; Thompson *et al.* 2010a; 2010b
PRO	ENV2006-05	The use of electronic monitoring technology in New Zealand longline fisheries	1. Trial the deployment of electronic monitoring systems in selected longline fisheries, monitoring incidental take of protected species. 2. Evaluate the efficacy of electronic monitoring in allowing enumeration and identification of protected species captures. 3. Recommend options for data management and information transfer arising from the deployment of electronic monitoring in selected fisheries.	Completed	McElderry *et al.* 2008
PRO	IPA2006-02	The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery	1. Groom the mitigation trial data and produce a summary of the data 2. Examine strike rates and capture rates on warps and mitigation devices 3. Determine the relative efficacy of mitigation devices tested in the trial 4. Make recommendations regarding future trials 5. Compare seabird warp strike data for 2005 and 2006 6. Work with SeaFIC and the mitigation trials TAG to produce analyses and outputs	Completed	Middleton & Abraham 2007

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	IPA2006-09	Modelling interactions between trawl fisheries and New Zealand Sea lion interactions	1. Model the New Zealand sea lion population and explore alternative management procedures for controlling New Zealand sea lion bycatch in the SQU 6T fishery 2. Collate and review all available sea lion biological data- fisheries data- and sea lion bycatch data relevant to a population model and management strategy evaluation for the Auckland Islands sea lion population 3. Update and improve the existing Breen and Kim sea lion population model (2003) to incorporate all relevant data and address model uncertainties including but not necessarily limited to those identified by the AEWG 4. Fit the revised model to all available data and test sensitivity including but not necessarily limited to runs identified by the AEWG 5. Test a range of management procedures (rules) with the model to determine if they meet agreed management criteria	Completed	Breen 2008
PRO	IPA2006-13	Identification of Marine Mammals Captured in New Zealand Fisheries	1. To determine, through examination of returned marine mammal carcasses, the species, sex, reproductive status, and age-class of marine mammals returned from New Zealand fisheries. 2. To detail any injuries and, where possible, the cause of mortality of marine mammals returned from New Zealand fisheries, and examine relationships between injuries and body condition, breeding status, and other associated demographic characteristics.	Completed	Roe 2009b
PRO	PRO2006-01	Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability	1 To gather demographic, distributional and dietary information on selected seabird species to allow assessment of effects of fishing on population viability.	Completed	Sagar & Thompson 2008; Sagar et al. 2009a; b; 2010a; b; c; Baker *et al.* 2008; 2009, 2010
PRO	PRO2006-02	Modelling of the effects of fishing on the population viability of selected seabirds	1. Model the effects of fisheries mortalities on population viability compared with other sources of mortality or trophic effects of fishing 2. Examine the overlap of fishing activity with species distribution at sea for different stages of the breeding and life-cycle and for different sexes, and assess the likely risk to species or populations from fisheries (by target species fisheries, fishing methods, area and season) in the New Zealand EEZ	Completed	Francis & Bell 2010, Francis 2012
PRO	PRO2006-04	Estimation of the nature and extent of incidental captures of seabirds in New Zealand commercial fisheries	1. To estimate the nature and extent of captures and warp-strikes of seabirds in New Zealand fisheries for the fishing year 2005/06.	Completed	Baird & Smith 2008

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PRO	PRO2006-05	Estimating the nature and extent of marine mammal captures in New Zealand commercial fisheries	1. To estimate and report the total numbers, releases and deaths of marine mammals where possible by species, fishery and fishing method, caught in commercial fisheries for the years 1990 to the end of the fishing year 2005/06. 2. To analyse factors affecting the probability of fur seal captures for the years 1990 to the end of the fishing year 2005/06. 3. To classify fishing areas, seasons and fishing methods into different risk categories in relation to the probability of marine mammal incidental captures for the years from 1990 through to the end of the fishing year 2005/06.	Completed	Mormede *et al.* 2008; Baird 2008a; 2008b; Smith & Baird 2009; Smith & Baird 2011; Baird 2011.
PRO	PRO2006-07	Characterise non-commercial fisheries interactions	1. To characterise non-commercial fisheries interactions with seabirds and marine mammals 2. Characterise non-commercial fisheries risk to seabirds and marine mammals by area and method Recommend mitigation measures appropriate for uptake in non-commercial fisheries in which seabird or marine mammal captures occur	Completed	Abraham et al. 2010a; Thompson & Abraham 2009a; 2009b; 2009c; 2010; 2011; Thompson et al. 2010a; b; c
PRO	ENV2005-01	Estimation of the nature and extent of incidental captures of seabirds in New Zealand fisheries	1. To estimate the nature and extent of captures of seabirds in selected New Zealand fisheries for the fishing year 2004/05.	Completed	Baird & Smith 2007a; Baird & Gibbert 2010
PRO	ENV2005-02	Estimation of the nature and extent of marine mammal captures in New Zealand fisheries	To examine the nature and extent of the captures of marine mammals in New Zealand fisheries, for the whole New Zealand EEZ, by Fishery Management Area and fishing season, and by smaller metric as appropriate for the fishing year 2004/05. 2. Examine alternative methods for estimating sea lion captures and recommend one or more alternative standardised methods for describing and estimating sea lion captures in the SQU 6T fishery.	Completed	Abraham 2008; Baird 2007; Smith & Baird 2007b; Baird & Smith 2007b

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PRO	ENV2005-04	Identification of marine mammals captured in New Zealand	1. To determine the species- sex- and where possible- age and reproductive status of marine mammals captured in New Zealand fisheries. 2. To necropsy marine mammals captured incidentally to New Zealand fishing operations to determine life-history characteristics and the likely cause of mortality. 3. To determine- through examination of returned marine mammal carcasses- the taxon to species-level- sex- and reproductive status- and age-class of marine mammals captured in New Zealand fisheries. 4. To detail the injuries and where possible the cause of mortality of marine mammals returned from New Zealand fisheries- along with their body condition and breeding status- and other associated demographic characteristics. 5. To detail the protocol used for the necropsy of marine mammals- to provide a standardised procedure for autopsy to determine species- age- sex and associated demographic characteristics for fishery-killed specimens.	Completed	Roe 2007
PRO	ENV2005-06	Estimation of protected species captures in longline fisheries using electronic monitoring	1. To provide estimates of seabird and marine mammal mortalities from longline fisheries in New Zealand using electronic monitoring systems and to recommend deployment and data management options for ongoing use of these systems for estimation of protected species incidental take.	Completed	McElderry et al. 2007
PRO	ENV2005-09	Data collection to estimate key performance indicators in the Chatham albatross, *Diomedea eremita*.	1. To gather data on key population parameters for Chatham albatross *Diomedea eremita*- to enable population viability to be assessed- and the responses of key parameters to fisheries mortality and fisheries management activities to mitigate fisheries related risk 2. To undertake field research to collect data on population growth rates- adult survival- inter-breeding season survival- mortality due to predation at the colony- fecundity and associated parameters for Chatham Albatross- following the study design project 3. To undertake field research to determine the range and extent foraging movements of Chatham albatrosses within New Zealand fishing waters- and examine the nature and extent of any association between Chatham albatrosses and fishing activities.	Completed	No reports specified as required output
PRO	ENV2005-13	Assessment of risk to yellow-eyed penguin Megady-ptes antipodes from fisheries incidental mortality	1. To review existing data on yellow-eyed penguin M. antipodes population performance and fisheries information and provide an analysis of the potential effect of fishing mortality and other factors on population viability. 2. To recommend data collection requirements and protocols for the assessment of the effects of fishing on yellow-eyed penguins.	Completed	Maunder 2007

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PRO	ENV2004-02	Estimation of New Zealand sea lion incidental captures in New Zealand Fisheries	1. To estimate the level of New Zealand sea lion (*Phocartos hookeri*) incidental capture in New Zealand fisheries	Completed	Smith & Baird 2007a
PRO	ENV2004-04	Characterisation of seabird captures in New Zealand fisheries	1. Characterisation of seabird captures in New Zealand fisheries.	Completed	Mackenzie & Fletcher 2006
PRO	ENV2004-05	Modelling of impacts of fishing-related mortality on New Zealand seabird populations	1. To examine and identify modelling approaches to analyse seabird demographic impacts that may be occurring as a result of fisheries mortality. 2. To compile databases of available demographic and distributional data on selected seabirds affected by fisheries mortality and New Zealand fisheries and estimate key population parameters and seasonal distribution for each species. 3. To estimate rates of removals related to fishing activities in New Zealand for selected seabird species, where possible by age class and sex. 4. To describe the spatial overlap of seabird distributions at sea, with fisheries where the risk of incidental mortality has been demonstrated to be moderate to high. 5. To examine the potential for factors other than fisheries removals within the New Zealand zone to influence the population dynamics of the selected study species. 6. To characterise selected seabird populations' abilities to sustain removals related to fishing operations within the New Zealand EEZ, and to recommend, where possible environmental standards for assessing the sustainability of selected fishing operations in relation to impacts on seabird populations.	Completed	Fletcher *et al.* 2008
PRO	ENV2004-06	Maui's dolphin study	1. To quantify and compare summer and winter distribution of Maui's dolphin	Completed	Slooten *et al.* 2005
PRO	IPA2004-14	Seabird warp strike in the southern squid trawl fishery	1. To document seabird warp strike in the southern squid trawl fishery, 2004-05	Completed	Abraham & Kennedy 2008
PRO	ENV2003-05	Review of the Current Threat Status of Associated or Dependent Species	1. To assess the current threat status of selected associated or dependent species.	Completed	Baird *et al.* 2010
PRO	No project number	QMA SQU6T New Zealand sea lion incidental catch and necropsy data for the fishing years 2000-01, 2001-02 and 2002-03	Objectives unknown	Completed	Mattlin 2004

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PRO	MOF2002-03L	Exploring alternative management procedures for controlling bycatch of Hooker's sea lions in the SQU 6T squid fishery	Objectives unknown	Completed	Breen & Kim 2006
PRO	ENV2001-01	Estimation of seabird incidental captures in New Zealand fisheries	1. To estimate the level of seabird incidental capture in New Zealand fisheries. 2. To recommend appropriate levels of observer coverage for estimation of seabird incidental capture in New Zealand fisheries.	Completed	Baird 2004a; b; c; Smith & Baird 2008b
PRO	ENV2001-02	Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2001-02.	1. To estimate and report the total numbers of captures, releases, and deaths of *Phocarctos hookeri* caught in fishing operations, including separate estimates for SQU 6T and other areas, as appropriate, during the 2001102 fishing year, including confidence limits and an investigation of any statistical bias in the estimate.	Completed	Baird 2005a; b; c; Baird & Doonan 2005
PRO	ENV2001-03	Estimation of *Arctocephalus forsteri* (New Zealand fur seal) incidental captures in New Zealand fisheries	1. To estimate the level of *Arctocephalus forsteri* incidental capture in New Zealand fisheries. 2. To recommend appropriate levels of observer coverage for estimation of *Arctocephalus forsteri* incidental capture in New Zealand fisheries.	Completed	Smith & Baird 2008a; Baird 2005d; e; f
PRO	ENV2000-01	Protected species bycatch	1. To estimate the total numbers of captures, releases, and deaths of seabirds and marine mammals - by species -caught in fishing operations during the 1999-2000 fishing year.	Completed	Baird 2003
PRO	ENV2000-02	Estimation of incidental mortality of New Zealand sea lions in New Zealand fisheries	1. To examine the factors that may influence the level of incidental mortality of New Zealand sea lion in New Zealand fisheries 2. To recommend appropriate levels of observer coverage for estimation of incidental mortality of New Zealand sea lion in New Zealand sea lion fisheries	Completed	Doonan 2001; Bradford 2002; Smith & Baird 2005a; b
PRO	ENV2000-03	ENV 2000-A Estimation of seabird and marine mammal incidental capture in New Zealand fisheries	1. To estimate the level of seabird and marine mammal incidental capture in New Zealand fisheries. 2. To determine the factors that influence the level of seabird and marine mammal incidental capture in New Zealand fisheries. 3. To recommend appropriate levels of observer coverage for estimation of seabird and marine mammal incidental capture in New Zealand fisheries.	Completed	Bradford 2002; 2003; Francis *et al.* 2004
PRO	ENV99-01	Incidental capture of seabirds, marine mammals and sealions in commercial fisheries in New Zealand waters	Objectives unknown	Completed	Baird 2001; Doonan 2000
PRO	No project number	Factors influencing bycatch of protected species	Objectives unknown	Completed	Baird & Bradford 2000a; b

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	ENV98-01	Estimation of non-fish bycatch in commercial fisheries in New Zealand waters, 1997–98	Objectives unknown	Completed	Baird 1999b; Baird & Bradford 1999
PRO	No project number	Annual review of bycatch in southern bluefin and related tuna longline fisheries in the New Zealand 200 n. mile Exclusive Economic Zone	Objectives unknown	Completed	Baird *et al.* 1998
PRO	SANF01	Report on the incidental capture of nonfish species during fishing operations in New Zealand waters	Objectives unknown	Completed	Baird 1997
PRO	No project number	Non-fish Species and Fisheries Interactions	Objectives unknown	Completed	Baird 1996
PRO	No project number	Analyses of factors which influence seabird bycatch in the Japanese southern bluefin tuna longline fishery in New Zealand waters, 1989-93	1. To assess the influence that 15 monitored environmental and fishery related factors had on seabird bycatch rates, and to gauge the effectiveness of various mitigation measures	Completed	Duckworth 1995
PRO	No project number	Incidental catch of Hooker's sea lion in the southern trawl fishery for squid, summer 1994	Objectives unknown	Completed	Doonan 1995
PRO	No project number	Nonfish Species and Fisheries Interactions	Objectives unknown	Completed	Baird 1995
PRO	No project number	Nonfish Species and Fisheries Interactions	Objectives unknown	Completed	Baird 1994
PRO	No project number	Incidental catch of fur seals in the west coast South Island hoki trawl fishery, 1989-92	Objectives unknown	Completed	Mattlin 1993

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PRO	No project number	Incidental catch of fur seals in the west coast South Island hoki trawl fishery, 1989-92	Objectives unknown	Completed	Mattlin 1993
PRO	No project number	Incidental catch of non-fish species by setnets in New Zealand waters	Objectives unknown	Completed	Taylor 1992
PRO	No project number	Seabird bycatch by Southern Fishery longline vessels in New Zealand waters	1. To describe the tuna longline fishery in the New Zealand EEZ and how seabirds are caught by longline vessels, 2. To summarise information available on seabird population trends, and estimates the scale of the incidental capture of seabirds in the larger of two tuna longline fisheries in the EEZ. 3. To describe measures which could reduce the number of seabirds caught by tuna longlines.	Completed	Murray *et al.* 1992
NPB	SEA2013-16	Data collation for shark risk assessments	1. To assemble and collate all available information on the distribution and intensity of all fishing methods for the most recent five full fishing years that potential cause fishing-related mortality of chondrichthyans 2. To assemble and collate all available information on the distribution, abundance, demographics and productivity of all New Zealand chondrichthyans.	Completed	
NPB	ENV2013-01	Development of model-based estimates of fish bycatch	1. To develop a statistical modelling approach to estimating total captures of fish and invertebrates using observer and catch-effort information from selected fisheries. 2. To compare estimates of total captures, confidence limits, and trends for selected species, species groups, and fisheries made using existing ratio-based methods and statistical models. 3. To estimate, within a simulation framework, the potential for bias in ratio-based and model-based methods, the sizes of confidence limits for estimates from the two approaches in comparable situations, and identify the factors associated with good and poor performance.	Ongoing analys is	

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NPB	DAE2010-02	Bycatch monitoring & quantification for scampi bottom trawl	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded in the specified fishery, for the fishing years since the last review, using data from Ministry of Fisheries Observers and commercial fishing returns. 2. To compare estimated rates and amounts of bycatch and discards from this study with previous projects on bycatch in the specified fishery. 3. To compare any trends apparent in bycatch rates in the specified fishery with relevant fishery independent trawl surveys. 4. To provide annual estimates of bycatch for nine Tier 1 species fisheries and incorporate into the Aquatic Environment and Biodiversity Report specified in Objective 3 for SQU, SCI, HAK, HOK, JMA, ORH, OEO, LIN, SBW	Completed	Anderson 2012, 2013a, b
NPB	ENV2009-02	Bycatch and discards in oreo and orange roughy trawl fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for oreos for the fishing years 2002/03 to 2008/09 using data from Scientific Observers and commercial fishing returns. 2. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for orange roughy for the fishing years 2004/05 to 2008/09 using data from Scientific Observers and commercial fishing returns.	Completed	Anderson 2011
NPB	IDG2009-01	Finfish field identification guide	1. To complement the field identification guide under IDG2006/01 with the remaining 120 fish species caught by commercial fishers in New Zealand waters	Completed	McMillan 2011 a,b,c; Rowden *et al.* 2013
NPB	ENV2008-01	Fish and invertebrate bycatch and discards in southern blue whiting fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for southern blue whiting for the fishing years 2002/03 to 2006/07 using data from Scientific Observers and commercial fishing returns.	Completed	Anderson 2009b
NPB	ENV2008-02	Estimation of non-target fish catch and both target and non-target fish discards in hoki, hake and ling trawl fisheries	Estimates of the catch of non-target fish species, and the discards of target and non-target fish species in the hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*), and ling (*Genypterus blacodes*) trawl fisheries for the fishing years 2003–04 to 2006–07 using data from Scientific Observers and commercial fishing returns	Completed	Ballara *et al.* 2010
NPB	ENV2008-04	Productivity of deepwater sharks	1. To determine the growth rate, age at maturity, longevity and natural mortality rate of shovelnose dogfish (*Deania calcea*) and leafscale gulper shark (*Centrophorus squamosus*).	Completed	Parker & Francis 2012
NPB	ENV2007-01 & ENV2007-02	Bycatch and Discards in Squid Trawl Fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for squid for the fishing years 2001/02 to 2005/06 using data from MFish Observers and commercial fishing returns.	Completed	Ballara & Anderson 2009

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NPB	ENV2007-03	Productivity and Trends in Rattail Bycatch Species	1. To estimate growth, longevity, rate of natural mortality, and length at maturity of four key rattail bycatch species in New Zealand trawl fisheries. 2. To examine data from trawl surveys and other data sources for trends in catch rates or indices of relative abundance for species in Objective 1.	Completed	Stevens *et al.* 2010
NPB	DEE2006-03	Monitoring the abundance of deepwater sharks	1. To monitor the abundance of deepwater sharks taken by commercial trawl fisheries	Completed	Blackwell 2010
NPB	ENV2006-01	Bycatch and discards in ling longline fisheries	To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the longline fisheries for ling for the fishing years 1998/99 to 2005/06 using data from MFish Observers and commercial fishing returns.	Completed	Anderson 2008
NPB	IDG2006-01	Finfish field identification guide	1. To produce a field guide for fish species in New Zealand 2. To produce a field identification guide for all QMS and other fish species commonly caught in commercial and non-commercial fisheries	Completed	McMillan 2011 a,b,c
NPB	TUN2006-02	Estimation of non-target fish catches in the tuna longline fishery	1. To estimate the catches, catch rates, and discards of non-target fish in tuna longline fisheries data from the Observer Programme and commercial fishing returns for the 2005/06 fishing year. 2. To describe bycatch trends in tuna longline fisheries using data from this project and the results of previous similar projects.	Completed	Griggs *et al.* 2008
NPB	ENV2005-17	Estimation of non-target fish catch and both target and non-target fish discards in jack mackerel trawl fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for jack mackerel for the fishing years 20011/2002 to 2004/05 using data from Mfish observers and commercial fishing returns.	Completed	Anderson 2007a
NPB	ENV2005-18	Estimation of non-target fish catch and both target and non-target fish discards in orange roughy trawl fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for orange roughy for the fishing years 1999/2000 to 2003/04 using data from Scientific Observers and commercial fishing returns.	Completed	Anderson 2009a

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NPB	TUN2004-01	Estimation of non-target fish catches in the tuna	To estimate the catch rates of non-target fish in the 10ngline fisheries for tuna using data from the Observer Programme and commercial fishing returns for the 2002/03, 2003/04 and 2004/05 fishing years. 2. To estimate the quantities of non-target fish caught in the longline fisheries for tuna using data from the Observer Programme and commercial fishing returns for the 2002/03, 2003/04 and 2004/05 fishing years. 3. To estimate the discards of non-target fish caught in the longline fisheries for tuna using data from the Observer Programme and commercial fishing returns for the 2002/03, 2003/04 and 2004/05 fishing years. 4. To describe trends in the non-target fish catches in the tuna longline fisheries using data from this project and the results of previous similar projects.	Completed	Griggs *et al.* 2007
NPB	ENV2003-01	Estimation of non-target catches in the hoki fishery	1. To estimate the catch rates, quantity and discards of non-target fish catches and the discards of target fish catches in trawl fisheries for hoki, using data from the Observer Programme and commercial fishing returns for the 1999/00 to 2002/03 fishing years. 2. To compare and contrast the estimates from the four years of data in Specific Objective 1 above with the 1990/91 through 1998/99 series previously reported.	Completed	Anderson & Smith 2005
NPB	ENV2002-01	Estimation of non-target fish catch and both target and non-target fish discards for the tuna longline fishery	1. To estimate the catch rates, quantity and discards of non-target fish, particularly oceanic shark species, broadbill swordfish and marlin species, caught in the longline fisheries for tuna, using data from Scientific Observers and commercial fishing returns for the 2000/01 and 2001/02 fishing years.	Completed	Ayers *et al.* 2004
NPB	ENV2001-04	Non-target fish catch and discards in selected New Zealand fisheries	To generate estimates of the catch of non-target fish species, and the discards of target and non-target fish species in three important New Zealand trawl fisheries: arrow squid (*Nototodarus sloani & N. gouldi*), jack mackerel (*Trachurus declivis, T. novaezelandiae, & T. symmetricus murphyi*) and scampi (*Metanephrops challengeri*)	Completed	Anderson 2004
NPB	ENV2001-05	To assess the productivity and relative abundance of deepwater sharks	1. To review the relative abundance, distribution and catch composition of the most commonly caught deepwater shark species: shovelnose dogfish (*Deania catcea*), Baxter's dogfish (*Etmopterus baxten*), Owston's dogfish (*Cenhoscymnus owstoni*), longnosed velvet dogfish (*Centroscymnus crepidater*), leafscale gulper shark (*Cenhophom squamosus*), and the seal shark (*Dalatias ticha*).	Completed	Balckwell & Stevenson 2003

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NPB	ENV2001-07	Reducing bycatch in scampi trawl fisheries	1. Collate and review the international literature on methods of reducing bycatch in crustacean trawl fisheries. 2. Review and analyse the data from New Zealand studies. 3. Develop recommendations on future approaches to reducing bycatch in the New Zealand scampi fishery, including some general thoughts on the experimental design of field trials.	Completed	Hartill *et al.* 2006
NPB	PAT2000-01	Review of rattail and skate bycatch, and analysis of rattail standardised CPUE from the Ross Sea toothfish fishery in Subarea 88.1, from 1997-1998 to 2001-02	Objectives unknown	Completed	Feanaughty *et al.* 2003; Marriot *et al.* 2003
NPB	ENV99-02	Estimation of non-target fish catch and both target and non-target fish discards in selected New Zealand fisheries	1. To estimate the quantity of non-target fish species caught in the trawl fisheries for hoki and orange roughy for the fishing years 1990-91 to 1998-99 using data from Scientific Observers, commercial fishing returns and from research trawl surveys. 2. To estimate the quantity of target and non-target fish species discarded in the trawl fisheries for hoki and orange roughy for the fishing years 1990-91 to 1998-99 using data from Scientific Observers, commercial fishing returns and from research trawl surveys. 3. To explore the effects of various factors on the total catch of non-target fish species and the discards of target and non-target fish species in the trawl fisheries for hoki and orange roughy for the fishing years 1990-91 to 1998-99. 4. To recommend appropriate levels of observer coverage for estimation of non-target fish catch and discards of target and non-target fish species in the hoki and orange roughy fisheries.	Completed	Anderson et al. 2001
NPB	ENV99-05	To identify trends in abundance of associated or dependent species from selected commercial fisheries	To estimate trends in abundance of associated and depeadent species, including invertebrates, from deepwater and middle depth fisheries on the Chatham Rise.	Completed	Livingston *et al.* 2003
NPB	ENV98-02	Pelagic shark bycatch in the New Zealand tuna longline fishery	To determine pelagic shark bycatch in the New Zealand tuna longline fishery	Completed	Francis *et al.* 2001
NPB	No project number	Fish bycatch in New Zealand tuna longline fisheries	Objectives unknown	Completed	Francis *et al.* 1999; 2000

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
NPB	ENV97-01	Estimation of nonfish bycatch in New Zealand fisheries	1. Unknown 2. To provide weekly within season estimates of total captures, releases, and deaths by sex and area for New Zealand sea lions taken in the southern squid trawl fishery beginning two (2) weeks after the start of the fishery until 15 May 1998. Estimates of the confidence intervals and coefficient of variation of the point estimates must also be provided. 3. Unknown	Completed	Doonan 1998; Baird 1999a; Baird *et al.* 1999
NPB	SCI97-01	Scampi stock assessment for 1998 and an analysis of the fish and invertebrate bycatch of scampi trawlers	1. To summarise catch, effort, observer, and research information for scampi fisheries in QMAs 1,2,3,4 (east and western portions), and 6A in 1998	Completed	Cryer *et al.* 1999
BEN	BEN2014-01	Risk assessment for benthic habitats, biodiversity, and production	1. To review the design and implementation of management frameworks, including objectives and targets, to manage the effects of mobile bottom fishing methods on vulnerable benthic taxa and habitats 2. To complete spatially explicit quantitative impact assessments for benthic taxa and/or habitats affected by bottom fisheries, within spatially distinct or overlapping zones within the New Zealand EEZ, consistent with available databases and the outputs of existing projects 3. To compile and combine impact assessments from Objective 2, to inform a spatially explicit quantitative risk assessment with reference to potential management targets for benthic taxa and/or habitats (from Objective 1) combined across all bottom fisheries in the New Zealand EEZ, 4. To conduct spatially explicit Management Strategy Evaluation to simulate and evaluate the effects of alternate fisheries management scenarios on benthic taxa and/or habitats in the EEZ	Delayed. Awaiting outcome of assessment of benthic approach in early 2015	
BEN	BEN2014-03	Monitoring recovery of benthic fauna in Spirits Bay	1. Using previous survey results, conduct a power analysis to estimate the likelihood of a range of survey designs consistent with the monitoring programme from project ENV2005/23 detecting changes in key indicators of the state of the benthic communities in Spirits Bay and Tom Bowling Bay since the last survey. 2. To survey Spirits Bay and Tom Bowling Bay benthic invertebrate communities in accordance with an agreed design from Objective 1. 3. To assess changes in benthic communities inside and outside of the closed area since 1997	Approved but not contracted	
BEN	BEN2014-02	Monitoring recovery of benthic fauna on the Graveyard complex	1. To repeat the quantitative photographic survey of benthic invertebrate communities on the Graveyard complex. 2. To assess changes in benthic communities since the first survey in 2001	Ongoing analysis	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BEN	BEN2014-04	Monitoring recovery of benthic fauna in areas where bottom fishing has decreased	1. To identify areas where bottom disturbing fishing has decreased or ceased that would be suitable for the establishment of cost-effective monitoring 2. To conduct the first quantitative survey of benthic epifaunal and infaunal assemblages in an agreed subset of areas identified in objective 1. 3. To design a cost-effective monitoring programme to monitor changes in the benthic epifaunal and infaunal assemblages in one or more of the areas surveyed in objective 2	Withdrawn	
BEN	BEN2012-02	Spatial overlap of mobile bottom fishing methods and coastal benthic habitats	1. To use existing information and classifications to describe the distribution of benthic habitats throughout New Zealand's coastal zone (0–200 m depth). 2. To rank the vulnerability to fishing disturbance of habitat classes from Objective 1. 3. To describe the spatial pattern of fishing using bottom trawls, Danish seine nets, and shellfish dredges and assess overlap with each of the habitat classes developed in Objective 1.	Completed	Baird et al In Press
BEN	DEE2010-06	Design a camera / transect study	1. To design and provide indicative costs for a programme to monitor trends in deepwater benthic habitats and communities. 2. To explore the feasibility of using existing trawl and acoustic surveys to capture data relevant to monitoring trends in deepwater benthic habitats and communities.	Ongoing analysis	Bowden *et a.l* In Press
BEN	DAE2010-04	Monitoring the trawl footprint for deepwater fisheries	1. To estimate the 2009/10 trawl footprint and map the spatial and temporal distribution of bottom contact trawling throughout the EEZ between 1989/90 and 2009/10. 2. To produce summary statistics, for major deepwater fisheries and the aggregate of all deepwater fisheries, of the spatial extent and frequency of fishing by year, by depth zone, by fishable area, and by habitat class, and to identify any trends or changes.	Ongoing analysis	Black *et al.* 2013; Black & Tilney Submitted
BEN	SEA2014-09	Review of New Zealand's SPRFMO VME protocol	1. To prepare a review of the scientific basis for the 'biodiversity component' of the move-on-rule thresholds comprising the current New Zealand Vulnerable Marine Ecosystem Evidence Process.	Completed	Penney 2014
BEN	Internally funded 1	SPRFMO	1. To develop detection criteria for measuring trawl impacts on vulnerable marine ecosystems in high sea fisheries of the South Pacific Ocean	Completed	Parker *et al.* 2009a
BEN	Internally funded 2	SPRFMO	1. To document protection measures implemented by New Zealand for vulnerable marine ecosystems in the South Pacific Ocean	Completed	Penney *et al.* 2009
BEN	Internally funded 3	CCAMLR	1. An Impact Assessment Framework for Bottom Fishing Methods in the CCAMLR Convention Area	Completed	Sharp *et al.* 2009
BEN	Internally funded 4	SPRFMO	1. to develop a bottom Fishery Impact Assessment: Bottom Fishing Activities by New Zealand Vessels Fishing in the High Seas in the SPRFMO Area during 2008 and 2009	Completed	Ministry of Fisheries 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BEN	BEN2009-02	Monitoring recovery of benthic communities in Spirits Bay	1. To survey Spirits Bay and Tom Bowling Bay benthic invertebrate communities according to the monitoring programme designed in ENV2005/23. 2. To assess changes in benthic communities inside and outside the closed area since 1997.	Completed	Tuck & Hewitt 2013
BEN	IFA2008-04	Guide for the rapid identification of material in the process of managing Vulnerable Marine Ecosystems	To produce a guide for the rapid identification of material in the process of managing Vulnerable Marine Ecosystems	Completed	Tracey *et al.* 2008
BEN	BEN2007-01	Assessing the effects of fishing on soft sediment habitat, fauna, and processes	1. To design and test sampling and analytical strategies for broad-scale assessments of habitat and faunal spatial structure and variation across a variety of seafloor habitats. 2. To design and carry out experiments to assess the effects of bottom trawling and dredging on benthic communities and ecological processes important to the sustainability of fishing at scales of relevance to fishery managers.	Ongoing analysis	
BEN	IFA2007-02	Development of a Draft New Zealand High-Seas Bottom Trawling Benthic Assessment Standard	1. To generate data summaries and maps of New Zealand's recent historic high-seas bottom trawling catch and effort in the proposed convention area of the South Pacific Regional Fisheries Management Organization (SPRFMO). 2. To map vulnerable marine ecosystems (VMEs) in the SPRFMO area. 3. To develop a draft standard for assessment of benthic impacts of high-seas bottom trawling on VMEs in the proposed SPRFMO convention area.	Completed	Parker 2008
BEN	BEN2006-01	Mapping the spatial and temporal extent of fishing in the EEZ	1. To update maps and develop GIS layers of fishing effort from project ENV2000/05 to show the spatial and temporal distribution of mobile bottom fishing throughout the EEZ between 1989/90 and 2004/05. 2. To produce summary statistics of major fisheries and the aggregate of all bottom impacting fisheries in terms of the extent and frequency of fishing by year, by depth zone, by fishable area, and, to the extent possible, by habitat type. 3. To identify and document any major trends or changes in fishing effort or fishing behaviour. 4. To identify, discuss the implications of, and make recommendations on data quality and other problems with current reporting systems that complicate characterisation and quantification of bottom fishing effort. 5. To integrate information on the distribution, frequency, and magnitude of fishing disturbance with habitat characteristics throughout the EEZ, using information stored in national databases, expert opinion, and the MEC.	Completed	Baird *et al.* 2009; 2011; Baird & Wood 2010; Leathwick *et al.* 2010; 2012

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BEN	ENV2005-15	Information for managing the Effects of Fishing on Physical Features of the Deep-sea Environment	1. To provide an updated database that identifies all known seamounts in the "New Zealand region", encompassing the area from 24°00' – 57°30'S, 157°00'E – 167°00'W. The database will catalogue relevant data (e.g. physical, biological, location, fishing effort) for individual seamounts. 2. To identify indicators and measures suitable for the assessment of risk pertaining to the effects of fishing disturbance on the benthic biota of seamounts, and review suitable ecological risk assessment methods, that can be derived or utilise information contained within the seamount database.	Completed	Rowden *et al.* 2008; Clark *et al.* 2010b
BEN	ENV2005-16	Investigate the Effects of Fishing on Physical Features of the Deep-sea Environment	1. To monitor changes in fauna and habitats over time on selected UTFs in the Chatham Rise area that have a range of fishing histories. 2. To continue development of the risk assessment model to predict the effects of fishing, and provide options for the management of UTF ecosystems.	Completed	Clark *et al.* 2010a; b; c; 2011
BEN	ENV2005-20	Benthic invertebrate sampling and species identification in trawl fisheries	1. To produce identification guides for benthic invertebrate species encountered in the catches of commercial and research trawlers.	Completed	Tracey *et al.* 2007; Williams *et al.* 2010; Clark *et al.* 2009
BEN	ENV2005-23	Monitoring recovery of the benthic community between North Cape and Cape Reinga	1. To design a monitoring programme that will provide the following quantitative estimates: i) Estimates of the nature and extent of past fishing impacts on the benthic community between North Cape and Cape Reinga; ii) Estimates of change over time in areas previously fished but subsequently closed to fishing. Estimated parameters will include indices representing biodiversity, community composition, and biogenic structure; iii) Estimates of change over time in areas environmentally comparable to those assessed in (ii), above, but subject to ongoing fishing impacts; and iv) Estimates of change over time in areas comparable to those above, but not impacted by fishing (if any such areas can be found).	Completed	Tuck *et al.* 2010

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BEN	ZBD2005-04	Information on benthic impacts in support of the Foveaux Strait Oyster Fishery Plan	1. To assess the distribution- vulnerability to disturbance- and ecological importance of habitats in Foveaux Strait- and describe the spatial distribution of the Foveaux Strait oyster fishery relative to those habitats. 2. To assemble and collate existing information on the Foveaux Strait system between the Solander Islands and Ruapuke Island or other area to be agreed with MFish. 3. To map- using best available information- substrate type- bathymetry- wave energy- and tidal flow in this area. 4. To assess the extent to which these data can be used to define useful functional categories that might serve as habitat classes. 5. To rank the vulnerability to fishing disturbance of habitat classes developed in Objective 3 using approximate regeneration times. 6. To describe the functional role and ecosystem services provided by each habitat class developed in Objective 3- including an assessment of the relative importance of each to overall ecosystem function and productivity. 7. To describe the spatial pattern and intensity of dredge fishing for Foveaux Strait oysters over the past 10 fishing years and relate this to natural disturbance regimes and habitat classes developed in Objective 3. 8. To carry out a qualitative video survey of benthic habitats in Foveaux Strait- both within the established commercial oyster fishery area and areas outside the fishery area but within OYU 5.	Completed	Michael et al. 2006
BEN	ZBD2005-15	Information on benthic impacts in support of the Coromandel Scallops Fishery Plan	1. To assemble and collate existing information on the coromandel Scallop Fishery between cape Rodney and Town Point or other, wider area to be agreed with Mfish. 2. To map, using best available information, substrate type, bathymetry, wave energy, and tidal flow in this area. 3. To assess the extent to which data can be used to define useful functional categories that might serves as habitat classes. 4. To rank the vulnerability of fishing disturbance of habitat classes developed in Objective 3 using approximate regeneration times. 5. To describe the functional role and ecosystem services provided by each habitat class developed in Objective 3, including an assessment of the relative importance of each to overall ecosystem function and productivity. 6. To describe the spatial pattern and intensity of dredge and trawl fishing within the Coromandel scallop fishery over the past 15 fishing years and relate this to natural disturbance regimes and habitat classes developed in Objective 3.	Completed	Tuck *et al.* 2006a; b

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BEN	ZBD2005-16	Information on benthic impacts in support of the Southern Blue Whiting Fishery Plan	1. To assemble and collate existing information on the Southern Blue Whiting fishery in SBW6A, SBW6B, SBW6I, and SBW6R or other wider area to be agreed with MFish 2. To map, using best available information, substratum type, bathymetry, wave energy, tides, and ocean currents in these areas 3. To assess the extent to which these data can be used to define useful functional categories that might serve as habitat categories. 4. To rank the vulnerability to fishing disturbance of habitat classes developed in Objective 3 using approximate regeneration times. 5. To describe the functional role and ecosystem services provided by each habitat class developed in Objective 3, including an assessment of the relative importance of each to overall ecosystem function and productivity. 6. To describe the spatial pattern and intensity of trawl fishing within the Southern Blue Whiting fishery over the past 10 fishing years and relate this to natural disturbance regimes and habitat classes developed in Objective 3.	Completed	Cole *et al.* 2007
BEN	ENV2003-03	Determining the spatial extent, nature and effect of mobile bottom fishing methods	1. To determine the spatial extent, nature and time between disturbances of mobile bottom fishing methods in the Chatham Rise trawl fisheries.	Completed	Baird *et al.* 2006
BEN	ENV2002-04	Benthic invertebrate sampling and specific identification in trawl fisheries	1. To quantify and map the benthic invertebrate species incidental catch in commercial and research trawling throughout the New Zealand EEZ	Completed	Tracey *et al.* 2005
BEN	ENV2001-09	The effects of mobile bottom fishing gear on bentho-pelagic coupling	To describe any effects of fishing that might modify bentho-pelagic coupling (a complex, interlinked suite of processes transferring energy, oxygen, carbon, and nutrients between pelagic and benthic systems), to consider the scale of such possible effects, and to put the summary in a New Zealand context.	Completed	Cryer et al. 2004
BEN	ENV2001-15	The effects of bottom impacting trawling on seamounts	1. To design a programme in New Zealand waters previously trawled and now closed to trawling to monitor the rate of regeneration of benthic communities on seamounts.	Completed	Clark & O'Driscoll 2003; Clark & Rowden 2009
BEN	OYS2001-01	Foveaux Strait oyster stock assessment	1. To carry out a survey and determine the distribution and absolute abundance of pre-recruit and recruited oysters in both non-commercial and commercial areas of Foveaux Strait. The target coefficient of variation (c.v.) of the estimate of absolute recruited abundance is 20%. 2. To estimate the sustainable yield for the areas of the commercial oyster fishery in Foveaux Strait for the year 2002 oyster season. 3. To identify and count benthic macro-biota collected during the dredge survey.	Completed	Rowden *et al.* 2007

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BEN	ENV2000-05	Spatial extent, nature and impact of mobile bottom fishing methods in the New Zealand EEZ	1. To determine the spatial extent, nature and impact of mobile bottom fishing methods within the New Zealand EEZ.	Completed	Cryer and Hartill 2002; Baird et al. 2002
BEN	ENV2000-06	Review of technologies and practices to reduce bottom trawl bycatch and seafloor disturbance in New Zealand	Objectives unknown	Completed	Booth *et al.* 2002; Beentjes & Baird 2004
BEN	ENV98-05	The effects of fishing on the benthic community structure between North Cape and Cape Reinga	1. To determine the effects of fishing on the benthic community structure between North Cape and Cape Reinga.	Completed	Cryer *et al.* 2000
ECO	SEA2013-01	Provision of identification guides (sea pens and black corals)	To produce identification guides for sea pens and black corals electronically as AEBR (including MPI review).	Complete	Tracey *et al.* 2014; Williams *et al.* 2014; Opresko *et al.* 2014
ECO	ENV2012-01	A literature review of Nitrogen levels and adverse ecological effects in embayments in temperate regions.	1. To complete a literature review of Nitrogen levels and adverse ecological impacts from temperate embayments in order to assist aquaculture consenting authorities in determining at what concentration of Nitrogen adverse effects may be expected.	Ongoing analysis	Hartstein Submitted
BIO	ZBD2012-02	Tier 1 statistic: Ocean	1. To identify candidate oceanographic variables for potential development as part of the proposed Tier 1 Statistic, Atmospheric and Ocean Climate Change	Almost complete. Publication undergoing revision	
ECO	SEA2012-17	NPOA Sharks extension work	NPOA Sharks extension work	Completed	Clark *et al.* 2013
ECO	DAE2010-01	Taxonomic identification of benthic specimens	1. To identify benthic invertebrates in samples taken during research trawls and by Observers on fishing vessels. 2. To update relevant databases recording the catch of invertebrates in research trawls and commercial fishing.	Completed	Mills *et al.* 2013
ECO	DAE2010-03	Ecological risk assessment for deepwater stocks	1. To undertake a qualitative (level 1) risk assessment for tier 3 fishstocks within the deepwater fisheries plan.	In development	

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ECO	DEE2010-05	Development of a suite of environmental indicators for deepwater fisheries	1. To review the literature and hold a workshop to recommend a suite of ecosystem and environmental indicators that will contribute to assessing the performance of deepwater fisheries within an environmental context. 2. To examine available data and design a data collection programme to enable future calculation of the indicators identified in Specific Objective 1.	Completed	Tuck *et al.* 2014
ECO	ENV2010-03	Habitats of particular significance for inshore finfish fisheries management	1. To review the literature to determine the most important juvenile or reproductive (spawning, pupping or egg-laying) areas for inshore finfish target species. 2. To use a gap analysis to prioritize areas for future research concerning the important juvenile or reproductive (spawning, pupping or egg-laying) areas for target inshore finfish fisheries	Completed	Morrison *et al.* 2014 b
ECO	ENV2010-05A&B and SEA2010-15	Habitats of particular significance for fisheries management: shark nursery areas	1. Identify, from the literature, important nursery grounds for rig in estuaries around mainland New Zealand. 2. Design and carry out a survey of selected estuaries and harbours around New Zealand to quantify the relative importance of nursery ground areas. 3. Identify threats to these nursery ground areas and recommend mitigation measures.	In the process of publication	Francis *et al.* 2012; Jones et al. Submitted
ECO	ZBD2010-42	Development of a National Marine Environment Monitoring Programme	1. To design a Marine Evnironment Monitoring Programme (MEMP) to track the physical, chemical and biological changes taking place across New Zealand's marine environment over the long term 2. To prepare an online inventory (metadatabase) of repeated (time series) biological and abiotic marine observations/datasets in New Zealand 3. To review, evaluate fitness for purpose, and identify gaps in the utility and interoperability of these datasets for inclusion in MEMP from both science and policy perspectives 4. To design a MEMP that includes relevant existing data collection and proposed new time series	Ongoing analysis	Hewitt In Press
ECO	DEE2010-04	Development of a methodology for Environmental Risk Assessments for deepwater fisheries	To review approaches to Ecological Risk Assessments (ERA) and methods available for deepwater fisheries both QMS and non-QMS. 2. To develop and recommend a generic, cost effective, method for ERA in deepwater fisheries by using or modifying methods identified in Objective 1.	Ongoing analysis	Clark *et al.* Submitted; Mormede & Dunn 2013
ECO	ENV2009-04	Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys	1. To evaluate relative changes in abundance of mesopelagic fish and other biological components from acoustic records collected during Chatham Rise and Sub-Antarctic trawl surveys. 2. To explore links between trends in mesopelagic biomass and climate variables and variations, and condition indices of commercial species in the Chatham Rise and Sub-Antarctic areas.	Completed	O'Driscoll *et al.* 2011

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ECO	ENV2009-07	Habitats of particular significance for fisheries management: kaipara harbour	1. Collate and review information on the role and spatial distribution of habitats in the Kaipara Harbour that support fisheries production. 2. Assess historical, current, and potential anthropogenic threats to these habitats that could affect fisheries values, including fishing and land-based threats. 3. Design and implement cost-effective habitat mapping and monitoring surveys of habitats of particular significance for fisheries management in the Kaipara Harbour.	Completed	Morrison *et al.* 2014 d
ECO	GMU2009-01	Spatial Mixing of GMU1 using Otolith Microchemistry	1. To determine the level of spatial mixing and connectivity of grey mullet (*Mugil cephalus*) populations using otolith microchemistry. 2. To collect and analyse the chemical composition of grey mullet otoliths. 3. To analyse the otoliths collected under Objective 1 to determine if the samples can be spatially separated.	Ongoing analysis	
ECO	IPA2009-11	Trophic studies publication of review	1. To publish the comprehensive review of New Zealand-wide trophic studies completed in 2000 that was prepared by NIWA.	Completed	Stevens *et al.* 2011
ECO	FLA2009-01	Assess the feasibility of using juvenile netting surveys to predict adult yellow-belly & sand flounder	1. Assess the feasibility of using juvenile netting surveys to predict adult yellow-belly and sand founder abundance in the Manukau Harbour and Firth of Thames (this also examined correlations between juvenile catch and environmental factors).	Completed	McKenzie *et al.* 2013
ECO	AQE2008-02	Review of ecological effects of farming shellfish and other species	1. To collate and review information on the ecological effects of farming mussels (*Perna canaliculus*), including offshore mussel farming and spat catching, in the New Zealand marine environment. 2. To collate and review information on the ecological effects of farming oysters in the New Zealand marine environment. 3. To collate and review information on the ecological effects of farming species other than mussels (*Perna canaliculus*), oysters, and finfish, in the New Zealand marine environment.	Completed	Keeley et al. 2009
ECO	IFA2008-08	Inputs to the Ross Sea bioregionalisation	1. To produce one or more benthic invertebrate classifications of the Ross Sea region; 2. To use fishery catch data to examine spatial distributions of major demersal fish species; 3. To prepare other biological or environmental spatial data layers for use in the Ross Sea workshop.	Completed	Pinkerton *et al.* 2009a

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ECO	TOH2008-01	Distribution and abundance of Toheroa	1. To estimate the size structure and absolute abundance of toheroa on Oreti Beach, during February 2009. The target c.v. for the estimate of absolute abundance of legal sized toheroa (100 mm shell length) is 20%. 2. To describe changes in the size structure and absolute abundance of toheroa on Oreti Beach by comparing the results from this work with those from previous surveys. 3. To estimate the size structure and absolute abundance of toheroa on Bluecliffs Beach, during February 2009. The target c.v. for the estimate of absolute abundance of legal sized toheroa (100 mm shell length) is 20%. 4. To describe changes in the size structure and absolute abundance of toheroa on Bluecliffs Beach by comparing the results from this work with those from previous surveys.	Completed	Beentjes 2010
ECO	TOH2007-03	Toheroa Abundance	1. To investigate variations in the abundance of toheroa. 2. To investigate sources of mortality of toheroa and factors affecting the recruitment of toheroa	Completed	Williams *et al.* 2013
ECO	BEN2007-05	Risk assessment framework for assessing fishing &other anthropogenic effects on coastal fisheries	1. To collate existing information on the distribution, intensity, and frequency of anthropogenic disturbances in the coastal zone that could be used in a risk assessment model to estimate their likely aggregate effect on ecosystem function across habitats and over different scales of ecosystem functioning and biological organization. 2. To develop a risk assessment framework in conjunction with a variety of stakeholders and environmental scientists.	Completed	MacDiarmid *et al.* 2012
ECO	ENH2007-01	Stock enhancement of blackfoot paua	1. To assess the survival rate of enhanced paua from introduction into the wild through to harvest. 2. To assess the genetic diversity of hatchery spawned juvenile paua bred for enhancement purposes. 3. To assess interactions between introduced and wild paua populations and to recommend research and monitoring to quantify those impacts that are potentially adverse.	Ongoing analysis	McCowan Submitted
ECO	ENV2007-04	Climate and Oceanographic Trends Relevant to New Zealand Fisheries	1. To summarise, for fisheries managers, climatic and oceanographic fluctuations and cycles that affect productivity, fish distribution and fish abundance in New Zealand.	Completed	Hurst *et al.* 2012
ECO	ENV2007-06	Trophic Relationships of Commercial Middle Depth Species on the Chatham Rise	1. To quantify the inter-annual variability in the diets of hoki, hake and ling on the Chatham Rise 1992–2007 2.To quantify seasonal dietary cycles for hoki, hake and ling that have been collected from the commercial fleet throughout the year	Completed	Horn & Dunn 2010

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ECO	HAB2007-01	Biogenic habitats as areas of particular significance for fisheries management	1. To collate and review available information on the location, value, functioning, threats to, and past and current status of biogenic habitats that may be important for fisheries production in the New Zealand marine environment. 2. To identify information gaps, in the New Zealand context, and recommend measures to address those important to an ecosystem approach to fisheries management	Completed	Morrison *et al.* 2014 a
ECO	IPA2007-07	Land Based Effects on Costal Fisheries	1. To review and collate scientific knowledge and research on the impacts of land-based activities on coastal fisheries and biodiversity	Completed	Morrisson *et al.* 2009
ECO	ENV2006-04	Ecosystem indicators for New Zealand fisheries	1. To carry out a literature review of potential fish-based ecosystem indicators and identify a suite of indicators to be tested in Objective 2 2. To test a suite of fish-based ecosystem indicators (identified by Objective 1) on existing trawl survey time series in New Zealand. The utility of these indicators for monitoring the effects of fishing in New Zealand should also be evaluated	Completed	Tuck *et al.* 2009
ECO	GBD2006-01	DNA database for commercial marine fish and invertebrates	1. To collect DNA sequences for vouchered specimens of commercially important marine fishes and submit the DNA data to the international Barcode of Life Database (BOLD). 2. To collect DNA sequences for vouchered specimens of commercially important marine invertebrates and submit the DNA data to the international Barcode of Life Database (BOLD). Note: The funding was limited to $60 000 for this Objective. Therefore MFish agreed to omit the invertebrate species (Objective 2) from this project and reduce the number of fish species sequenced from 100 to 80 (up to 5 specimens per species). During the course of the project MFish staff asked NIWA to identify smoked eel product, suspect shark fillets, and possible paua slime with DNA markers, consequently the project was modified to accommodate these requests	Completed	No reports specified as required output
ECO	IPA2006-08	Review of the Ecological Effects of Marine Finfish aquaculture: Final Report	1. Summarise and review existing information on ecological effects of finfish farming on the marine environment in New Zealand and overseas	Completed	Forrest *et al.* 2007
ECO	SAP2006-06	West coast south island review	1. To publish a review document summarising oceanic and environmental research information particularly relevant to hoki- but also other fisheries- that spawn off Westland in winter 2. Update the draft chapters prepared in 2004 by oceanographers- modellers and scientists towards the overall objective 3. Incorporate a section on other west coast spawning fisheries	Completed	Bradford-Grieve & Livingston 2011

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ECO	ENV2005-08	Experimental design of a programme of indicators	1. To assess the utility/feasibility of using demographic information to assess the effects of fishing on seabird populations. 2. To identify population indicators and to provide sampling protocols and experimental design for selected high to medium priority seabird populations. 3. To recommend experimental protocols for sampling of selected seabird populations in New Zealand influenced by fisheries mortality, employing robust-design methodology and including recommendations for inclusions of data into Ministry of Fisheries databases.	Completed	MacKenzie & Fletcher 2010
ECO	IPA2005-02 and MOF2003-03A	A guide to common offshore crabs in New Zealand Waters	1. Develop a guide to common offshore crabs in new Zealand waters	Completed	Naylor *et al.* 2005
ECO	SAM2005-02	Effects of climate on commercial fish abundance	To examine the possible effects of climate on fishery yields and abundance indices for commercial fisheries around New Zealand	Completed	Dunn *et al.* 2009
ECO	HOK2004-01	Hoki Population modelling and stock assessment	2. To investigate the prediction of year class strength from environmental variables.	Completed	Francis *et al.* 2005
ECO	AQE2003-01	Effects of aquaculture and enhancement stock sources on wild fisheries resources and the marine environment.	1. To identify, discuss the effects and qualitatively assess the risks of aquaculture and enhancement stocks improved by hatchery technology on New Zealand's wild fisheries resources and the marine environment. 2. To identify, discuss the effects and qualitatively assess the risks associated with the translocation of aquaculture and enhancement stocks on New Zealand's wild fisheries resources and the marine environment. 3. To make recommendations on priority issues, risks, or research to be undertaken, as a result of information discussed and evaluated in objectives 1-2.	Completed	Speed 2005
ECO	EEL2003-01	Non-fishing mortality of freshwater eels	1. To undertake a feasibility study on establishing an estimate of the mortality of eels caused by hydroelectric turbines and other point sources of mortality caused by human activity.	Completed	Bentjees *et al.* 2005
ECO	MOF2003-01	The implications of marine reserves for fisheries resources and management in the New Zealand context	Objectives unknown	Completed	Speed *et al.* 2006

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ECO	ENV2002-03	Beach cast seaweed review	1. To collate existing information on the role of beach-cast seaweed in coastal ecosystems to assess the nature and extent of the impacts that the removal of beach cast seaweed may have on the marine environment. 2. On the basis of the review in Specific Objective 1 above, to identify key research gaps related to any marine environment impacts that the removal of beach cast seaweed may have.	Completed	Zemke-White et al. 2005
ECO	ENV2002-07	Energetics and trophic relationships of important fish and invertebrate species	1. To quantify food webs supporting important fish and invertebrate species	Completed	Livingston 2004
ECO	CRA2000-01	Rock lobster stock assessment	Objective 11: To conduct a desktop study to identifi and explore data needs associated with managing the effects of rock lobsterfishing on the environment.	Completed	Breen 2005
ECO	ENV2000-04	Identification of areas of habitat of particular significance for fisheries management within the New Zealand EEZ	1. To review literature and existing data for all significant fish species, including all QMS species, encountered from the 200 1500 m contour within the New Zealand EEZ to: a) determine areas of important juvenile fish habitat; b) determine areas of importance to spawning fish populations; and c) determine areas of importance for shark populations for pupping or egg laying. 2. To review literature and existing data for all significant pelagic fish species (excluding highly migratory species) encountered within the New Zealand EEZ to: a) determine areas of important juvenile fish habitat; b) determine areas of importance to spawning fish populations; and c) determine areas of importance for shark populations for pupping or egg laying 3. To review literature and existing data for all significant marine invertebrate species encountered within the New Zealand EEZ to: a) determine areas of important juvenile habitat; and b) determine areas of importance to spawning populations	Completed	O'Driscoll *et al.* 2003
ECO	MOF2000-02A	Future research requirements for the Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) fishery.	Objectives unknown	Completed	Hanchet 2000

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
ECO	ENV99-03	Identification of areas of habitat of particular significance for fisheries management within the NZ EEZ.	1. To determine areas of habitat of importance to fisheries management within the New Zealand EEZ for selected fish species in selected areas	Completed	Hurst *et al.* 2000
ECO	ENV99-04	A framework for evaluating spatial closures as a fisheries management tool	Unknown	Completed	Bentley *et al.* 2004
ECO	No project number	The fishery for freshwater eels (*Anguilla spp.*) in New Zealand	Objectives unknown	Completed	Jellyman 1994
BIO	ZBD2014-01	Live corals: Age and growth study of deepsea coral in aquaria.	Ocean acidification and temperature manipulation are now underway to look at the physiological responses (e.g., growth) of deepsea corals to future predicted environmental conditions.	Ongoing	
BIO	ZBD2013-02	VME Genetic Connectivity	This project addresses the critical lack of data concerning deep sea genetic connectivity of VME indicator taxa, and will clarify the spatial relationships and distribution of biodiversity of several protected invertebrate VME species within New Zealand's EEZ and beyond.	Ongoing	
BIO	ZBD2013-03	Continuous Plankton Recorder - Phase 2	The overall objective of the CPR programme is to map changes in the quantitative distribution of epipelagic plankton, including phytoplankton, zooplankton and euphausiid (krill) life stages, in New Zealand's EEZ and transit to the Ross Sea, Antarctica. To enable trend analysis, the Contractor will continue the annual time series for a further 5 year period (years 6-10).	Ongoing analys is	
BIO	ZBD2013-06	Shell generation and maintenance of aquaculture species	Shells of individuals of NZ paua, flat oysters and cockles will undergo detailed analysis to determine how the decreased pH/increased temperature modified their shell (i) thickness, (ii) mineralogy and (iii) construction.	Underway	
BIO	ZBD2013-07	Interactive keys for easy identification keys ofamphipods	Generate interactive identification keys for marine Amphipoda families Synopiidae and Epimeriidae for easy and free use online.	Underway	
BIO	ZBD2012-01	Tier 1 Stat. Marine Biodiversity	To perform a preliminary investigation of the utility and feasibility of developing the variables published by Costello et al (2010) as a Tier 1 statistic.	Approved for publication	Lundquist *et al.* Submitted
BIO	ZBD2012-03	Chatham Rise Benthos - Ocean Survey	1. In relation to the Fishing Intensity Effects Survey, determine whether there are quantifiable effects of variations in seabed trawling intensity on benthic communities. 2. In relation to the Crest Survey, conduct seabed mapping and photographic surveys in previously un-sampled areas on the central crest of the Chatham Rise.	Ongoing analys is	Pinkerton *et al* Submitted

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	SRP2011-02	IDG 2009-01 MPI fish ID field guide	1. IDG 2009-01 field guide	Completed	McMillan 2011 a,b,c
BIO	ZBD2011-01	Evaluation of ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in NZ waters	Evaluation of ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in NZ waters	Completed	Horn *et al.* 2013
BIO	ZBD2010-39	Improved benthic invertebrate species identification in trawl fisheries	1. To revise and update the document "A guide to common deepsea invertebrates in New Zealand waters (second edition)" to allow a third edition of this guide to be printed	Completed	Tracey *et al.* 2011a
BIO	ZBD2010-40	Predictive modelling of the distribution of vulnerable marine ecosystems in the South Pacific Ocean region.	1. To develop & test spatial habitat modelling approaches for predicting distribution patterns of vulnerable marine ecosystems in the convention Area of the South Pacific Regional Fisheries Management Organisation with agreed international partners. 2. To collate datasets and evaluate modelling approaches which are likely to be useful to predict the distribtuion of vulnerable marine ecosystmes in the South pacific Ocean region.	Completed	Rowden *et al* 2013
BIO	ZBD2010-41	Ocean acidification in fisheries habitat	1. To assess the risks of ocean acidification to deep sea corals and deepwater fishery habitat 2. To determine the carbonate mineralogy of selected deep sea corals found in the New Zealand region 3. To assess the distribution of deep sea coral species in the New Zealand region relative to improved knowledge of current and predicted aragonite and calcite saturation horizons, assessment of potential locations vulnerable to deep water upwelling 4. Through a literature search and analysis, determine the most appropriate tools to age and measure the effects of ocean acidification on deep sea habitat-forming corals, and recommend the best approach for future assessments of the direct effects	Completed	Tracey *et al.* 2011b

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2009-25	Predicting impacts of increasing rates of disturbance on functional diversity in marine benthic ecosystems	1. Further develop the landscape ecological model of disturbance/recovery dynamics in marine benthic communities, incorporating habitat connectivity, based on existing model by Lundquist, Thrush, and Hewitt. 2. Predict impacts of increasing rates of disturbance on rare species abundance, functional diversity, relative importance of biogenic habitat structure, and ecosystem productivity. 3. Use literature and expert knowledge to quantify rare species abundance, biomass, functional diversity, habitat structure, and productivity of various successional community types in the model. 4.Field test predictions of the model in appropriate marine benthic communities where historical rates of disturbance are known, and benthic communities have been sampled.	Completed	Lundquist *et al.* 2010; Lundquist *et al.* 2013
BIO	IPA2009-14	Bryozoan identificaiton guides	1. For each of ~50 species of common bryozoans, provide photos and text to allow for identification. Provide information on distribution and habitat (as far as is known) and further references for each species and on bryozoans as a whole. 2. Submit these data for publication in the Ministry of Fisheries series New Zealand Aquatic Environment and Biodiversity Research.	Completed	Smith & Gordon 2011
BIO	ZBD2009-03	To evaluate the vulnerability of New Zealand rhodolith species to environmental stressors and to characterise diversity of rhodolith beds.	1. To characterise the distribution and physical characteristics of two New Zealand rhodolith beds and characterise the associated biodiversity. 2. To measure the growth rates and evaluate the vulnerability of New Zealand species of rhodoliths to environmental stressors.	Completed	Nelson *et al.* 2012
BIO	ZBD2009-10	Multi-species analysis of coastal marine connectivity	1. Determine overall patterns of regional connectivity in a broad range of NZ coastal marine organisms to define the geographic units of genetic diversity for protection and the dispersal processes that maintain this diversity. 2. Review previous studies of marine connectivity and population genetics in NZ coastal organisms to determine the preliminary range of patterns observed and the principal gaps (taxonomic geographic and ecological) in our understanding. 3. In a range of invertebrate and vertebrate marine organisms determine geographic patterns of genetic variation using standardised sampling and molecular techniques. 4. Analyse data across past and present studies to reveal both common and unique patterns of connectivity around the NZ coastline and the locations of common barriers to dispersal.	Completed	Gardner *et al.* 2010

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BIO	ZBD2009-13	Ocean acidification impact on key nz molluscs	1. Controlled laboratory experiments will be used to determine the effect of pCO2 levels that are predicted to occur in NZ waters over the next few decades on appropriate life history stages of at least two key NZ mollusc species. A number of response variables will be assessed. 2. Implications of these responses to the local and broader ecosystems will be assessed.	Completed	Cummings 2011; Cummings *et al.* 2011b; Cummings *et al* Submitted
BIO	ZBD2008-01	Biogenic large–habitat–former hotspots in the near-shore coastal zone (50–250 m); quantifying their location, identity, function, threats and protection	1. To collect and integrate existing knowledge on biogenic habitat-formers in the <5–150 m depth zone of New Zealand's continental shelf, from sources including structured fisher interviews, primary and grey literature, and other sources as available. 2. Using the findings of Objective 1, design and deploy a series of sampling voyages to selected locations, to map and characterise locations of significant biogenic structure (either still existing, or historical), and collect relevant biological samples (both through visual census, and physical collection). 3. Process and analyse the samples collected in Objective 2, to provide a hierarchical, quantitative description of the biogenic habitats and associated species encountered. 4. Using the findings from Objective 1–3, assess the present status, likely extent, ecological role, and threats to, biogenic habitat formers in the <5–150 m depth zone. This should include a spatial modelling and risk assessment framework. Integrate (as appropriate) with other information sources and/or approaches that may exist by the year 2010/11.	Ongoing analysis	
BIO	ZBD2008-05	Macroalgal diversity associated with soft sediment habitats	1. Conduct a targeted collection programme across diverse soft sediment environments to develop a permanent reference collection of representative macroalgae. 2. Examine algal distribution in soft sediment habitats in relation to selected environmental variables. 3. Prepare an annotated checklist of macroalgae found in soft sediment environments in the New Zealand region.	Completed	Neill *et al.* 2012
BIO	ZBD2008-07	Carbonate sediments: the positive and negative effects of land-coast interactions on functional diversity	1. To quantify shifts in community structure and functional diversity in mollusc dominated habitats along gradients associated with an estuary-coast interface in two locations. 2. To characterise the influence of estuary-derived food sources across these gradients for key species. 3. To measure changes in growth of key species in relation to changes in food supply and land-derived sediment impacts. 4. To quantify carbon and nitrogen uptake and tissue turnover rates of key species in laboratory experiments.	Completed	Thrush *et al.* In Press; Savage *et al.* 2012

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2008-11	Predicting changes in plankton biodiversity and productivity of the EEZ in response to climate change induced ocean acidification	1. To document the spatial and inter-annual variability of coccolithophore abundance and biomass- and assess in terms of the phytoplankton abundance-biomass and community composition in sub-tropical and sub-Antarctic water. 2. To document the seasonal and inter-annual variability of foraminifera and pteropod abundance and biomass at fixed locations in sub-tropical and sub-Antarctic water by analysis of sediment trap material from time-series data collection. 3. To document the spatial and seasonal distribution of the key coccolithophore species- *Emiliana huxleyi*- using both archived and ongoing ingestion of satellite images of Ocean Colour- and ground-truth the reflectance. 4. To determine the sensitivity of- and response of *E. huxleyi* and other EEZ coccolithophores to pH under a range of realistic atmospheric CO2 concentrations in perturbation experiments- using monocultures and mixed populations from in situ sampling. 5. To document the spatial variability of diazotrophs (nitrogen-fixing organisms) and associated nitrogen fixation rate- and assess in terms of phytoplankton abundance- biomass and community composition in sub-tropical waters north of the STF. 7. To determine the sensitivity of- and response of *Trichodesmium* spp. and other diazotrophs to pH under a range of realistic atmospheric CO2 concentrations in perturbation experiments using monocultures	Ongoing analysis	Law *et al.* 2012: Boyd & Law 2011
BIO	ZBD2008-14	What and where should we monitor to detect long-term marine biodiversity and environmental changes- remote sensing, biota, context, inshore offshore workshop	1. Identify the key questions to be addressed by long-term monitoring of marine biodiversity and environment. 2. Identify appropriate monitoring indices, how they should be spatially distributed and their sampling frequency. 3. Identify relevant existing monitoring programmes across the range of New Zealand agencies and science providers and identify gaps. 4. Provide those agencies setting environmental goals/ standards or research needs (MoRST, FRST, MFish, DoC, MfE, Commissioner for the Environment) with a thorough situational analysis, including a list of priority monitoring projects/plans.	Ongoing analysis	Livingston 2009

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BIO	ZBD2008-15	Continuous plankton recorder project: implementation and identification	1. To set up a time series of annual CPR data collection by deployment from a toothfish vessel on the annual summer transit between New Zealand and the Ross Sea. 2. To identify phytoplankton and zooplankton according to strict observation protocols determined by the SAHFOS[1] CPR Survey and SO-CPR[2]. 3. To enter species data, frequency and location along the transect into a spreadsheet that will allow spatial mapping of the plankton density and distribution. 4. To analyse the full dataset after 5 years of data collection to: (a) determine trends in the dataset and (b) compare results with Australian datasets available through SO-CPR. 5. To evaluate the continuation of the programme	Completed	Robinson *et al.* 2014
BIO	ZBD2008-20	Ross sea benthic ecosystem function: predicting consequences of shifts in food supply	1. To increase understanding of Ross Sea coastal benthic ecosystem function 2. Conduct in situ investigations into responses to and utilisation of primary food sources by key species, at two contrasting coastal Ross Sea locations	Completed	Cummings & Lohrer 2011; Cummings *et al.* 2011a; Lohrer *et al.* 2012
BIO	ZBD2008-22	Acidification and ecosystem impacts in NZ and southern ocean waters (data collected during IPY).	1. To assess the response of cocolithophorids, and their replacement by non-calcifying organisms during incubation under a range of dissolved CO2 concentrations. 2. To describe and characterise changes in abundance and biodiversity of microbial components of the samples incubated at sea under a range of dissolved CO2 concentrations. 3.To predict the likely impacts of higher acidity on foodwebs and on carbon fixation under scenarios to be encountered in the Southern Ocean under forecasted trends associated with climate change.	Completed	Maas *et al.* 2010b
BIO	ZBD2008-23	Macroalgae diversty and benthic community structure at the Balleny Islands	1. To describe and characterise macroalgae diversity from the Balleny Islands and the Western Ross Sea. 2. To describe and quantify benthic community structure from one location at the Balleny Islands 3. To complete anatomical and morphological investigations & molecular sequencing required for the identification of macroalgae samples from the Balleny Islands & western Ross Sea coastline to describe & characterise macroalgae diversity in Balleny Isds 4. To process and analyse samples collected at the Balleny Islands- to analyse them using ICECUBE methodology- and compare results with those from other ICECUBE sampling locations along the Ross Sea coastline	Completed	Nelson *et al.* 2010

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BIO	ZBD2008-27	Scoping investigation into New Zealand abyss and trench biodiversity	1. Review what is already known of abyssal, canyon and trench faunas in NZ. 2. Review what is already known of abyssal, canyon and trench faunas around the world. 3. Prioritise science questions and locations for exploration. 4. Assess NZ capacity to sample at the required depths; identify sampling equipment needs. 5. Design a suitable vessel-based sampling programme	Completed	Lörz *et al.* 2012
BIO	ZBD2008-50	OS2020 Chatham Rise Biodiversity Hotspots	1. To improve understanding of the effects of trawl fishing in New Zealand on the biodiversity of seamounts- knolls and hills. 2. To describe differences in benthic biodiversity between northwestern and eastern regions of the Chatham Rise 3. To continue the time series of observations in the NW Chatham Rise to demonstrate recovery in terms of biodiversity 4. To extend the observations on fished-unfished contrasts and recovery of fauna on protected seamounts to an oceanographically distinct location	Completed	Clark *et al.* 2009

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BIO	IPY2007-01	International polar year census of antarctic marine life post-voyage analysis:Ross Sea - Southern Ocean Biodiversity	1. To measure seabed depth and rugosity using the multibeam system to identify topographic features such as bottom type, iceberg scouring, seamounts etc and to determine areas for targeted benthic faunal sampling. 2. To continue the analysis of opportunistic seabird and marine mammal distribution observations from this and previous BioRoss voyages and published records, and in relation to environmental variables. 3. To identify and determine near-surface spatial distribution, diversity and abundance of phytoplankton, and zooplankton, based on Continuous Plankton Recorder samples collected during transit to and from the Ross Sea. 4. To collect & analyse data collected both underway, & at stations for salinity, temperature nutrient and chlorophyll a data, spot optical measurements with the SeaWiFS. 5. To identify and determine the spatial distribution, abundance (biomass), diversity, and size structure of epipelagic, mesopelagic (and possibly bathypelagic) species using acoustics and net sampling. 6. To identify and measure diversity, distribution & densities of mesozooplankton, macrozooplankton & meroplankton (as collected by all plankton sampling methods except transit CPR samples). 7. To determine diversity, distribution & densities of viral, bacterial, phytoplankton & microzooplankton species in the water column. 8. To determine the spatial distribution, abundance (biomass), diversity, and size structure of shelf and slope demersal fish species and associated invertebrate species using a demersal survey. 9. To determine the diversity, abundance/density, spatial distribution, and physical habitat associations of benthic assemblages across a body size spectrum from megafauna to bacteria, for shelf, slope, seamounts, and abyssal sites in Ross Sea. 10. To describe trophic/ecosystem relationships in the Ross Sea ecosystem (pelagic and benthic, fish and invertebrates). 11. Assess molecular taxonomy and population genetics of selected Antarctic fauna and flora to estimate evolutionary divergence within and among ocean basins in circumpolar species. Provide DNA barcoding.	Completed	Allcock *et al*. 2009; 2010; Submitted; Alvaro *et al.* 2011; Baird *et al.* 2014; Bowden *et al.* 2011a; In Prep; Clark *et al.* 2010a; Dettai et al. 2011; Eakin *et al*. 2009; Eleaume *et al*. 2011; In Prep; Ghiglione *et al.* 2012; Gordon 2000; Grotti *et al.* 2008; Hanchet *et al.* 2008a; 2008b; 2008c; 2008d; Hanchet 2009; 2010; Hanchet *et al.* 2013; Heimeier *et al.* 2010; Hemery *et al*. In prep; Koubbi *et al*. 2011; Leduc *et al.* 2012a; b; c; 2013; 2014; Linse *et al.* 2007; Lörz 2009; Lörz 2010a; 2010b; 2010c; Lörz & Coleman 2009; Lörz *et al*. 2007; 2009; 2012a; b;c ; In Prep; Maas *et al*. 2010a; McMillan *et al.* 2012.; Mitchell 2008; Nielsen *et al.* 2009; Norkko *et al.* 2005; O'Driscoll 2009; O'Driscoll *et al.* 2009; 2010; O'Driscoll *et al*. 2012; O'Loughlin *et al.* 2011; Pakhomov *et al*. 2011; Pinkerton *et al*. 2007a; Pinkerton *et al*. 2009; 2010; Pinkerton *et al*. 2010; 2013; Schiaparelli *et al*. 2006; 2008; 2010; Smith *et al*. 2011a; b; Stein 2012; Strugnell *et al.* 2012

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BIO	IPY2007-02	International polar year census of antarctic marine life post-voyage analysis:Ross Sea - Southern Ocean Biodiversity	1. To measure and describe key elements of species distribution- abundance (density or biomass) & biodiversity for the Ross Sea and Southern Ocean for main habitats and key functional ecosystem roles- for major groups- viruses- bacteria- archaea. 2. To report on the diversity of Antarctic Cephalopoda (Octopus and Squid)- including a complete inventory of taxa- & reports on ontogenetic & sexual variation in species- their systematics- diversity- distribution- life histories- & trophic importance. 3. To Beak/Biomass Regression Equations 4. Life cycle determination	Completed	Garcia 2010
BIO	ZBD2007-01	Chatham-Challenger Oceans 20/20 Post-Voyage	1. To quantify in an ecological manner- the biological composition and function of the seabed at varying scales of resolution- on the Chatham Rise and Challenger Plateau 2. To elucidate the relative importance of environmental drivers- including fishing- in determining sea bed community composition and structure. 3. To determine if remote-sensed data (e.g. acoustic) and environmentally derived classification schemes (e.g. marine environmental classification system) can be utilized to predict bottom community composition- function and diversity 4. To count- measure- and identify to species-level (where possible- otherwise to genus) all macro invertebrates (> 2 mm) and fish collected during Oceans 20/20 voyages. 5. To count- measure and identify to species-level (where possible- otherwise to genus or family) all meiofauna (> 2 mm) from multicore samples collected during the Oceans 20/20 voyages. 6. To count- measure and identify to species- level (where possible- otherwise to genus or family) all fauna collected by hyper-benthic sled during the Oceans 20/20 voyages. 7. To count- measure- and identify to species-level all macrofauna observed on DTIS images collected during the Oceans 20/20 voyages. The number of biogenic features (burrows/mounds) and habitat (spatial) complexity should also be estimated. 8. To count- measure- and identify to species-level (where possible- otherwise to genus or family) all macrofauna observed on DTIS video footage collected during the Oceans 20/20 voyages. 9. To calculate and compare the performance of a suite of diversity measures (species and taxonomic-based) at varying levels of resolution. 10. To estimate particle size composition and organic content of sediment samples. Sediment samples should be aggregated over the top 5 cm of	Completed	Bowden 2011; Bowden *et al.* 2011 ; 2014; Bowden & Hewitt 2012; Compton *et al.* 2012; Coleman and Lörz 2010; Hewitt *et al.* 2011a; 2011b; Lörz 2011a; 2011b; Nodder *et al.* 2012; Floerl et al. 2012

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			sediment. 11. To measure the bacterial biomass (top 2 cm) of the sediment and in the sediment surface water samples- collected during the Oceans 20/20 voyages 12. To elucidate the relationships- patterns and contrasts in species composition- assemblages- habitats- biodiversity and biomass (abundance) both within and between stations- strata and areas. 13. To define habitats (biotic) encountered during the survey and assess their relative sensitivity to modification by physical disturbance- their recoverability and their importance to ecosystem function / production. 14. To quantify the productivity- energy flow (trophic networks) and the energetic coupling (bentho pelagic or otherwise) of the area surveyed areas at various levels of resolution. 15. To assess the extent to which patterns of species distributions and communities can be predicted using environmental data (including fishing) collected during the Ocean 20/20 voyages or held in other databases. 16. To provide an interactive- high resolution mapping facility for displaying & plotting all data collected & derived indices. Includes environmental data- the abundance of species- indices of biomass or diversity- and statistically derived groupings 17. To assess the extent to which acoustic- environmental- or other remote-sensed data can provide cost-effective- reliable means of assessing biodiversity at the scale of the Oceans 20/20 surveys. 18. To assess the extent to which the 2005 MEC and subsequent variants can provide cost-effective- reliable means of assessing biodiversity at the scale of the Oceans 20/20 surveys. 19. Collating all information and analysis from all objectives- devise a series of statistically supported recommendations for surveying marine biodiversity in the future. Including- but may not be limited to- statistical analyses and modelling.		

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BIO	ZBD2006-02	Ongoing NABIS development	As part of NABIS, users will be able to identify spatial information relating to the annual distribution (average distribution over the period of a year) of particular species within the waters around New Zealand and in the terrestrial environment (including off shore islands) of New Zealand. Users will also be able to interrogate metadata and attribute data related to the information layers presented. Users will employ NABIS to identify where a particular species is found, to identify what species are found within an area of interest, and be able to compare the spatial distribution of a particular species with other information layers. 2. Some species may have notable changes in their spatial distribution throughout a year. For such species, users of NABIS will be able to view spatial information relating to the seasonal distribution of particular species within the waters around New Zealand and in the terrestrial environment (including offshore islands) of New Zealand. Users will also be able to interrogate metadata and attribute data related to the information layers presented. For species with a seasonal component to their biological distribution, users will employ NABIS to identify where a particular species is found within the waters around New Zealand and in the terrestrial environment (including off shore islands) of New Zealand at a particular time of the year, to identify what species are found within an area of interest at a particular time of year, or be able to compare the distribution of a particular species at a particular time of year, with other information layers. 3. To provide analysis of the data used in determining the hotspot distribution.	Completed	Anderson 2007b
BIO	ZBD2006-03	Antarctic coastal marine systems	1. Quantify patterns in benthic community structure and function at two coastal Ross Sea locations (Terra Nova Bay and Cape Evans). 2. Quantify benthic community structure and function at selected locations in Terra Nova Bay and Cape Evans.	Completed	Cummings *et al.* 2003; 2006b; 2008; Thrush & Cummings 2011; Thrush *et al.* 2010

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BIO	ZBD2006-04	Chatham/challenger oceans 20/20	1. To collect seabed fauna, sediment samples and photographic images along transects in the Chatham Rise and the Challenger Plateau, as determined by the sampling protocol described in the Voyage Programmes for Voyages 2 and 3 of the project. Multibeam data should be collected opportunistically as time allows. 2. To describe the distribution of broad macro epifauna groups (I.D. level to be determined at sea during Surveys 2 & 3), their relative abundance, the substrate and habitat types, including representative photographic images of each sea-bed habitat and associated fauna along transects in the survey areas. 3. To provide a description of the observed evidence of fishing along transects. 4. To provide indicative measures of alpha biodiversity (richness, number of taxonomic groups) at appropriate scales within and between transects, and between the Chatham Rise and the Challenger Plateau. 5. To determine broad scale variability in sea-bed habitats and associated biodiversity within and between MEC classes at 20 class level. 6. To process and archive biological samples and data into databases and collections for future analysis in meeting the Overall Objectives above.	Completed	Nodder 2008; Nodder *et al.* 2011

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BIO	ZBD2005-01	Balleny Islands Ecology Research, Tiama Voyage (2006)	1. To characterise shallow benthic communities across a range of habitat settings around the Balleny Islands, utilising a range of data collection methodologies (including SCUBA-based rock-wall suspension feeder photo quadrats, SCUBA-based linear video transects, and drop camera photography), and to analyse community patterns with reference to possible physical/oceanographic, biological, and/or biogeographic influences on community structure. 2. To characterise aspects of the marine food web of the Balleny Islands area, using stable isotope analysis of specimens from important functional groups, and to make inferences about factors affecting ecosystem-scale trophodynamics in the Balleny Islands area and potential implications for the function of the wider ecosystem. 3. To characterise the spatial and temporal distributions of higher-level consumer species (birds, seals and whales) and of dominant pelagic prey (i.e. krill swarms) by opportunistically recording all at-sea sightings, and by systematic observation of landbased top predators (birds and seals) while sailing along the coast of the islands. 4. To collect and photograph and/or retain fish specimens from shallow benthic environments using a range of fishing methods, including food-baited fish traps, lightbaited fish traps, rotenone sampling, and/or baited lines. 5. To continuously collect bathymetric data and water-column acoustic data (i.e. mesopelagic acoustic marks) throughout the voyage, using an acoustic sounder. 6. To opportunistically collect a variety of data/materials during shore-based landings, including wherever possible: i) breast feathers from living penguins; ii) tissue samples/feathers/bones from dead seals/penguins/other sea birds; iii) seal scats; iv) visual estimates of adult and juvenile penguin numbers; v) visual assessments of penguin colony status; vi) photographs of penguin colonies; vii) sediment excavations of occupied and abandoned colonies. (Where appropriate these data will contribute to Objective 2).	Terminated	Smith 2006
BIO	ZBD2005-02	Marine Environment Classification Project	1. Co-fund the Marine Environment Classification Project (being done by NIWA) with the Department of Conservation.	Completed	Snelder *et al.* 2005; 2006; Leathwick *et al.* 2006a; b; c

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BIO	ZBD2005-03	Tangaroa ross sea voyage	1. To test the feasibility of obtaining estimates of demersal fish relative abundance using cameras with and without flood lights in areas of high importance for the Ross Sea toothfish fishery (principally 800-1200 m). 2. To utilise deepwater camera transects, supported by other direct sampling methods, to characterise the relative abundance, distribution, and diversity of demersal fish species (assuming Objective 1 yields satisfactory results) and of benthic macro-invertebrates, and to examine relationships between demersal fishes and benthic habitats/communities. Camera transects will be deployed opportunistically, with focus on the following high-priority areas (in order of high to low priority) wherever possible: i) Areas of the continental shelf break at depths of high importance for the toothfish fishery (principally 800-1200 m but also 600-800m & 1200-1500 m if time permits), ii) Shallow (50-200 m) water in the immediate vicinity of the Balleny Islands; iii) Deeper water in the vicinity of the Balleny Islands; iv) seamounts around and between Scott Island and the Balleny Islands; and v) at other locations (< 600 m) as opportunity arises (e.g. around Scott Island, western Ross Sea, south-eastern Ross Sea). 3. To collect specimens/tissues of selected benthic and pelagic organisms with priority in the vicinity of the Balleny Islands (and to the east/southeast, for pelagic specimens especially Antarctic krill species) and deliver specimens to other projects for stable isotope analysis in order to contribute to understanding of trophic relationships. 4. To acquire a continuous acoustic survey of the water column, opportunistically undertake species verification of acoustic marks, integrate the acoustic marks and produce a GIS map of verified and unverified distributions of functionally important mesopelagic species (e.g. krill, Antarctic silverfish). 5. To undertake routine identification and abundance estimates of marine mammal and seabird species and deliver raw and GIS summarised data to other related projects in order to generate spatially and temporally explicit population biomass and foraging distribution estimates for top air-breathing predators in the Ross Sea. 6. To undertake automated water sampling in order to monitor the identities and spatial and temporal distributions of plankton in the Ross Sea region and to allow ground-truthing of data collection from satellites (e.g. surface seawater temperature, and chlorophyll-a concentration).	In the process of publication	MacDiarmid & Stewart In Press; Mitchell & MacDiarmid 2006

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BIO	ZBD2005-05	Long-term effects of climate variation and human impacts on the structure and functioning of New Zealand shelf ecosystems	1. To estimate changes in marine productivity via fluctuations in ocean climate and terrestrial nutrient input over the last 1000 years. 2. To assess and collate existing archaeological, historical and contemporary data (including catch records and stock assessments) on relevant components of the marine ecosystem to provide a detailed description of change in the shelf marine ecosystem in two areas of contrasting human occupation over last 1000 years. 3. To collect additional oral histories from Maori and non-Maori fishers and shellfish gathers regarding the distribution, sizes and relative abundance (compared to present availability) of key fish and invertebrate stocks in both regions during the first half of the 20th century before the start of widespread modern industrial fishing. 4. To build mass-balance ecosystem models (e.g. Ecopath) of the coastal and shelf ecosystem in each area for five critical time periods: now, 60 years BP (before modern industrial fishing), 250 years BP (before European whaling and sealing), 600 y BP (early Maori phase) and 1000 years BP (before human settlement). 5. To use qualitative modelling techniques to determine the critical interactions amongst species and other ecosystem components in order to identify those that should be a priority for future research.	In the process of publication	Carroll *et al.* Submitted; Jackson *et al.* Submitted; Lalas *et al.* In Press, 2014; Lalas & MacDiarmid 2014; Lorrey *et al.* 2013; MacDiarmid *et al.* Submitted a; b c; d; Maxwell & MacDiarmid Submitted; McKenzie & MacDiarmid Submitted; Neil et al. In Press; Paul 2012; 2014; Parsons *et al.* In Press; Pinkerton Submitted; Smith 2011
BIO	ZBD2005-09	Rocky reef ecosystems - how do they function? Integrating the roles of primary and secondary production, biodiversity and connectivity across coastal habitats	1. To develop a qualitative numerical model of how New Zealand's rocky reef systems are functionally structured 2. To quantify the effects of human predation, and environmental degradation across reef gradients – top-down, or bottom-up functioning? 3. To advance our understanding of how subtidal reef systems are fuelled through primary and secondary production (from a range of sources), the role that biodiversity plays, and how this varies across different reef settings. 4. To quantify how subtidal reef systems are linked with other habitats and ecosystems at broader spatial scales, including the connectivity of MPAs with other habitats and areas.	In the process of publication	MacDiarmid *et al.* Submitted e
BIO	ZBD2004-01	Baseline information on the diversity and function of marine ecosystems	1. To quantify, and compare, the macro-invertebrate assemblage composition of a number of seamounts at the southernmost end of the Kermadec volcanic arc. 2. To compare the macro-invertebrate diversity of the southernmost end of the Kermadec volcanic arc with that of seamounts already sampled and reported on.	Completed	Rowden & Clark 2010; Smith *et al.* 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2004-02	Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the chatham rise	1. To quantitatively characterise the diets of abundant middle-depth fish species on the Chatham Rise, by analysis of fish stomach contents collected from the January 2005, January 2006 and January 2007 Chatham Rise middle-depths trawl surveys. 2. To quantitatively characterise Chatham Rise fish diets throughout the year, for a period of 24 months, by analysis of fish stomach contents collected opportunistically aboard industry vessels. 3. To describe and examine patterns of diet variation within each fish species as a function of spatial, temporal, and environmental variables, and of fish size. 4. To define and characterise trophic guilds for abundant fish species on the Chatham Rise, using multivariate analysis of fish diet data, and to analyse the nature and relative strength of potential trophic interactions between guilds. 5. To create and populate a diets database to store all of the dietary information collected under Objectives 1 and 2, and for use in subsequent dietary studies.	Completed	Connell *et al.* 2010; Dunn 2009; Dunn *et al.* 2010a; b; c; Dunn *et al.* In press; Forman & Dunn 2010; Horn *et al.* 2010; Stevens & Dunn 2011;
BIO	ZBD2004-05	Assessment and definition of the biodiversity of coralline algae of northern New Zealand	1. To assess and define the biodiversity of coralline algae in northern New Zealand. 2. To develop rapid identification tools for coralline algae using molecular sequencing data. 3. To contribute representative material to the national Coralline Algal Collections. 4. To produce ID guides to common coralline algae of northern New Zealand.	Completed	Farr et al. 2009
BIO	ZBD2004-08	Sea-grass meadows as biodiversity and connectivity hotspots	1.Quantify the biodiversity values and functioning of New Zealand sea-grass assemblages 2.Complete national bio-geographic assessment of sea-grass associated biodiversity 3.Quantify sea-grass connectivity with surrounding marine landscapes through nursery functions and detritus export 4.Quantify sea-grass replication connectivity mechanisms 5.Develop a risk assessment and appraisal model for sea-grass systems	Ongoing analysis	Morrison *et al.* 2014 c
BIO	ZBD2004-10	Development of bioindicators in coastal ecosystems	1. Investigate linkages between land use patterns in catchments and nitrogen loading to recipient estuaries and coastal ecosystems 2. Characterise isotopic signatures of selected bioindicator organisms in relation to different terrestrial nutrient loads; and 3. Validate the use of bioindicators using controlled laboratory and field experiments.	Completed	Savage 2009

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2004-19	Ecological function and critical trophic linkages in New Zealand soft-sediment habitats	1. Define the interactive effects of two functionally important benthic species in maintaining critical trophic linkages in soft-sediment systems from a series of integrated field experiments. 2. Quantify effects of heart urchins (*Echinocardium australe*) on sediment properties- benthic primary production- and macrofaunal diversity through manipulative field experiments in Mahurangi Harbour. 3. Test for interactions between pinnid bivalves (*Atrina zelandica*) and heart urchins (*Echinocardium australe*) in field experiments- and measure their respective and combined contributions to sediment properties- benthic primary production- and macrofau na 4. Determine the dependence of results from objectives 1 and 2 (functional contributions of *Echinocardium* and *Atrina*) in an environmental context by conducting experiments along an estuarine-coastal gradient.	Completed	Lohrer *et al.* 2010
BIO	ZBD2003-02	Biodiversity of Coastal Benthic Communities of the North Western Ross Sea.	1. Quantify patterns in biodiversity and community structure in the coastal Ross Sea region 2. Quantify biodiversity in benthic communities at selected locations in the Ross sea north of Terra Nova Bay 3. Describe ecosystem function at selected locations in the Ross Sea north of Terra Nova Bay.	Completed	Cummings *et al.* 2003; 2006a; 2010; De Domenico et al. 2006; Guidetti et al. 2006; Norkko et al. 2004
BIO	ZBD2003-03	Biodiversity of deepwater invertebrates and fish communities of the north western Ross Sea	1. To describe, and quantify the diversity of, the benthic macroinvertebrates and fish assemblages of the Balleny Islands and adjacent seamounts, and to determine the importance of certain environmental variables influencing assemblage composition.	Completed	Rowden *et al.* 2012a; In Press; Mitchell & Clark 2004
BIO	ZBD2003-04	Fiordland Biodiversity Research Cruise	1. How can ecotone boundaries be defined? 2. If you have an ecotone boundary defining the edge of a commercial exclusion zone how wide is the transition zone across the boundary? 3. If you have an area delineated as a marine protected area or a commercial exclusion zone, does it adequately represent the different habitats or biodiversity of the whole region?	Completed	Wing 2005
BIO	ZBD2003-09	Macquarie Ridge Complex Research Review	To review and summarise both biological and physical research carried out on or around the section of the Macquarie Ridge Complex that lies between New Zealand and Macquarie Island	Completed	Grayling 2004
BIO	ZBD2002-01	Ecology of Coastal Benthic Communities in Antarctica	Objectives unknown	Completed	Schwarz *et al.* 2003; 2005; Thrush *et al.* 2006; Thrush & Cummings 2011; Cummings *et al.* 2003; Sharp *et al.* 2010; Sutherland 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2002-02	Whose larvae is that? Molecular identification of planktonic larvae of the Ross Sea.	1. To use molecular sequencing tools in the taxonomic identification of cryptic/invasive marine 2. To provide a molecular description and characterisation of gobies that are introduced (*Arenigobius bifrenatus* and *Acentrogobius pflaumii*) cryptogenic (*Parioglossus marginalis*) or native (eg.*Favonigobius lentiginosus* and *F. expuisitus*). 3. To describe the molecular diversity of the above species throughout their native and introduced distributions- and characterise a range of the greatest potential invasive gobioid and blennioid species from the Australasian region. 4. To develop molecular criteria to rapidly identify invasive or cryptogenic gobioid and blennioid fish	Completed	Sewell 2005; 2006; Sewell *et al.* 2006
BIO	ZBD2002-06A	Impacts of terrestrial run-off on the biodiversity of rocky reefs	1. Conduct field and laboratory experiments to determine relationships between sediment loading, epifaunal assemblages, and mortality of filter feeding invertebrates. 2. Conduct field and laboratory experiments to identify the influence of sediment on early life stages of key grazers. 3. Determine photosynthetic characteristics and survival of large brown seaweeds and understorey algal species in relation to a sediment gradient.	Completed	Schwarz *et al.* 2006
BIO	ZBD2002-12	Molecular identification of cryptogenic/invasive marine species – gobies.	1. To use molecular sequencing tools in the taxonomic identification of cryptic/invasive marine species 2. To provide a molecular description and characterisation of gobies that are introduced (*Arenigobius bifrenatus* and *Acentrogobius pflaumii*) cryptogenic (*Parioglossus marginalis*) or native (eg.*Favonigobius lentiginosus* and *F. expuisitus*). 3. To describe the molecular diversity of the above species throughout their native and introduced distributions- and characterise a range of the greatest potential invasive gobioid and blennioid species from the Australasian region. 4. To develop molecular criteria to rapidly identify invasive or cryptogenic gobioid and blennioid fish.	Completed	Lavery *et al.* 2006
BIO	ZBD2002-16	Joint New Zealand and Australian Norfolk Ridge	1. To describe the marine biodiversity of the Norfolk Ridge and Lord Howe Rise seamount communities. 2. To survey- sample and document the marine biodiversity and environmental data from seamounts on the Norfolk Ridge and Lord Howe Rise to a depth of at least 1-000m depth. (b) To preserve samples of fishes and invertebrates and hold these in ac...	Completed	Clark & Roberts 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2002-18	Quantitative survey of the intertidal benthos of Farewell Spit Golden Bay	1. To undertake a baseline survey of intertidal macrobenthic organisms at Farewell Spit Nature Reserve and adjacent flats. 2. To undertake an initial field survey of Zostera distribution at Farewell Spit Nature Reserve and adjacent intertidal flats. 3. To undertake a preliminary survey of sediment characteristics of the intertidal flats at Farewell Spit Nature Reserve and adjacent flats.	Completed	Battley *et al.* 2005
BIO	ZBD2001-02	Documentation of New Zealand Seaweed	1. To publish a regional algal flora of Fiordland based on voucher herbarium specimens. 2. To assemble a database of references and to review the current state of knowledge about New Zealand macroalgae.	Completed	Nelson et al. 2002
BIO	ZBD2001-03	Ecology and biodiversity of coastal benthic communities in Antarctica.	1. To develop sampling protocols for estimating the relative abundance of algae and benthic invertebrates 2. To quantify patterns in biodiversity and benthic community structure at two locations in McMurdo Sound 3. To analyse Ross Island Sea-Level data.	Completed	Norkko et al 2002
BIO	ZBD2001-04	“Deep Sea New Zealand”	To help publish the book "Deep Sea New Zealand"	Completed	Batson 2003
BIO	ZBD2001-05	Crustose coralline algae of New Zealand	1. To assess the biodiversity of crustose coralline algae in NZ using modern taxonomic methods and molecular sequence tools. 2. To establish the NZ National Coralline Algal Collection. 3. To produce identification guides to NZ species.	Completed	Harvey et al. 2005; Farr et al. 2009; Broom et al 2008
BIO	ZBD2001-06	Biodiversity of New Zealand’s soft-sediment communities	1. To review the current knowledge of the biodiversity of macroinvertebrates and macrophytes living in and on soft-sediment substrates in New Zealand“s harbours- estuaries- beaches and to 1000 m water depth. 2. To review existing published and unpublished sources of information on soft-sediment marine assemblages around New Zealand. 3. Using the results of Objective 1- identify gaps in the knowledge- hotspots of biodiversity- areas of particular vulnerability- and make recommendations on areas or assemblages that could be the subject of directed research in future years.	Completed	Rowden *et al.* 2012b

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2001-10	Additional Research on Biodiversity of Seamounts	1. To determine the macro-invertebrate assemblage composition on Cavalii seamount, and adjacent seamount W1, by photographic transects and epibenthic sled sampling. 2. To determine the distniution of macro-invertebrate assemblages on the seamounts. 3. To compare the macro-invertebrate species diversity of neighbouring seamounts. 4. To evaluate and collect samples fiom suitable macro-invertebrate species for genetic analysis. 5. To map bathymetry and habitat characteristics of the seamounts. 6. To compare macro-invertebrate assemblage composition of the seamounts with nearby hard bottom low relief (under 100 m) on the slope, if suitable areas can be located.	Completed	Rowden *et. al* 2004
BIO	MOF2000-01	Bryozoan thickets off Otago Peninsula	Objectives unknown	Completed	Batson & Probert 2000
BIO	ZBD2000-01	A review of current knowledge describing the biodiversity of the Ross Sea region	1. To review and document existing published and unpublished information describing the biodiversity of the Ross Sea region. 2. To identify and document Ross Sea region marine communities that are under high pressure or likely to come under high pressure from human activities in the near future.	Completed	Bradford-Grieve & Fenwick 2001a; 2001b; Fenwick & Bradford-Grieve 2002a; 2002b; Bradford-Grieve & Fenwick 2002; Varian 2005
BIO	ZBD2000-02	Exploration and description of the biodiversity, in particular the benthic macrofauna, of the western Ross Sea	1. To utilise sampling opportunities provided by the presence of RV Tangaroa in the western Ross Sea in February / March 2001 to make collections of (primarily) benthic organisms as a contribution to the understanding of biodiversity in the region. 2. To identify and document the organisms collected and provide for their proper storage in national collections. 3. To describe the logistic constraints of working in the Ross Sea region, and make recommendations for future research to improve understanding of biodiversity in the Ross Sea.	Completed	Page *et al.* 2001
BIO	ZBD2000-03	The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay	1. To assess the present state and extent of bryozoan communities around Separation Point. 2. To characterise the bryozoan communities around Separation Point.	Completed	Grange *et al.* 2003

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
BIO	ZBD2000-04	Supplementary Research on Biodiversity of Seamounts	1. To determine the biodiversity of seamounts of the southern Kermadec volcanic arc (Rumble V, Rumble 111, Brothers). 2. To describe the distribution of fauna, with an emphasis on mapping the nature and extent, of biodiversity associated with hydrothermal vents. 3. To compare the biodiversity of the thee seamounts, and adjacent slope. 4. To collect samples from near the vent sources (if possible, as these are thought to be very localised) to measure chemical and thermal aspects of the environment	Completed	Rowden *et al.* 2002 and 2003; Clark & O'Driscoll 2003
BIO	ZBD2000-06	"The Living Reef: The Ecology of New Zealand's Rocky Reefs"	1. Funding to support the publication of this book.	Completed	Andrew & Francis (Eds.) 2003
BIO	ZBD2000-08	A review of current knowledge describing New Zealand's Deepwater Benthic Biodiversity	1. To review and document existing published and unpublished reports and data describing New Zealand's deepwater benthic biodiversity. 2. To make recommendations on representative communities and potentially impacted communities that could be the subject of directed research.	Completed	Key 2002
BIO	ZBD2000-09	Antarctic fish taxonomy	1. Ross Sea fishes processing and identification	Completed	Roberts & Stewart & 2001

16.10REFERENCES

Abraham, E. (2008). Evaluating methods for estimating the incidental capture of New Zealand sea lions. New Zealand Aquatic Environment and Biodiversity Report No. 15: 25.

Abraham, E. (2010). Warp strike in New Zealand trawl fisheries, 2004-05 to 2008-09. New Zealand Aquatic Environment and Biodiversity Report No. 60: 29.

Abraham, E. (2011). Probability of Mild Traumatic Brain Injury for sea lions interacting with SLEDs. Unpublished Final Research Report for Ministry of Fisheries project SRP2011-03 (held by the Ministry of Fisheries, Wellington): 21.

Abraham, E., et al. (2010). The capture of seabirds and marine mammals in New Zealand non-commercial fisheries. New Zealand Aquatic Environment and Biodiversity Review. No. 64: 52.

Abraham, E. and A. Kennedy (2008). Seabird warp strike in the southern squid trawl fishery, 2004-05. New Zealand Aquatic Environment and Biodiversity Report No. 16: 39.

Abraham, E. and Y. Richard (In Press). Overlap of the distribution of black petrel (*Procellaria parkinsoni*) with New Zealand trawl and longline fisheries. New Zealand Aquatic Environment and Biodiversity Report: 35 p.

Abraham, E. and F. Thompson (2009). Capture of protected species in New Zealand trawl and longline fisheries, 1998-99 to 2006-07. New Zealand Aquatic Environment and Biodiversity Report No. 32: 197.

Abraham, E. and F. Thompson (2009). Warp strike in New Zealand trawl fisheries, 2004-05 to 2006-07. New Zealand Aquatic Environment and Biodiversity Report No. 33: 21.

Abraham, E. and F. Thompson (2010). Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998-99 to 2008-09. New Zealand Aquatic Environment and Biodiversity Report No. 80.: 172 p.

Abraham, E. and F. Thompson (2011). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002-03 to 2008-09. New Zealand Aquatic Environment and Biodiversity Report No. 79.: 74.

Abraham, E. and F. Thompson (2011). Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998-99 to 2008-09. Unpublished Final Research Report for the Ministry of Fisheries project PRO2007-01 170 p.

Abraham, E., et al. (2010). Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998-99 to 2007-08. New Zealand Aquatic Environment and Biodiversity Report No. 45: 148.

Allcock, A., et al. (2010). "Cryptic speciation and the circumpolarity debate: A case study on endemic Southern Ocean octopuses using the COI barcode of life." Deep Sea Research doi:10.1016/j.dsr2.2010.05.016.

Allcock, A., et al. (2009). Cryptic speciation and the circumpolarity debate: a case study on endemic Southern Ocean octopuses using the COI barcode of life. CAML Symposium. Genoa.

Allcock, A. and Others (Submitted). Bipolarity in marine invertebrates: myth or marvel. .

Alvaro, M., et al. (2011). "Skin-digging tanaids: the unusal parasitic behaviour of Exspinia typica in Antarctic waters and worldwide deep basins." CCAMLR document WG-FSA-10/P3 23:: 343-348.

Anderson, O. (2004). Fish discards and non-target fish catch in the trawl fisheries for arrow squid, jack mackerel, and scampi in New Zealand waters. New Zealand Fisheries Assessment Report 2004/10: 61.

Anderson, O. (2007). Fish discards and non-target fish catch in the New Zealand jack mackerel trawl fishery, 2001-02 to 2004-05. New Zealand Aquatic Environment and Biodiversity Report No. 8: 36.

Anderson, O. (2007). NABIS biological distributions. Unpublished Final Research Report for Ministry of Fisheries Project ZBD2006-02, held by the Ministry of Fisheries. : 20

Anderson, O. (2008). Fish and invertebrate bycatch and discards in ling longline fisheries, 1998-2006. New Zealand Aquatic Environment and Biodiversity Report No. 23: 43.

Anderson, O. (2009). Fish and invertebrate bycatch and discards in southern blue whiting fisheries, 2002–07. New Zealand Aquatic Environment and Biodiversity Report. No. 43: 42.

Anderson, O. (2009). Fish discards and non-target fish catch in the New Zealand orange roughy trawl fishery: 1999-2000 to 2004-05. New Zealand Aquatic Environment and Biodiversity Report No. 39: 40.

Anderson, O. (2011). Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990-91 until 2008-09. New Zealand Aquatic Environment and Biodiversity Report No. 67: 60.

Anderson, O. (2012). Fish and invertebrate bycatch and discards in New Zealand scampi fisheries from 1990–91 until 2009–10. New Zealand Aquatic Environment and Biodiversity Report No. 100: 65.

Anderson, O. (2013). Fish and invertebrate bycatch and discards in New Zealand arrow squid fisheries from 1990-91 until 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 112 62

Anderson, O. (2013). Fish and invertebrate bycatch in New Zealand deepwater fisheries from 1990-91 until 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 113: 57.

Anderson, O., et al. (2001). Fish discards and non-target catch in the trawl fisheries for orange roughy and hoki in New Zealand waters for the fishing years 1990-91 to 1998-99. New Zealand Fisheries Assessment Report 2001/16: 57.

Anderson, O. and M. Smith (2005). Fish discards and non-target fish catch in the New Zealand hoki trawl fishery, 1999/2000 to 2002/03. New Zealand Fisheries Assessment Report 2005/03: 37.

Andrew, N. and M. Francis, Eds. (2003). The living Reef: the ecology of New Zealand's Living Reef. Nelson, Criag Potton Publishing.

Ayers, D., et al. (2004). Fish bycatch in New Zealand tuna longline fisheries, 2000-01 and 2001-02. New Zealand Fisheries Assessment Report 2004/46: 47.

Baird, S. (1994). Nonfish Species and Fisheries Interactions Working Group Report. . N.Z. Fisheries Assessment Working Group Report 94/1, N.Z. Ministry of Agriculture and Fisheries, Wellington: 54.

Baird, S. (1995). Nonfish Species and Fisheries Interactions Working Group Report. . N.Z. Fisheries Assessment Working Group Report - April 1995. 95/1, N.Z. Ministry of Agriculture and Fisheries, Wellington: 24.

Baird, S. (1996). Nonfish Species and Fisheries Interactions Working Group Report. . N.Z. Fisheries Assessment Working Group Report - May 1996. 96/1, N.Z. Ministry of Agriculture and Fisheries, Wellington: 34.

Baird, S. (1997). Report on the incidental capture of nonfish species during fishing operations in New Zealand waters. Unpublished Final Research Report for Ministry of Fisheries SANF01 contract: 15 p plus appendices on New Zealand fur seal-trawl fishery interaction (54 p) and seabird-tuna longline fishery interaction (34 p).

Baird, S. (1999). Determination of factors which affect nonfish bycatch in some New Zealand fisheries. Unpublished Final Research Report for Ministry of Fisheries Project ENV9701 – Objective 3: 83.

Baird, S. (1999). Estimation of nonfish bycatch in commercial fisheries in New Zealand waters, 1997-98. Unpublished Final Research Report for Objective 1 of Ministry of Fisheries Project ENV9801: 57.

Baird, S. (2001). Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1998-99. New Zealand Fisheries Assessment Report 2001/14: 43.

Baird, S. (2003). New Zealand breeding seabirds: human-induced mortality — a review. Unpublished Report prepared for the Ministry of Fisheries Project ENV2000/09: 74.

Baird, S. (2004). Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999-2000. New Zealand Fisheries Assessment Report 2004/41: 56.

Baird, S. (2004). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000-01. New Zealand Fisheries Assessment Report 2004/58: 63.

Baird, S. (2004). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001-02. . New Zealand Fisheries Assessment Report 2004/60: 51.

Baird, S. (2005). Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2000-01. New Zealand Fisheries Assessment Report 2005-11: 34.

Baird, S. (2005). Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2002-03. New Zealad Fisheries Assessment Report 2005/12: 35.

Baird, S. (2005). Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2001-02. New Zealand Fisheries Assessment Report 2005/12: 33.

Baird, S. (2005). Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2002-03. New Zealand Fisheries Assessment Report 2005/8: 17.

Baird, S. (2005). Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2002-03. New Zealand Fisheries Assessment Report 2005/9: 13.

Baird, S. (2005). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002/03. New Zealand Fisheries Assessment Report 2005/02: 50.

Baird, S. (2007). Incidental capture of cetaceans in commercial fisheries in New Zealand waters 2003-04 and 2004-05. New Zealand Aquatic Environment and Biodiversity Report. No. 13: 27.

Baird, S. (2008). Incidental capture of cetaceans in commercial fisheries in New Zealand waters, 1994-95 to 2005-06. New Zealand Aquatic Environment and Marine Biodiversity Report No. 21: 29.

Baird, S. (2008). Incidental capture of New Zealand fur seals (*Arctocephalus Jorsteri*) in longline fisheries in New Zealand waters, 1994-95 to 2005-06. . New Zealand Aquatic Environment and Biodiversity Report No. 20: 21.

Baird, S. (2011). New Zealand fur seals - summary of current knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 72: 51.

Baird, S., et al. (2002). The spatial extent and nature of mobile bottom fishing methods within the New Zealand EEZ, 1989-90 to 1998-99. Unpublished Final Research Report for Objective 1 of project ENV2000/05. .

Baird, S., et al. (2010). To review the current threat status of selected associated or dependent species. Unpublished Final Research Report for the Ministry of Fisheries: 101.

Baird, S. and E. Bradford (1999). Factors that may influence the bycatch of nonfish species in some New Zealand fisheries. Unpublished final Research Report completed for Objective 3 of Ministry of Fisheries Project ENV9801: 106.

Baird, S. and E. Bradford (2000). Factors that may have influenced bycatch of New Zealand fur seals (*Arctocephalus forsteri*) in the west coast South Island hoki fishery. NIWA Technical Report 92: 35.

Baird, S. and E. Bradford (2000). Factors that may have influenced the capture of seabirds in New Zealand tuna longline fisheries. NIWA Technical Report 93: 61.

Baird, S. and L. Doonan (2005). *Phocarctos hookeri* (New Zealand sea lions): incidental captures in New Zealand commercial fisheries during 2000-2001 and in-season estimates of captures during squid trawling in SQU 6T in 2002. New Zealand Fisheries Assessment Report 2005/17: 18.

Baird, S., et al. (1998). Annual review of bycatch in southern bluefin and related tuna longline fisheries in the New Zealand 200 n. mile Exclusive Economic Zone. CCSBT-ERS/9806/31 (Report prepared for the Third Meeting of the Ecologically Related Species Working Group, Tokyo, 9-13 June 1998).

Baird, S. and D. Gilbert (2010). Initial assessment of risk posed by trawl and longline fisheries to selected seabird taxa breeding in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 50: 98.

Baird, S. and L. Griggs (2005). Estimation of within-season chartered southern bluefin tuna (*Thunnus maccoyii*) longline seabird incidental captures, 2003. New Zealand Fisheries Assessment Report 2OO5/01: 15.

Baird, S., et al. (In Press). Benthic habitat classes and trawl fishing disturbance in New Zealand waters shallower than 250 m. New Zealand Aquatic Environment and Biodiversity Report

Baird, S. and S. Mormede (2014). Environmental preferences of seabirds and spatial distribution of seabirds and marine mammals in the Ross Sea area. . New Zealand Aquatic Environment and Biodiversity Report No. 121.: 43.

Baird, S., et al. (1999). Estimation of nonfish bycatch in commercial fisheries in New Zealand waters, 1990-91 to 1993-94. Final Research Report for Ministry of Fisheries Project ENV9701 - Objective 1: 63.

Baird, S. and M. Smith (2007). Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003-04 and 2004-05. New Zealand Aquatic Environment and Biodiversity Report. No. 14: 98.

Baird, S. and M. Smith (2007). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2003-04 and 2004-05. New Zealand Aquatic Environment and Biodiversity Report No. 9: 108.

Baird, S. and M. Smith (2008). Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005-06. New Zealand Aquatic Environment and Biodiversity Report, No. 18: 124.

Baird, S. and B. Wood (2010). Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. Aquatic Environment and Biodiversity Report No. 89: 43.

Baird, S., et al. (2009). The extent of trawling on or near the seafloor in relation to benthic-optimised marine environment classes within the New Zealand EEZ. Unpublished Final Research Report for Objective 5 of project BEN200601. .

Baird, S., et al. (2011). Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. Mile Exclusive Economic Zone, 1989-90 to 2004-05. . New Zealand Aquatic Environment and Biodiversity Report No. 73: 143.

Baird, S., et al. (2006). Description of the spatial extent and nature of disturbances by bottom trawls in Chatham Rise and Southern Plateau fisheries. Unpublished Final Research Report for project ENV2003/03: 139.

Baker, B., et al. (2008). Data collection of demographic, distributional and trophic information on the Westland petrel to allow estimation of effects of fishing on population viability. Unpublished Final Research Report to the Ministry of Fisheries: 47.

Baker, B., et al. (2010). Data collection of demographic, distributional, and trophic information on the flesh-footed shearwater to allow estimation of effects of fishing on population viability: 2009— 10 Field Season. Unpublished Final Research Report for the Ministry of Fisheries 62.

Baker, G., et al. (2009). Data collection of demographic, distributional and trophic information on the white-capped albatross to allow estimation of effects of fishing on population viability — 2009 Field Season. Unpublished Research Report for the Ministry of Fisheries: 15.

Ballara, S. and O. Anderson (2009). Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 38: 102.

Ballara, S., et al. (2010). Fish discards and non-target fish catch in the trawl fisheries for hoki, hake, and ling in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report. No. 48: 100.

Batson, P. (2003). Deep New Zealand: Blue Water, Black Abyss. Christchurch, Canterbury University Press.

Batson, P. and P. K. Probert (2000). Bryozoan thickets off Otago Peninsula. New Zealand Fisheries Assessment Report 2000/46: 31.

Battley, P., et al. (2005). Quantitative survey of the intertidal benthos of Farewell Spit, Golden Bay. Marine Biodiversity Biosecurity Report No. 7: 119.

Beentjes, M. (2010). Toheroa survey of Oreti Beach, 2009, and review of historical surveys. New Zealand Fisheries Assessment Report 2010/6: 40.

Beentjes, M. and S. Baird (2004). Review of dredge fishing technologies and practice for application in New Zealand. New Zealand Fisheries Assessment Report 2004/37: 40.

Beentjes, M., et al. (2005). Non-fishing mortality of freshwater eels (Anguilla spp.). New Zealand Fisheries Assessment Report 2005/34: 38.

Bentley, N., et al. (2004). A framework for evaluating spatial closures as a fisheries management tool. New Zealand Fisheries Assessment Report 2004/25: 25.

Berkenbusch, K., et al. (2013). New Zealand marine mammals and commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 119: 104.

Black, J. and R. Tilney (Submitted). Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2010–2011. Draft New Zealand Aquatic Environment and Biodiversity Report: 49.

Black, J., et al. (2013). Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989-1990 to 2009-2010. New Zealand Aquatic Environment and Biodiversity Report No. 110, : 57.

Blackwell, R. (2010). Distribution and abundance of deepwater sharks in New Zealand waters, 2000-01 to 2005-06. New Zealand Aquatic Environment and Biodiversity Report No. 57: 51.

Blackwell, R. and M. Stevenson (2003). Review of the distribution and abundance of deepwater sharks in New Zealand waters. New Zealand Fisheries Assessment Report 2003/40: 48.

Booth, J., et al. (2002). Review of technologies and practices to reduce bottom trawl bycatch and seafloor disturbance in New Zealand. Unpublished Fisheries Research Assessment Report prepared for the Ministry of Fisheries as completion of ENV2000/06: 61.

Bowden, D. (2011). Benthic invertebrate samples and data from the Ocean Survey 20/20 voyages to the Chatham Rise and Challenger Plateau, 2007. New Zealand Aquatic Environment and Biodiversity Report No. 65: 40.

Bowden, D., et al. (In Press). Designing a programme to monitor trends in deep-water benthic communities. Draft New Zealand Aquatic Environment and Biodiversity Report.

Bowden, D., et al. (2011). Evaluation of the New Zealand Marine Environment Classifications using Ocean Survey 20/20 data from Chatham Rise and Challenger Plateau. . New Zealand Aquatic Environment and Biodiversity Report No. 77: 27.

Bowden, D., et al. (In Prep). "Population estimates of Ross Sea demersal fish: a comparison between video and trawl methods." (Submitted as short note to Fisheries Research).

Bowden, D. and J. Hewitt (2012). Recommendations for surveys of marine benthic biodiversity: outcomes from the Chatham-Challenger Ocean Survey 20/20 Post-Voyage Analyses Project New Zealand Aquatic Environment and Biodiversity Report, No. 91: 34.

Bowden, D., et al. (2014). Assessing the potential of multibeam echosounder data for predicting benthic invertebrate assemblages across Chatham Rise and Challenger Plateau. Aquatic Environment and Biodiversity Report No. 126.: 35.

Bowden, D., et al. (2011). "A lost world? Archaic crinoid-dominated assemblages on an Antarctic seamount." Deep Sea Research Part II: Topical Studies in Oceanography 58: 119-127.

Boyd, P. and C. Law (2011). An Ocean Climate Change Atlas for New Zealand waters:A primer for a major new web-based tool to help predict how oceanic species will be affected by climate change. NIWA Information Series No. 79 ISSN 1174-264X, : 24.

Bradford, E. (2002). Estimation of the variance of mean catch rates and total catches of non-target species in New Zealand fisheries. New Zealand Fisheries Assessment Report 2002/54: 60.

Bradford, E. (2003). Factors that might influence the catch and discards of non-target fish species on tuna long-lines. New Zealand Fisheries Assessment Report 2003/57: 75.

Bradford-Grieve, J. and G. Fenwick (2001). A review of the current knowledge describing the biodiversity of the Balleny Islands. Unpublished Final Research Report to the Ministry of Fisheries.

Bradford-Grieve, J. and G. Fenwick (2001). A review of the current knowledge describing the biodiversity of the Ross Sea region. Unpublished Final Research Report to the Ministry of Fisheries.

Bradford-Grieve, J. and G. Fenwick (2002). A review of the current knowledge describing the biodiversity of the Balleny Islands. Unpublished Final Research Report for Ministry of fisheries Project ZBD2000/01: xx.

Bradford-Grieve, J. and M. E. Livingston (2011). Spawning fisheries and the productivity of the marine environment off the west coast of the South Island, New Zealand. New Zealand Aquatic Environment and Biodiversity Report. 84: 136.

Breen, P. (2005). Managing the effects of fishing on the environment what does it mean for the rock lobster (*Jasus edwardsii*) fishery? New Zealand Fisheries Assessment Report 2005/73: 45.

Breen, P. (2008). Sea lion data for use in the population model for Project IPA200609. . Unpublished Final Research Report for Ministry of Fisheries, 30 March 2008 18 pp. plus Confidential Appendix of 16.

Breen, P., et al. (2010). Sea lion population modelling and management procedure evaluations. Unpublished Report for Project SAP2008/14, Objective 2: Presented to AEWG March 22 2010, Wellington, New Zealand: xx.

Breen, P. and S. Kim (2006). Exploring alternative management procedures for controlling bycatch of Hooker's sea lions in the SQU 6T squid fishery. Unpublished Final Research Report

For Ministry of Fisheries Project M0F2002/03L, Objective 3. Revision 5, 3 February 2006: 88.

Broom, J., et al. (2008). "Utility of psbA and nSSU for phylogenetic reconstruction in the Corallinales based on New Zealand taxa." Molecular Phylogenetics and Evolution 46: 958-973.

Carroll, E., et al. (Submitted). Estimating nineteenth and twentieth century right whale catches and removals around east Australia and New Zealand. New Zealand Aquatic Enviornment and Biodiversity Report: xx.

Clark, M., et al. (2010). Effects of fishing on the benthic biodiversity of seamounts of the "Graveyard" complex, northern Chatham Rise. New Zealand Aquatic Environment and Biodiversity Report, No. 46: 40.

Clark, M., et al. (2010). "Latitudinal variation of demersal fish assemblages in the western Ross Sea." CCAMLR document WG-FSA-10/P3 22(6): 782-792.

Clark, M. and R. O'Driscoll (2003). "Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand." Journal of Northwest Atlantic Fishery Science 31: 441–458.

Clark, M. and C. Roberts (2008). Fish and invertebrate biodiversity on the Norfolk Ridge and Lord Howe Rise, Tasman Sea (NORFANZ voyage, 2003). New Zealand Aquatic Environment and Biodiversity Report. No. 28: 131.

Clark, M. and A. Rowden (2009). "Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand." Deep Sea Research I 56: 1540-1554.

Clark, M., et al. (Submitted). Development of a methodology for ecological risk assessments for New Zealand deepwater fisheries. New Zealand Aquatic Environment and Biodiversity Report No. xx: 56.

Clark, M., et al. (2009). Voyage report of a survey of "seamounts" on the northwest and southeast Chatham Rise (TAN0905). Unpublished report available from NIWA, Wellington: 49.

Clark, M., et al. (2010). "A global seamount classification to aid the scientific design of marine protected area networks." Journal of Ocean and Coastal Management 54: 19-36.

Clark, M., et al. (2011). Development of seamount risk assessment: application to the ERAEF approach to Chatham Rise seamount features. New Zealand Aquatic Environment and Biodiversity Report No. 74: 18 p.

Clarke, S., et al. (2013). Review of shark meat markets, discard mortality and pelagic shark data availability, and a proposal for a shark indicator analysis. New Zealand Fisheries Assessment Report 2013/65: 77.

Clement, D. and R. Mattlin (2010). "Abundance, distribution and productivity of Hector's (and Maui's) dolphins." Unpublished Final Research report for the Ministry of Fisheries.

Cole, R., et al. (2007). Information on benthic impacts in support of the Southern Blue Whiting Fishery Plan. Unpublished Final Research Report for Ministry of Fisheries Research Project ZBD2005-16, Objectives 1-6.

Coleman, C. and A. Lörz (2010). "A new species of Camacho (Crustacea, Amphipoda, Aoridae) from the Chatham Rise, New Zealand." Zeitschrift fűr Zoologische Systematik und Evolutionsforschung 86(1): 33-40.

Compton, T., et al. (2012). "Biophysical patterns in benthic assemblage composition across contrasting continental margins off New Zealand." Journal of Biogeography: doi:10.1111/j.1365-2699.2012.02761.x.

Connell, A., et al. (2010). "Diet and dietary variation of New Zealand hoki *Macruronus novaezelandiae*." New Zealand Journal of Marine and Freshwater Research 44(4): 289 - 308.

Cryer, M., et al. (1999). Scampi stock assessment for 1998 and an analysis of the fish and invertebrate bycatch of scampi trawlers. New Zealand Fisheries Assessment Research Document 99/4: 74.

Cryer, M. and B. Hartill (2002). Relative impacts on benthic invertebrate community structure of trawl fisheries for scampi and finfish in the Bay of Plenty. Unpublished Final Research Report for Ministry of Fisheries Research Project ENV2000/05 Objective 2: 28.

Cryer, M., et al. (2004). The effects of trawling and dredging on bentho-pelagic coupling processes in the New Zealand EEZ. Final Research Report: 66.

Cryer, M., et al. (2000). Distribution and structure of benthic invertebrate communities between North Cape and Cape Reinga Unpublished Final Research Report for Ministry of Fisheries Research Project ENV1998-05 Objectives 1-4.

Cummings, V. (2011). Ocean acidification: impacts on key NZ molluscs. Unpublished Progress Report for ZBD2009-13: 6.

Cummings, V., et al. (Submitted). Ocean acidification: impacts on key NZ molluscs, with a focus on flat oysters (*Ostrea chiliensis*). New Zealand Fisheries Research Report. xx: xx.

Cummings, V., et al. (2011). "Ocean acidification at high latitudes: potential effects on functioning of the Antarctic bivalve *Laternula elliptica*." PLoS ONE 6 (1): e16069. doi:16010.11371/journal.pone.0016069.

Cummings, V. and D. Lohrer (2011). Ross Sea ecosystem function: predicting consequences of shifts in food supply. Unpublished Final Research Report for Ministry of fisheries Project ZBD2008-20, held by the Ministry of Fisheries: 53 p.

Cummings, V., et al. (2003). Ecology and biodiversity of coastal benthic communities in McMurdo Sound, Ross Sea: emerging results. Unpublished Final Research Report for the Ministry of Fisheries: xx.

Cummings, V., et al. (2010). "Macrobenthic communities of the north western Ross Sea shelf: links to depth, sediment characteristics and latitude." CCAMLR document WG-FSA-10/P3 22(6): 793-804.

Cummings, V., et al. (2008). Antarctic coastal marine ecosystems (ICECUBE). Unpublished Final Research Report for Ministry of Fisheries Research Project: 73.

Cummings, V., et al. (2006). "Accounting for local scale variability in benthos: implications for future assessments of latitudinal trends in the coastal Ross Sea." CCAMLR document WG-FSA-10/P3 18(4): 633-644.

Cummings, V., et al. (2006). Ecology of coastal benthic communities of the northwestern Ross Sea. New Zealand Aquatic Environment and Biodiversity Report. No. 6: 67.

Currey, R., et al. (2012). A risk assessment of threats to Maui's dolphins. Ministry for Primary Industries and Department of Conservation, Wellington: 51.

De Domenico, F., et al. (2006). "Latitude versus local effects on echinoderm assemblages along the Victoria Land coast, Ross Sea, Antarctica." CCAMLR document WG-FSA-10/P3 18(4): 655-662.

Dettai and (+45 authors) (2011). "DNA barcoding and molecular systematics of the benthic and demersal organisms of the CEAMARC survey." Polar Science 5 298-312.

Doonan, I. (1995). Incidental catch of Hooker's sea lion in the southern trawl fishery for squid, summer 1994. N.Z. Fisheries Assessment Research Document 95/22: 13.

Doonan, I. (1998). Estimation of sealion captures in southern fisheries in 1998. Final Research Report for Ministry of Fisheries Research Project ENV1997/01 Objective 2: 7.

Doonan, I. (2001). Estimation of Hooker's sea lion, *Phocarctos hookeri*, captures in the southern squid trawl fisheries, 2001. New Zealand Fisheries Assessment Report 2001/67: 10.

Doonan, I. J. (2000). Estimation of Hooker's sea lion, *Phocarctos hookeri*, captures in the southern squid trawl fisheries in 2000. New Zealand Fisheries Assessment Report 2000/41: 11.

Duckworth, K. (1995). Analyses of factors which influence seabird bycatch in the Japanese southern bluefin tuna longline fishery in New Zealand waters, 1989-93. New Zealand Fisheries Assessment Report 1995/26: 59.

Dunn, M. (2009). "Feeding habits of the ommastrephid squid *Nototodarus sloanii* on the Chatham Rise, New Zealand." Journal of marine and Freshwater Research 43: 1103-1113

Dunn, M., et al. (2010). "Diet of Two Large Sympatric Teleosts, the Ling (*Genypterus blacodes*) and Hake (*Merluccius australis*)." PLoS ONE 5(10): e13647. doi:13610.11371/journal.pone.0013647

Dunn, M., et al. (2010). "Feeding habits and niche separation among the deep-sea chimaeroid fishes *Harriotta raleighana*, *Hydrolagus bemisi* and *Hydrolagus novaezealandiae* " Marine Ecology Progress Series 407: 209-225.

Dunn, M., et al. (2009). Fish abundance and climate trends in New Zealand. New Zealand Aquatic Environment and Biodiversity Report. No. 31: 75.

Dunn, M., et al. (In Press). Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the Chatham Rise. New Zealand Aquatic Environment and Biodiversity Report.

Dunn, M., et al. (2010). "The diet of deepwater sharks and the benefits of using DNA identification of prey." Deep-Sea Research Part 1 57(7): 923-930.

Eakin, R., et al. (2009). "A new species and a molecular phylogenetic analysis of the Antarctic Fish Genus Pogonophryne (*Notothenioidei: Artedidraconidae*)." Copeia No. 4: 705-713.

Eléaume, M., et al. (2011). "A large new species of the genus Ptilocrinus (Echinodermata, Crinoidea, Hyocrinidae) from Antarctic seamounts." Polar Biology, DOI: 10.1007/s00300-011-0993-2.

Eleaume, M., et al. (In Prep.). "Southern Ocean crinoid diversity patterns and processes." Polar Biology.

Farr, T., et al. (2009). Common coralline algae of northern New Zealand: an identification guide. NIWA Information Series No. 70: 120.

Fenaughty, J., et al. (2003). "Diet of the Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea, Antarctica (Subarea 88.1)." CCAMLR Science 10: 113-123.

Fenwick, G. and J. Bradford-Grieve (2002). Human pressures on Ross Sea region marine communities: recommendations for future research. Unpublished Final Research Report for the Ministry of Fisheries: xx.

Fenwick, G. and J. Bradford-Grieve (2002). Recommendations for future directed research to describe the biodiversity of the Ross Sea region. Unpublished Final Research Report for the Ministry of Fisheries: xx.

Fletcher, D., et al. (2008). Modelling of impacts of fishing-related mortality on NZ seabird populations. Unpublished Final Research Report on ENV2004/05: xx.

Floerl, O., et al. (2012). Chatham-Challenger Ocean Survey 20/20 Post Voyage analyses: Objective 9 – Patterns in Species Composition. New Zealand Aquatic Environment and Biodiversity Report No. 97: 40.

Floerl, O., et al. (2012). Chatham-Challenger OS 20/20 Post Voyage Analyses: (ZBD2007-01) Objective 9- Patterns in species composition. . New Zealand Aquatic Environment and Biodiversity Report No. 97: 40.

Forman, J. and M. Dunn (2010). "The influence of ontogeny and environment on the diet of lookdown dory, *Cyttus traversi* " New Zealand Journal of Marine and Freshwater Research 44(4): 329-342.

Forrest, B., et al. (2007). Review of the Ecological Effects of Marine Finfish Aquaculture: Final Report. Unpublished Cawthron Report for the Ministry of Fisheries: 80.

Francis, M., et al. (2001). "Pelagic shark bycatch in the New Zealand tuna longline fishery." Marine and Freshwater Research 52: 165-178.

Francis, M., et al. (2004). Fish bycatch in New Zealand tuna longline fisheries, 1998-99 to 1999-2000. New Zealand Fisheries Assessment Report 2004/22: 62.

Francis, M., et al. (1999). Fish bycatch in New Zealand tuna longline fisheries. NIWA Technical Report 55: 70.

Francis, M., et al. (2000). Fish bycatch in New Zealand tuna longline fisheries, 1988-89 to 1997-98. NIWA Technical Report 76: 79.

Francis, M. and W. Lyon (2012). Review of research and monitoring studies on New Zealand sharks, skates, rays and chimaeras, 2008–2012. New Zealand Aquatic Environment and Biodiversity Report No. 102: 70.

Francis, M. and W. Lyon (2013). Review of anthropogenic impacts other than fishing on cartilaginous fishes. New Zealand Aquatic Environment and Biodiversity Report No. 107: 17.

Francis, M., et al. (2012). Rig nursery grounds in New Zealand: a review and survey. New Zealand Aquatic Environment and Biodiversity Report No. 95.

Francis, M. and M. Smith (2010). Basking shark (*Cetorhinus maximus*) bycatch in New Zealand fisheries, 1994-95 to 2007-08. New Zealand Aquatic Environment and Biodiversity Report No. 49: 57.

Francis, R. (2012). Fisheries Risks to the Population Viability of White-capped Albatross *Thalassarche steadi*. New Zealand Aquatic Environment and Biodiversity Report. No. 104: 24.

Francis, R. and E. Bell (2010). Fisheries risks to the population viability of black petrel (*Procellaria parkinsoni*). New Zealand Aquatic Environment and Biodiversity Report No. 51: 57.

Francis, R., et al. (2005). Environmental predictors of hoki year-class strengths: an update. New Zealand Fisheries Assessment Report 2005/58.

Garcia, A. (2010). Comparative study of the morphology and anatomy of octopuses of the family Octopodidae, Auckland University of Technology: 247.

Gardner, J., et al. (2010). Multi-species coastal marine connectivity: a literature review with recommendations for further research. New Zealand Aquatic Environment and Biodiversity Report. No. 58: 47.

Ghiglione, J.-F., et al. (2012). "Pole to pole biogeography of surface and deep marine bacterial communities." Proceedings of the national Academy of Sciences of the United States of America www.pnas.org/cgi/doi/10.1073/pnas.1208160109. .

Gordon, D. (2000). "The Pacific Ocean and global OBIS: a New Zealand perspective." Oceanography 13: 41-47.

Grange, K., et al. (2003). The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay. Marine Biodiversity Biosecurity Report No. 4: 22.

Grayling, S. (2004). A review of scientific studies conducted on the Macquarie Ridge. Unpublished Final Research Report (ZBD2003-09) for the Ministry of Fisheries: 33.

Griggs, L., et al. (2007). Fish bycatch in the New Zealand tuna longline fisheries 2002-03 to 2004-05. New Zealand Fisheries Assessment Report 2007/18: 58.

Griggs, L., et al. (2008). Fish bycatch in New Zealand tuna longline fisheries in 2005-06. New Zealand Fisheries Assessment Report 2008/27: 47.

Grotti, M., et al. (2008). "Natural variability and distribution of trace elements in marine organisms from Antarctic coastal environments." CCAMLR document WG-FSA-10/P3 20(1): 39-51.

Guidetti, M., et al. (2006). "Exchange between populations of *Adamussium colbecki* (Mollusca: Bivalvia) in the Ross Sea." CCAMLR document WG-FSA-10/P3 18(4): 645-653.

Hanchet, S. (2000). Future research requirements for the Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) fishery. Unpublished Final Research Report for MFish Research Project MOF2000/02A Objective 8: 10.

Hanchet, S., et al. (2008). Indicative estimates of biomass and yield of Whitson's grenadier (*M. whitsoni*) on the continental slope of the Ross Sea in Subareas 88.1 and 88.2. . WG-FSA-08/32.

Hanchet, S., et al. (2008). Ocean survey 20/20: New Zealand IPY-CAML Final Voyage Report. NIWA Client Report: WLG2008-74, October 2008: 193.

Hanchet, S., et al. (2008). Preliminary report of the New Zealand RV Tangaroa IPY-CAML survey of the Ross Sea region, Antarctica in February-March 2008. Unpublished NIWA report to CCAMLR working group on ecosystem monitoring and management, WG-EMM-08/18: 15.

Hanchet, S., et al. (2008). Biomass estimates and size distributions of demersal finfish on the Ross Sea shelf and slope from the New Zealand IPY-CAML survey, February-March 2008. WG-FSA-08/31.

Hanchet, S., et al. (2013). "Diversity, relative abundance, new locality records, and updated fish fauna of the Ross Sea, Antarctica." CCAMLR document WG-FSA-10/P3 25: 619-636.

Hanchet, S. C. (2009). New Zealand IPY-CAML Progress Report: 76.

Hanchet, S. C. (2010). New Zealand IPY-CAML Progress Report: 76.

Hartill, B., et al. (2006). Reducing bycatch in New Zealand's scampi trawl fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 4: 53 p.

Hartstein, N. (Submitted). Nitrogen Levels and Adverse Marine Ecological Effects from Aquaculture. Draft New Zealand Aquatic Environment and Biodiversity Report.

Harvey, A., et al. (2005). Coralline algae of central New Zealand: an identification guide to common 'crustose' species. NIWA Information Series No. 57.

Heimeier, D., et al. (2010). "Using DNA barcoding and phylogenetics to identify Antarctic invertebrate larvae: Lessons from a large scale study." Marine Genomics 3: 165-177.

Hemery, L., et al. (In Prep). "Circumpolar distribution of a complex of cryptic species."

Hewitt, J. (In Press). Development of a National Marine Environment Monitoring Programme (MEMP). Draft New Zealand Aquatic Environment and Biodiversity Report.

Hewitt, J., et al. (2011). Chatham-Challenger Ocean Survey 20/20 Post-Voyage Analyses: Objective 10 - Biotic habitats and their sensitivity to physical disturbance. New Zealand Aquatic Environment and Biodiversity Report No. 81: 36.

Hewitt, J., et al. (2011). Chatham-Challenger Ocean Survey 20/20 Post Voyage Analyses: Diversity Metrics. New Zealand Aquatic Environment and Biodiversity Report No. 83: 64.

Horn, P., et al. (2013). Evaluation of the diets of highly migratory species in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 116: 141.

Horn, P. and M. Dunn (2010). Inter-annual variability in the diets of hoki, hake, and ling on the Chatham Rise from 1990 to 2009. New Zealand Aquatic Environment and Biodiversity Report No. 54: 57.

Horn, P., et al. (2010). "Feeding habits of alfonsino Beryx splendens." Journal of Fish Biology 76: 2382-2400

Hurst, R., et al. (2012). Climate and ocean trends of potential relevance to fisheries in the New Zealand Region, 2010. New Zealand Aquatic Environment and Biodiversity Report No. 90: 202.

Hurst, R., et al. (2000). Areas of importance for spawning, pupping or egg-laying and juveniles of new Zealand coastal fish. Unpublished Final Research Report for Ministry of Fisheries Research Project ENV1999/03 Objective 1: 56.

Jackson, J., et al. (Submitted). Taking stock – the historical demography of the New Zealand right whale (the Tohora) 1820-2008. New Zealand Aquatic Enviornment and Biodiversity Report: xx.

Jellyman, D. (1994). The fishery for freshwater eels (Anguilla spp.) in New Zealand New Zealand Fisheries Assessment Research Document 94/14: 25.

Jones, E., et al. (Submitted). Habitats of particular significance for fisheries management: identification of threats and stressors to rig nursery areas. New Zealand Aquatic Environment and Biodiversity Report: xx.

Keeley, N., et al. (2009). Sustainable aquaculture in New Zealand: Review of the Ecological Effects of farming shellfish and other Non-finfish species Cawthron Report No. 1476, prepared for the Ministry of Fisheries: 150p. plus appendices.

Key, J. (2002). A review of current knowledge describing New Zealand's deepwater benthic biodiversity. Marine Biodiversity Biosecurity Report No. 1: 25.

Koubbi, P., et al. (2011). "Ecological importance of micronektonic fish for the ecoregionalisation of the Indo-Pacific sector of the Southern Ocean: role of myctophids. ." Deep Sea Research II. 58: 170-180.

Lalas, C., et al. (2014). Estimates for annual consumption rates by New Zealand sea lions. New Zealand Fisheries Research Report. 2014/11: xx.

Lalas, C., et al. (In Press). Estimates for annual consumption by a recovered population of New Zealand fur Seals. New Zealand Aquatic Enviornment and Biodiversity Report: xx.

Lalas, C. and A. MacDiarmid (2014). Rapid recolonisation of south-eastern New Zealand by New Zealand fur seals *Arctocephalus forsteri*. New Zealand Fisheries Research Report. 2014/13: xx.

Lavery, S., et al. (2006). Molecular identification of cryptogenic/invasive gobies in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 5: 48.

Law, C., et al. (2012). "No stimulation of nitrogen fixation by non-filamentous diazotrophs under elevated CO2 in the South Pacific" Global Change Biology 18: 3004-3014, doi: 3010.1111/j.1365-2486.2012.02777.x.

Leathwick, J., et al. (2006). Development of a marine environmental classification optimised for demersal fish. NIWA Client report HAM2006-063.

Leathwick, J., et al. (2006). "Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees." Marine Ecology Progress Series 321: 267-281.

Leathwick, J., et al. (2006). Development of a demersal fish community map for New Zealand's Exclusive Economic Zone. NIWA Client Report HAM2006-062, prepared for Department of Conservation. Hamilton, New Zealand. , National Institute of Water & Atmospheric Research.

Leathwick, J., et al. (2010). Development of a benthic-optimised marine environment classification for waters within the New Zealand EEZ Unpublished Final Research Report for Ministry of Fisheries Research Project BEN200601, Objective 5.: xx.

Leathwick, J., et al. (2012). A Benthic-optimised Marine Environment Classification (BOMEC) for New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No 88: 54.

Leduc, D., et al. (2012). "Direct evidence for a unimodal relationship between productivity and deep-sea benthic diversity." Marine Ecology Progress Series 454: 53-64.

Leduc, D., et al. (2012). "A unimodal relationship between biomass and species richness of deep-sea nematodes: implications for the link between productivity and diversity." Marine Ecology Progress Series 454: 53-64.

Leduc, D., et al. (2014). "Unusually high food availability in Kaikoura Canyon linked to distinct deep-sea nematode community." Deep Sea Research Part II: Topical Studies in Oceanography 104: 310-318.

Leduc, D., et al. (2013). "Is there a link between deep-sea biodiversity and ecosystem function?" Marine Ecology 34: 334-344.

Leduc, D., et al. (2012). "Nematode beta diversity on the continental slope of New Zealand: spatial patterns and environmental drivers." Marine Ecology Progress Series 545: 37-52.

Linse, K., et al. (2007). "Is the Scotia Sea a centre of Antarctic marine diversification? Some evidence of cryptic speciation in the circum-Antarctic bivalve *Lissarca notorcadensis* (Arcoidea : Philobryidae)." Polar Biology 30: 1059-1068.

Livingston, M. (2004). A sampling programme to construct and quantify food-webs in two key areas supporting important fish and invertebrate species in New Zealand. Unpublished Final Research Report for Ministry of Fisheries Project ENV2002-07, Objective 1 NIWA: xx.

Livingston, M. (2009). Towards a National Marine Environment Monitoring Programme in New Zealand: A discussion paper submitted to the Biodiversity Research Advisory Group Workshop on Marine Environmental Monitoring. Unpublished report held at MPI, Wellington: xx.

Livingston, M., et al. (2003). Trends in incidental catch of major fisheries on the Chatham Rise for Orfishing years 1989-90 to 1998-99. New Zealand Fisheries Assessment Report 2003/52: 74.

Lohrer, A., et al. (2010). Isolated and interactive effects of two key species on ecosystem function and trophic linkages in New Zealand soft-sediment habitats. New Zealand Aquatic Environment and Biodiversity Report No. 44: 69.

Lohrer, A., et al. (2012). "Altered sea ice thickness and permanence affects benthic ecosystem functioning in coastal Antarctica." Ecosystems: 10.1007/s10021-10012-19610-10027.

Lorrey, A., et al. (2013). A synthesis of climatic and geophysical driver activity in New Zealand and environmental changes during the last 1000 years. Unpublished Final Research Report for Project ZBD2005-05, Ministry for Primary Industries, Wellington, New Zealand: 23.

Lörz, A. (2009). "Synopsis of Amphipoda from two recent Ross Sea voyages with description of a new species of Epimeria (Epimeriidae, Amphipoda, Crustacea)." Zootaxa 2167: 59-68.

Lörz, A. (2010). "Deep-sea Rhachotropis (Crustacea: Amphipoda: Eusiridae) from New Zealand and the Ross Sea with key to the Pacific, Indian Ocean and Antarctic species." Zootaxa 2482: 22-48.

Lörz, A. (2010). New Zealand Amphipoda, Conference presentation. XIVth International Colloquium on Amphipoda. Seville, Spain

Lörz, A. (2011). "Biodiversity of unknown New Zealand habitat: bathyal invertebrate assemblages in the benthic boundary layer." Marine Biodiversity 41(2): 287-297.

Lörz, A. (2011). "Pacific Epimeriidae (Amphipoda, Crustacea): Epimeria." Journal of the Marine Biological Association of the United Kingdom 91(2): 471-477.

Lörz, A., et al. (2009). "Do circum-Antarctic species exist in peracarid Amphipoda? A case study in the genus Epimeria Costa, 1851 (Crustacea, Peracarida, Epimeriidae). In: Bruce N (Ed) Advances in the taxonomy and biogeography of Crustacea in the Southern Hemisphere." Zookeys 18: 91-128.

Lörz, A., et al. (2007). "*Epimeria schiaparelli* sp. nov., an amphipod crustacean (family Epimeriidae) from the Ross Sea, Antarctica, with molecular characterisation of the species complex." Zootaxa 1402: 23-37.

Lörz, A., et al. (2012). "First Molecular Evidence for Underestimated Biodiversity of Rhachotropis (Crustacea, Amphipoda), with Description of a New Species." PLoS ONE 7(3): e32365. doi:32310.31371/journal.pone.0032365.

Lörz, A., et al. (2012). "High genetic diversity within *Epimeria georgiana* (Amphipoda) from the southern Scotia Arc." Marine Biodiversity 42(2): 137-159.

Lörz, A., et al. (In Prep). "Molecular insights to deep-sea Rhachotropis from New Zealand and the Ross Sea with description of a new species."

Lörz, A.-N. (2010). "Deep-sea Rhachotropis (Crustacea: Amphipoda: Eusiridae) from New Zealand and the Ross Sea with key to the Pacific, Indian Ocean and Antarctic species." Zootaxa 2482 22-48.

Lörz, A.-N., et al. (2012). A review of deep-sea biodiversity associated with trench, canyon and abyssal habitats deeper than 1500 m in New Zealand waters New Zealand Aquatic Environment and Biodiversity Report, No. 92: 133.

Lörz, A.-N. and O. Coleman (2009). "Living jems: jewel-like creatures from the deep." Water and Atmosphere 17(1): 16-17.

Lörz, A.-N., et al. (2009). "Do circum-Antarctic species exist in peracarid Amphipoda? A case study in the genus Epimeria Costa, 1851 (Crustacea: Peracarida: Epimeriidae)." Zookeys 18: 91-128 SI.

Lundquist, C., et al. (Submitted). Development of a Tier 1 National Reporting Statistic for New Zealand's Marine Biodiversity. Draft New Zealand Aquatic Environment and Biodiversity Report.

Lundquist, C., et al. (2013). Bottom disturbance and seafloor community dynamics: Development of a model of disturbance and recovery dynamics for marine benthic ecosystems. . New Zealand Aquatic Environment and Biodiversity Report No. 118: 59.

Lundquist, C., et al. (2010). " Interactions between distributions and dispersal decrease persistence thresholds of a marine benthic community." Marine Ecology Progress Series 413: 217-228.

Lyle, J. (2011). SRP2010-03: Fur seal interactions with SED excluder device. Unpublished Final Research Report for Ministry of Fisheries, 26 July 2011: 20.

Maas, E., et al. (2010). Impacts of ocean acidification on planktonic ecosystems of the southern ocean. Unpublished Final Research Report for Ministry of Fisheries Project ZBD2008-22, held by the Ministry of Fisheries: 44.

Maas, E., et al. (2010). Bacterial and Archaeal diversity and exo-enzyme activity in Ross Sea, Antarctica sediments. . Poster presented at SAME 11- Symposium on Aquatic Microbial Ecology, Piran, Slovenia, 30th August - 4th September 2010.

MacDiamid, A., et al. (Submitted). Taking Stock – the impacts of humans on New Zealand marine ecosystems since first settlement: synthesis of major findings, and policy and management implications. New Zealand Aquatic Environment and Biodiversity Report. xx: xx.

MacDiamid, A., et al. (Submitted). Top-down effects on rocky reef ecosystems in north-eastern New Zealand: a historic and qualitative modelling approach. New Zealand Aquatic Environment and Biodiversity Report. xx: xx.

MacDiarmid, A., et al. (Submitted). Rocky reef ecosystems – how do they function. New Zealand Aquatic Environment and Biodiversity Report: xx.

MacDiarmid, A., et al. (Submitted). Historical evidence for the state and exploitation of the marine environment in the Hauraki Gulf and along the Otago-Catlins shelf 1769 - 1950. New Zealand Aquatic Environment and Biodiversity Report.

MacDiarmid, A., et al. (2012). Assessment of anthropogenic threats to New Zealand marine habitats. Aquatic Environment and Biodiversity Report No. 93: 255.

MacDiarmid, A., et al. (Submitted). A complete history of the exploitation of an ecologically important inshore finfish species in the Hauraki Gulf, New Zealand: a synthesis of archaeological, historical and fisheries data. New Zealand Aquatic Environment and Biodiversity Report

MacDiarmid, A. and R. Stewart (In Press). Routine and opportunistic sampling of Ross Sea and Balleny Islands Biodiversity. New Zealand Aquatic Environment and Biodiversity Report: xx.

MacKenzie, D. and D. Clement (2014). Abundance and distribution of ECSI Hector's dolphin. New Zealand Aquatic Environment and Biodiversity Report No. 123.: 79.

MacKenzie, D., et al. (2013). Abundance, distribution, and productivity of Hector's (and Maui's) dolphins. Unpublished Final Research Report for Project PRO2009-01B, Ministry for Primary Industries, Wellington, New Zealand: 121.

MacKenzie, D., et al. (2013). Abundance, distribution, and productivity of Hector's (and Maui's) dolphins. Unpublished Final Research Report for Project PRO2009-01B, Ministry for Primary Industries, Wellington, New Zealand: 121.

MacKenzie, D. and D. Fletcher (2006). Characterisation of seabird captures in NZ fisheries. Unpublished Final Research Report prepared for the Ministry of Fisheries, Proteus Wildlife Research Consultants: 99.

MacKenzie, D. and D. Fletcher (2010). Designing a programme of indicators of population performance with respect to captures of seabirds in New Zealand fisheries. Unpublished Final Research Report for Ministry of fisheries project ENV2005-08, held by the Ministry of Fisheries.

Marriot, P., et al. (2003). "Species identification and age estimation for the ridge-scaled Macrourid (*Macrourus whitsoni*) the Ross Sea." CCAMLR Science 10: 37-51.

Mattlin, R. (1993). Incidental catch of fur seals in the west coast South Island hoki trawl fishery, 1989-92. New Zealand Fisheries Assessment Report 1993/19.

Mattlin, R. (2004). QMA SQU6T New Zealand sea lion incidental catch and necropsy data for the fishing years 2000-01, 2001-02 and 2002-03. Unpublished Report prepared for the NZ Ministry of Fisheries, Wellington, NZ. July 2004: 21.

Mattlin, R. H. (1993). Incidental catch of fur seals in the west coast South Island hoki trawl fishery, 1989-92. New Zealand Fisheries Assessment Research Document 93/19.: 17.

Maunder, M. (2007). Assessment of risk of yellow-eyed penguins Megadyptes antipodes from fisheries incidental mortality in New Zealand fisheries and definition of information requirements for managing fisheries related risk. Unpublished Final Research Report for the Ministry of Fisheries: 29.

Maxwell, K. and A. MacDiarmid (Submitted). Oral histories of Maori marine resource state and use in the Hauraki Gulf and along the Otago-Catlins coast 1940-2008. Darft Aquatic Environment and Biodiversity Report: xx.

McCowan, T. (Submitted). Genetic approaches to management of New Zealand's blackfoot pāua, *Haliotis iris*. Unpublished Final Research Report for Project ENH2007-01, Ministry for Primary Industries, Wellington, New Zealand.: 271.

McElderry, H., et al. (2007). Electronic Monitoring to Assess Protected Species Interactions in New Zealand Longline Fisheries: A Pilot Study Unpublished report prepared for the New Zealand Ministry of Fisheries, Wellington, NZ by Archipelago Marine Research Ltd., Victoria, British Columbia, Canada.: 45.

McElderry, H., et al. (2008). Electronic monitoring to assess protected species interactions in New Zealand longline fisheries: a pilot study. New Zealand Aquatic Environment and Biodiversity Report No. 24: 39.

McKenzie, J., et al. (2013). Can juvenile yellowbelly and sand flounder abundance indices and environmental variables predict adult abundance in the Manukau and Mahurangi Harbours? New Zealand Fisheries Assessment Report 2013/10: 31.

McMillan, P., et al. (2011). New Zealand fishes 3: A guide to common species caught by surface fishing methods. New Zealand Aquatic Environment and Biodiversity Report No. 69: 147.

McMillan, P., et al. (2011). New Zealand fishes. 1: A guide to common species caught by trawling. New Zealand Aquatic Environment and Biodiversity Report. No. 68: 331.

McMillan, P., et al (2011). New Zealand fishes. 2: A guide to less common species caught by trawling. New Zealand Aquatic Environment and Biodiversity Report. No 78: 184.

McMillan, P., et al. (2012). "A new species of grenadier, genus Macrourus (Teleostei, Gadiformes, Macrouridae) from the Antarctic and a revision of the genus." Zootaxa 3165: 1-24.

McMillan, P., et al. (2007). Field identification guide to the main fishes caught in the Ross Sea long-line fishery. Unpublished Final Research Report to the Ministry of Fisheries. Project ANT2005/02, objective 7. : 14.

Meynier, L. (2010). New Zealand sea lion bio-energetic modelling. Unpublished Final Report for Project IPA2009-09. Presented to AEWG May 17 2011, Wellington, New Zealand: 34.

Michael, K., et al. (2006). Summary of information in support of the Foveaux Strait Oyster Fishery Plan: the Foveaux Strait ecosystem and effects of oyster dredging. Unpublished Final Research Report for Ministry of Fisheries project ZBD2005-04: xx.

Middleton, D. and E. Abraham (2007). The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery. Unpublished Final Research Report for the Ministry of Fisheries for project IPA2006-02: xx.

Mills, S., et al. (2013). Identification of benthic invertebrate samples from research trawls and observer trips 2012-2013. Unpublished Final Research Report for the Ministry of Fisheries: 62.

Ministry of Fisheries (2008). Bottom Fishery Impact Assessment: Bottom Fishing Activities by New Zealand Vessels Fishing in the High Seas in the SPRFMO Area during 2008 and 2009. Available from http://www.southpacificrfmo.org/benthic-impact-assessments/. Wellington: 102.

Mitchell, J. (2008). Initial environmental evaluation (IEE) NZ IPY-CAML voyage 2008 report. Unpublished Report prepared for Antarctic Policy Unit, Ministry of Foreign Affairs and Trade.: 35.

Mitchell, J. and M. Clark (2004). Voyage report TAN04-02. Western Ross Sea voyage 2004. Hydrographic and biodiversity survey RV Tangaroa 27 January to 13 March 2004. Cape Adare, Cape Hallett, Possession Islands and Balleny Islands, Antarctica. . NIWA Voyage Report TAN04-02, Unpublished report held in NIWA library, Wellington: 102.

Mitchell, J. and A. MacDiarmid (2006). Voyage Report TAN06-02 Eastern Ross Sea Voyage. Unpublished report for MFish project ZBD2005-03: xx.

Mormede, S., et al. (2008). Factors that may influence the probability of fur seal capture in selected New Zealand fisheries. New Zealand Aquatic Environment and Biodiversity Report. No. 19: 42.

Mormede, S. and A. Dunn (2013). An initial development of spatially explicit population models of benthic impacts to inform Ecological Risk Assessments in New Zealand deepwater fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 106: 16.

Morrison, M. and P. D (2008). Distribution and abundance of toheroa (*Paphies ventricosa*) on Ninety Mile Beach, March 2006. New Zealand Fisheries Assessment Report 2008/26: 27.

Morrison, M., et al. (2014). Linking marine fisheries species to biogenic habitats in New Zealand: a review and synthesis of knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 130.: 156.

Morrison, M., et al. (2014). Habitats and areas of particular significance for coastal finfish fisheries management in New Zealand: A review of concepts and life history knowledge, and suggestions for future research. New Zealand Aquatic Environment and Biodiversity Report No. 125.: 202.

Morrison, M., et al. (2014). Seagrass meadows as biodiversity and productivity hotspots. New Zealand Aquatic Environment and Biodiversity Report. 137.

Morrison, M., et al. (2014). Habitats of particular significance for fisheries management: the Kaipara Harbour. New Zealand Aquatic Environment and Biodiversity Report No. 129.: 169.

Morrison, M., et al. (2009). A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 37: 100.

Murray, T., et al. (1992). Seabird bycatch by Southern Fishery longline vessels in New Zealand waters. New Zealand Fisheries Assessment Research Document 92/22: 21.

Naylor, J., et al. (2005). A guide to common offshore crabs in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 2: 47.

Neil, H., et al. (In Press). Insights into historical New Zealand marine shelf productivity using ancient fish otoliths. Unpublished Final Research Report for Project ZBD200505 MS6 - Part B, Ministry of Fisheries, Wellington, New Zealand.: xx.

Neill, K., et al. (2012). Macroalgal diversity associated with soft sediment habitats in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 87: 130.

Nelson, W., et al. (2010). Macroalgae and benthic biodiversity of the Balleny Islands, Southern Ocean. New Zealand Aquatic Environment and Biodiversity Report No. 55: 99.

Nelson, W., et al. (2012). Rhodolith Beds in Northern New Zealand: Characterisation of Associated Biodiversity and Vulnerability to Environmental Stressors. New Zealand Aquatic Environment and Biodiversity Report No. 99: 102.

Nelson, W., et al. (2002). "Marine Macroalgae of Fiordland, New Zealand" Tuhinga 13: 117-152

Nielsen, J., et al. (2009). "Synopsis of a new collection of sea spiders (*Arthropoda: Pycnogonida*) from the Ross Sea, Antarctica." Polar Biology 32: 1147-1155.

Nodder, S. (2008). OS 20/20 Chatham Rise & Challenger Plateau Hydrographic, Biodiversity & Seabed Habitats. NIWA Client Report: WLG2008-27. Wellington, New Zealand, National Institute of Water & Atmospheric Research.

Nodder, S., et al. (2012). Seafloor habitats and benthos of a continentalridge: Chatham Rise, New Zealand. . Seafloor geomorphology as benthic habitat: GEOHAB atlas of geomorphic features and benthic habitats. P. Harris and E. Baker. London, Elsevier: 763-776.

Nodder, S., et al. (2011). Physical, biogeochemical, and microbial characteristics of sediment samples from the Catham Rise and Challenger Plateau. Aquatic Environment and Biodiversity Report No. 70.

Norkko, A., et al. (2002). Ecology and biodiversity of coastal benthic communities in McMurdo Sound, Ross Sea: development of sampling protocols and initial results. Unpublished Final Research Report for Ministry of Fisheries Research Project ZBD2001/02, Objectives 1, 2 & 3. : 119.

Norkko, A., et al. (2004). "Ecological role of *Phyllophora antarctica* drift accumulations in coastal soft-sediment communities of McMurdo Sound, Antarctica." Polar Biology 27: 482-494.

Norkko, A., et al. (2007). "Trophic structure of coastal Antarctic food webs associated with changes in sea ice and food supply." Ecology 88: 2810-2820.

Norkko, J., et al. (2005). "Growth under environmental extremes: spatial and temporal patterns in nucleic acid ratios in two Antarctic bivalves." Journal of Experimental Marine Biology and Ecology 326: 114-156

O’Driscoll, R., et al. (2011). Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys. New Zealand Aquatic Environment and Biodiversity Report. No. 96: 99.

O’Driscoll, R., et al. (2010). "Distribution, abundance and acoustic properties of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea." Deep-Sea Research II 58(1-2): 181-195.

O'Driscoll, R. (2009). Preliminary acoustic results from the New Zealand IPY-CAML survey of the Ross Sea region in February-March 2008. Unpublished Final Research Report for MFish project IPY200701 objective 8: 14.

O'Driscoll, R., et al. (2003). Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. NIWA Technical Report 119: 377.

O'Driscoll, R., et al. (2012). "Can acoustic methods be used to monitor grenadier (Macrouridae) abundance in the Ross Sea region." Journal of Ichthyology 53: 700-708.

O'Driscoll, R., et al. (2009). Preliminary acoustic results from the New Zealand IPY-CAML survey of the Ross Sea region in February-March 2008. CCAMLR SG-ASAM-09-05: 37.

O'Loughlin, M., et al. (2011). "The Antarctic region as a marine biodiversity hotspot for echinoderms: Diversity and diversification of sea cucumbers." Deep Sea Research Part II: Topical Studies in Oceanography 58: 264-275.

Opresko, D., et al. (2014). ANTIPATHARIA (BLACK CORALS) FOR THE NEW ZEALAND REGION. A field guide of commonly sampled New Zealand black corals including illustrations highlighting technical terms and black coral morphology. New Zealand Aquatic Enviornment and Biodiversity Report No. 136: 20.

Page, M., et al. (2001). Preliminary assessment of the biodiversity of benthic macrofauna of the western Ross Sea, Antarctica. Unpublished Final Research Report to the Ministry of Fisheries: 29.

Pakhomov, E., et al. (2011). "Biology of *Salpa thompsoni* in waters adjacent to the Ross Sea, Southern Ocean, during austral summer 2008." Polar Biology 34: 257-271.

Parker, S. (2008). Development of a New Zealand High Seas Bottom Trawling Benthic Assessment Standard for Evaluation of Fishing Impacts to Vulnerable Marine Ecosystems in the South Pacific Ocean. Unpublished Final Research Report for Ministry of Fisheries Research Projects IFA2007-02 Objectives 3 and 4.

Parker, S. and D. Bowden (2010). "Identifying taxonomic groups vulnerable to bottom longline fishing gear in the Ross Sea region." CCAMLR Science 17: 105-127.

Parker, S. and M. Francis (2012). Productivity of two species of deepwater sharks, *Deania calcea* and *Centrophorus squamosus* in New Zealand. Aquatic Environment and Biodiversity Report No. 103: 48.

Parker, S., et al. (2009). Evaluation of VME taxa monitoring by scientific observers from five vessels in the Ross Sea Antarctic toothfish longline fishery during the 2008-09 season. Unpublished Final Research Report for the Ministry of Fisheries: xx.

Parker, S., et al. (2009). "Detection criteria for measuring trawl impacts on vulnerable marine ecosystems in high sea fisheries of the South pacific Ocean." Marine Ecology Progress Series 397: 309-317.

Parker, S., et al. (2008). Classification guide for potentially vulnerable invertebrate taxa in the Ross Sea long-line fishery.

Unpublished Final Research Report for Ministry of Fisheries Research Project ANT2007-01 (Objective 3): 7.

Parker, S., et al. (2009). CCAMLR VME taxa Identification guide Version 2009. Available at http://www.ccamlr.org/pu/e/sc/obs/vme-guide.pdf. Hobart, Tasmania, Australia: 4.

Parker, S., et al. (2010). A bathymetric data framework for fisheries management in the Ross Sea region. Unpublished Final Research Report for the Ministry of Fisheries: 14.

Parsons, D., et al. (In press). Long-term effects of climate variation and human impacts on the structure and functioning of New Zealand's Shelf Ecosystems. New Zealand Aquatic Environment and Biodiversity Report: xx.

Paul, L. (2012). A history of the Firth of Thames dredge fishery for mussels: use and abuse of a coastal resource. New Zealand Aquatic Environment and Biodiversity Report No. 94: 27.

Paul, L. (2014). History of and trends in the commercial landings of finfish from the Hauraki Gulf, 1850–2006. . New Zealand Aquatic Environment and Biodiversity Report No. 124.: 178.

Penney, A. (2014). Review of the biodiversity component of the New Zealand Vulnerable Marine Ecosystem Evidence Process. New Zealand Aquatic Environment and Biodiversity Report No. 135: 40.

Penney, A., et al. (2009). "Protection measures implemented by New Zealand for vulnerable marine ecosystems in the South Pacific Ocean." Marine Ecology Progress Series 397: 341-354.

Pinkerton, M. (Submitted). Trophic modelling of a New Zealand marine shelf ecosystem since AD 1000 New Zealand Aquatic Enviornment and Biodiversity Report.

Pinkerton, M., et al. (Submitted). Reporting on the state of the marine environment: recommendations for tier 1 oceanic statistics. New Zealand Aquatic Environment and Biodiversity Report xx: xx.

Pinkerton, M., et al. (2010). "A balanced model of the food web of the Ross Sea, Antarctica." CCAMLR Science 17: 1-31.

Pinkerton, M., et al. (2007). Stable isotope analysis of Southern Ocean fish tissue samples: preliminary results. Unpublished Final Research Report to the Ministry of Fisheries. Project ANT2005/04, objective 1: 32.

Pinkerton, M., et al. (2009). Trophic connections in the Ross Sea: information from stomach contents analysis and stable isotopes of carbon and nitrogen. Unpublished Report to Ministry of Fisheries, project IPY200701 Obj10: 18.

Pinkerton, M., et al. (2007). Ecological risk management and the fishery for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea, Antarctica. Document EMM-07-24, CCAMLR. Hobart, Australia: 22.

Pinkerton, M., et al. (2013). "Diet and trophic niche of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea, Antarctica." Journal of Fish Biology 82(1): 141-164.

Pinkerton, M., et al. (2005). Modelling the effects of fishing in the Ross Sea. Unpublished Final Research Report for MFish Research Project ANT2004/05: 130.

Pinkerton, M., et al. (2006). Modelling the effects of fishing in the Ross Sea. Unpublished Final Research Report for Ministry of Fisheries Research Project ANT2004-05: 169.

Pinkerton, M., et al. (2009). Inputs to the Ross Sea Bioregionalisation/Spatial Management planning workshop. Unpublished Final Research Report to the Ministry of Fisheries: 40.

Ponte, G., et al. (2010). Impact characteristics of the New Zealand Fisheries sea lion exclusion device stainless steel grid. IPA2009-16 Report prepared for NZ Ministry of Fisheries (Project IPA2009-16), Oct. 2010: 24.

Ponte, G., et al. (2011). Further analysis of the impact characteristics of the New Zealand Fisheries sea lion exclusion device stainless steel grid. Unpublished Report prepared for NZ Ministry of Fisheries (Project SRP2010-05): 24.

Richard, Y. and E. Abraham (2013). Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108: 30.

Richard, Y. and E. Abraham (2013). Risk of commercial fisheries to New Zealand seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 109: 58.

Richard, Y. and E. Abraham (2013). Risk of commercial fisheries to New Zealand seabird populations (supplementary material). New Zealand Aquatic Environment and Biodiversity Report No. 117 78.

Richard, Y. and E. Abraham (Submitted). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2011–12. Draft New Zealand Aquatic Environment and Biodiversity Report: 129.

Richard, Y., et al. (2011). Assessment of the risk to seabird populations from New Zealand commercial fisheries. Unpublished Final Research Report held by the Ministry of Fisheries: xx.

Roberts, C. and A. Stewart (2001). "Ross Sea fishes: a collection-based biodiversity research programme." Seafood New Zealand 9(11): 79-84.

Robinson, V., et al. (2014). Continuous Plankton Recorder Time Series. New Zealand Aquatic Environment and Biodiversity Report No. 128.: 76.

Roe, W. (2007). Necropsy of marine mammals captured in New Zealand fisheries in the 2005-06 fishing year. New Zealand Aquatic Environment and Biodiversity Report No. 11: 24.

Roe, W. (2009). Necropsy of marine mammals captured in New Zealand fisheries in the 2006-07 fishing year. New Zealand Aquatic Environment and Biodiversity Report No. 29: 32.

Roe, W. (2009). Necropsy of marine mammals captured in New Zealand fisheries in the 2007-08 fishing year. New Zealand Aquatic Environment and Biodiversity Report. No. 34: 35.

Roe, W. (2010). Necropsy of marine mammals captured in New Zealand fisheries in the 2008-09 fishing year. New Zealand Aquatic Environment and Biodiversity Report No. 47: 22.

Roe, W. (2010). External review of NZ sea lion bycatch necropsy data and methods. Unpublished Report prepared for the NZ Ministry of Fisheries, Wellington: 8.

Roe, W. and L. Meynier (2012). Review of Necropsy Records for Bycaught NZ sea lions (*Phocarctos hookeri*), 2000-2008. New Zealand Aquatic Environment and Biodiversity Report No. 98: 46.

Rowden, A., et al. (2012). A review of the marine soft-sediment assemblages of New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 92: 165.

Rowden, A. and M. Clark (2010). Benthic biodiversity of seven seamounts on the southern end of the Kermadec volcanic arc, northeast New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 62: 31.

Rowden, A., et al. (2004). Benthic biodiversity of seamounts on the Northland Plateau. Marine Biodiversity Biosecurity Report No. 5: 21.

Rowden, A., et al. (2003). Benthic biodiversity of seamounts on the southern Kermadec volcanic arc. Marine Biodiversity Biosecurity Report. No. 3: 23.

Rowden, A., et al. (2007). Benthic macrofauna bycatch of oyster dredging in Foveaux Strait. New Zealand Fisheries Assessment Report 2007/10: 27.

Rowden, A., et al. (2013). Predictive modelling of the distribution of vulnerable marine ecosystems in the South Pacific Ocean region. New Zealand Aquatic Environment and Biodiversity Report No. 120.: 74.

Rowden, A., et al. (2012). Biodiversity of macroinvertabrates and fish assemblages of the northwestern Ross Sea shelf. New Zealand Aquatic Environment and Biodiversity Report No. 101: 111.

Rowden, A., et al. (In Press). Biodiversity of macroinvertabrates and fish assemblages of the Balleny Islands seamounts. New Zealand Aquatic Environment and Biodiversity Report: xx.

Rowden, A., et al. (2013). Biodiversity of macroinvertebrate and fish assemblages of the Balleny Islands seamounts. New Zealand Aquatic Environment and Biodiversity Report No. 115: 76.

Rowden, A., et al. (2008). New Zealand's "SEAMOUNT" database: recent updates and its potential use for ecological risk assessment. New Zealand Aquatic Environment and Biodiversity Report. No. 27: 49.

Rowden, A., et al. (2002). Benthic biodiversity of seamounts on the northwest Chatham Rise. . Marine Biodiversity and Biosecurity Report. 2: 1-21.

S, G. (2004). A review of scientific studies conducted on the Macquarie Ridge. Unpublished Final Research Report for Ministry of Fisheries project ZBD 2003-09: 33.

Sagar, P., et al. (2010). Population assessment of Salvin's albatrosses at the Snares Western Chain, 29 September - 14 October 2009. Unpublished Final Research Report for Ministry of Fisheries: 4.

Sagar, P., et al. (2009). Population assessment of Salvin's albatrosses at the Snares Western Chain, 29 September - 17 October 2008. Unpublished Final Research Report for the Ministry of Fisheries: 4.

Sagar, P., et al. (2010). Population assessment of Northern Buller's Albatross and Northern Giant Petrels at the Forty-Fours, Chatham Islands, 1 - 8 December 2009. Unpublished Final Research Report to the Ministry of Fisheries. Project PRO2006-05: 11.

Sagar, P., et al. (2009). Population dynamics of the Chatham Albatross at The Pyramid, 9 November- 7 December 2008. Unpublished Final Research Report for the Ministry of Fisheries: 5.

Sagar, P., et al. (2010). Population dynamics of the Chatham Albatross at The Pyramid, 20 November- 14 December 2009. Unpublished Final Research Report for the Ministry of Fisheries: 6.

Sagar, P. and D. Thompson (2008). Data collection of demographic, distributional, and trophic information on selected petrels. New Zealand Aquatic Environment and Biodiversity Report No. 17: 12.

Savage, C. (2009). Development of bioindicators for the assimilation of terrestrial nutrient inputs in coastal ecosystems as a tool for watershed management. New Zealand Aquatic Environment and Biodiversity Report No. 30: 35.

Savage, C., et al. (2012). "Ecosystem Services Transcend Boundaries: Estuaries Provide Resource Subsidies and Influence Functional Diversity in Coastal Benthic Communities." PLoS ONE 7(8): e42708. doi:42710.41371/journal.pone.0042708.

Schiaparelli, S., et al. (2010). "'Hitchhiker' polynoid polychaetes in cold deep waters and their potential influence on benthic soft bottom food webs." CCAMLR document WG-FSA-10/P3 22: 399-407.

Schiaparelli, S., et al. (2006). "Diversity and distribution of mollusc assemblages on the Victoria Land coast and the Balleny Islands, Ross Sea, Antarctica." CCAMLR document WG-FSA-10/P3 18 (4): 615-631.

Schiaparelli, S., et al. (2008). "Circumpolar distribution of the pycnogonid-ectoparasitic gastropod *Dickdellia labioflecta* (Dell, 1990) (Mollusca: Zerotulidae)." CCAMLR document WG-FSA-10/P3 20: 497-498.

Schwarz, A., et al. (2006). Impacts of terrestrial runoff on the biodiversity of rocky reefs. New Zealand Aquatic Environment and Biodiversity Report No. 7: 109.

Schwarz, A.-M., et al. (2005). "Primary production potential of non-geniculate coralline algae at Cape Evans, Ross Sea, Antarctica." Marine Ecology Progress Series 294: 131-140.

Schwarz, A.-M., et al. (2003). "Macroalgal photosynthesis near the southern global limit for growth; Cape Evans, Ross Sea, Antarctica." Polar Biology 26: 789-799.

Sewell, M. (2005). " Examination of the meroplankton community in the southwestern Ross Sea, Antarctica, using a collapsible plankton net." Polar Biology 28: 119-131.

Sewell, M. (2006). "The meroplankton community of the northern Ross Sea: a preliminary comparison with the McMurdo Sound region." CCAMLR document WG-FSA-10/P3 18: 595-602.

Sewell, M., et al. (2006). Whose larva is that? Molecular identification of larvae of the Ross Sea. New Zealand Aquatic Environment and Biodiversity Report No. 3: 57.

Sharp, B., et al. (2010). Bioregionalisation and Spatial Ecosystem Processes in the Ross Sea Region. CCAMLR document WG-EMM-10/30, Hobart, Australia: xx.

Sharp, B., et al. (2009). "An Impact Assessment Framework for Bottom Fishing Methods in the CCAMLR Convention Area." CCAMLR Science 16: 195-210.

Sharp, B., et al. (2011). A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ. Unpublished report held by the Ministry of Fisheries, Wellington.: 39.

Slooten, E., et al. (2005). Distribution of Maui's dolphin, *Cephalorynchus hectori maui*. New Zealand Fisheries Assessment Report. 2005/28: 21.

Smith, A. and D. Gordon (2011). Bryozoans of southern New Zealand: a field identification guide. New Zealand Aquatic Environment and Biodiversity Report. No. 75: 65.

Smith, F. (2006). Balleny Islands Ecology Research Voyage Report, R.V. Tiama. Unpublished report held at Ministry of Fisheries for project ZBD2005/01.

Smith, I. (2011). Estimating the magnitude of pre-European Maori marine harvest in two New Zealand study areas. New Zealand Aquatic Environment and Biodiversity Report, No. 82: 72.

Smith, M. and S. Baird (2005). Factors that may influence the level of incidental mortality of New Zealand sea lions (*Phocarctos hookeri*) in the squid (*Nototodarus* spp.) trawl fishery in SQU 6T. New Zealand Fisheries Assessment Report 2005/20: 35.

Smith, M. and S. Baird (2005). Representativeness of past observer coverage, and future coverage required for estimation of New Zealand sea lion (*Phocarctos hookeri*)captures in the SQU 6T fishery. New Zealand Fisheries Assessment Report 39.

Smith, M. and S. Baird (2007). Estimation of incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2003-04, with particular reference to the SQU 6T squid trawl fishery. New Zealand Fisheries Assessment Report 2007/7: 32.

Smith, M. and S. Baird (2007). Estimation of incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2004-05, with particular reference to the SQU 6T squid trawl fishery. New Zealand Aquatic Environment and Biodiversity Report No. 12: 31.

Smith, M. and S. Baird (2008). Observer coverage required for the prediction of incidental capture of New Zealand fur seals in New Zealand commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report. No. 26: 76.

Smith, M. and S. Baird (2008). Observer coverage required for the prediction of incidental capture of seabirds in New Zealand commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 25: 107.

Smith, M. and S. Baird (2009). Model-based estimation of New Zealand fur seal (*Arctocephalus forsteri*) incidental captures and strike rates for trawl fishing in New Zealand waters for the years 1994-95 to 2005-06. New Zealand Aquatic Environment and Biodiversity Report No. 40: 90.

Smith, M. and S. Baird (2011). Predicted incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in the Auckland Islands SQU 6T squid trawl fishery for 1995 to 2006. New Zealand Aquatic Environment and Biodiversity Report. No. 71: 40.

Smith, P. and P. Notman (2005). Inventory of biological samples collected from Antarctic toothfish *Dissostichus mawsoni* over summer 2005. Unpublished Final Research Report for Ministry of Fisheries Project ANT200401, Objective 5.

Smith, P., et al. (2007). Identification and speciation of Antarctic skates. Unpublished Final Research Report to the Ministry of Fisheries ANT2005/02, objective 5: 27.

Smith, P., et al. (2008). DNA database for commercial marine fish. New Zealand Aquatic Environment and Biodiversity Report No. 22: 62.

Smith, P., et al. (2011). "DNA barcoding highlights a cryptic species of grenadier (genus Macrourus) in the Southern Ocean" Journal of Fish Biology 78(1): 355-365.

Smith, P., et al. (2011). "DNA barcoding of morids (*Actinopterygii, Moridae*) reveals deep divergence in the anti tropical *Halargyreus johnsoni* but little distinction between *Antimora rostrata* and *A. microlepis*" Mitochondrial DNA (doi:10.3109/19401736.2010.532329).

Snelder, T., et al. (2006). "Development of an ecological marine classification in the New Zealand region." Environmental Management 39: 12-29.

Snelder, T. H., et al. (2005). The New Zealand Marine Environmental Classification. Unpublished Report for the Ministry for the Environment: 80.

Speed, S. (2005). Review of the effects of aquaculture and enhancement stock sources on wild fisheries resources and the marine environment- report on Objective 1 & 2. Unpublished Final Research Report for the Ministry of Fisheries: 128.

Speed, S., et al. (2006). The implications of marine reserves for fisheries resources and management in the New Zealand context. Unpublished Final Research Report for the Ministry of fisheries: 72.

Stein, D. (2012). "Snailfishes (Family Liparidae) of the Ross Sea, Antarctica, and closely adjacent waters." Zootaxa 3285(ISBN 978-1-86977-870-5 (Online edition)): 120.

Stevens, D. (2006). Stomach contents of sub-adult Antarctic toothfish (*Dissostichus mawsoni*) from the western Ross Sea, Antarctica. Unpublished Final Research Report to Ministry of Fisheries, New Zealand for project ANT2004-01, Objective 4.: xx.

Stevens, D. and M. Dunn (2010). "Different food preferences in four sympatric deep-sea Macrourid fishes." Marine Biology DOI 10.1007/s00227-010-1542-1.

Stevens, D., et al. (2011). Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000. New Zealand Aquatic Environment and Biodiversity Report, No. 85: 218.

Stevens, D., et al. (2010). Age, growth, and maturity of four New Zealand rattail species. Aquatic Environment and Biodiversity Report. No. 59: 39.

Strugnell, J., et al. (2012). "Persistent genetic signatures of historic climatic events in an Antarctic octopus." Molecular Ecology 21(11): 2775-2787.

Sutherland, D. (2008). "Surface-associated diatoms from marine habitats at Cape Evans, Antarctica, including the first record of living *Eunotogramma marginopunctatum*." Polar Biology DOI 10.1007/s00300-008-0426-z.

Sutton, C., et al. (2006). Biological parameters for icefish (*Chionobathyscus dewitti*) in the Ross Sea, Antarctica. Unpublished Final Research Report to the Ministry of Fisheries. Project ANT2005/02, objective 5: 27.

Taylor, P. (1992). Incidental catch of non-fish species by setnets in New Zealand waters. New Zealand Fisheries Assessment Research Document 92/21: 23.

Thatje, S. and A. Lörz (2005). "First record of lithodid crabs from Antarctic waters off the Balleny Islands." Polar Biology 28(4): 334-337.

Thompson, F. and E. Abraham (2009). Dolphin bycatch in New Zealand trawl fisheries, 1995-96 to 2006-07. New Zealand Aquatic Environment and Biodiversity Report No. 36: 24

Thompson, F. and E. Abraham (2009). Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries from 1995-96 to 2006-07. New Zealand Aquatic Environment and Biodiversity Report No. 41: 31.

Thompson, F. and E. Abraham (2009). Six monthly summary of the capture of protected species in New Zealand commercial fisheries, summer 2007-08. New Zealand Aquatic Environment and Biodiversity Report. No. 35: 22.

Thompson, F. and E. Abraham (2010). Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002-03 to 2008-09. New Zealand Aquatic Environment and Biodiversity Report No. 61: 37.

Thompson, F. and E. Abraham (2011). Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995-96 to 2008-09. New Zealand Aquatic Environment and Biodiversity Report No. 66: 25.

Thompson, F., et al. (2010). Common dolphin (*Delphinus delphis*) bycatch in New Zealand mackerel trawl fisheries, 1995–96 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 63: 20.

Thompson, F., et al. (2012). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Unpublished Final Research Report for Project PRO2010-01, Ministry for Primary Industries, Wellington, New Zealand: 68.

Thompson, F., et al. (2010). Estimation of fur seal bycatch in New Zealand trawl fisheries, 2002-03 to 2007-08. New Zealand Aquatic Environment and Biodiversity Report. No. 56: 29.

Thompson, F., et al. (2013). Marine mammal bycatch in New Zealand trawl fisheries, 1995-96 to 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 105: 73.

Thompson, F., et al. (Submitted). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2011–12. Draft New Zealand Aquatic Environment and Biodiversity Report: 80.

Thompson, F., et al. (In Press). Reported New Zealand sea lion (*Phocarctos hookeri*) captures in commercial trawl fisheries, 1991–92 to 2012–13. New Zealand Aquatic Environment and Biodiversity Report. xx: 47.

Thompson, F., et al. (2010). Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995-96 to 2007-08. New Zealand Aquatic Environment and Biodiversity Report No. 52: 25.

Thrush, S. and V. Cummings (2011). "Massive icebergs, alteration in primary food resources and change in benthic communities at Cape Evans, Antarctica." Marine Ecology: DOI: 10.1111/j.1439-0485.2011.00462.x.

Thrush, S., et al. (2006). Broad-scale factors influencing the biodiversity of coastal benthic communities of the Ross Sea. Deep Sea Research II. 53: 959-971.

Thrush, S., et al. (2010). "β-diversity and species accumulation in Antarctic coastal benthic communities: the role of habitat, distance and productivity on ecological connectivity. ." PLoSONE http://dx.plos.org/10.1371/journal.pone.0011899.

Thrush, S., et al. (In Press). Carbonate sediments: the positive and negative effects of land-coast interactions of functional diversity. Aquatic Environment and Biodiversity Report: xx.

Tracey, D., et al. (2005). A guide to common deepsea invertebrates in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 1: 160.

Tracey, D., et al. (2011). A guide to common deepsea invertebrates in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No. 86: 317.

Tracey, D., et al. (2007). A guide to common deepsea invertebrates in New Zealand waters. New Zealand Aquatic Environment and Biodiversity Report No.10.: 282

Tracey, D., et al. (2010). Evaluation of VME taxa monitoring by scientific observers. Unpublished Final Research Report for Ministry of Fisheries Research Project ANT2009/01 Objective 8: 17.

Tracey, D., et al. (2014). Live Coral Experiment. Unpublished Final Research Report for Ministry of Fisheries Research Project SEA2013-01: 9.

Tracey, D., et al. (2008). Classification guide for potentially vulnerable invertebrate taxa in the SPRFMO Area. Idenitifcation guide for Ministry of fisheries 1.

Tracey, D., et al. (2011). "Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. ." Marine Ecology Progress Series 430: 1-22.

Tuck, I., et al. (2009). Ecosystem indicators for New Zealand fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 42: 188.

Tuck, I., et al. (2010). Designing a programme to monitor the recovery of the benthic community between North Cape and Cape Reinga. New Zealand Aquatic Environment and Biodiversity Report No. 53: 78.

Tuck, I. and J. Hewitt (2013). Monitoring change in benthic communities in Spirits bay. Aquatic Environment and Biodiversity Report, No. 111.: 50.

Tuck, I., et al. (2006). Information on benthic impacts in support of the coromandel Scallops fishery plan. Unpublished Ministry of Fisheries Final Research Report 64.

Tuck, I., et al. (2006). Information on benthic impacts in support of the Coromandel scallop fisheries plan. info for SCA-CS fish plan. Unpublished Final Research Report for Ministry of Fisheries Research Project ZBD2005-15.

Tuck, I., et al. (2014). Ecosystem and environmental indicators for deepwater fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 127.: 143.

Varian, S. (2005). A summary of the values of the Balleny Islands, Antarctica. Marine Biodiversity Biosecurity Report No. 6: 13.

Waugh, S., et al. (2008). Updated preliminary results of an ecological risk assessment for seabirds and marine mammals with risk of fisheries interactions Western and Central pacific Fisheries Comission (WCPFC) Working Group - Fisheries Stock Assessment. 08/51.

Waugh, S., et al. (2009). Ecological Risk Assessment for Seabirds in New Zealand fisheries. Unpublished Final Research Report for the Ministry of Fisheries 58.

Williams, A., et al. (2010). "Seamount megabenthic assemblages fail to recover from trawling impacts." Marine Ecology 31(suppl. 1): 183-199.

Williams, G., et al. (2014). PENNATULACEA (SEA PENS) DESCRIPTIONS FOR THE NEW ZEALAND REGION. A field guide of commonly sampled New Zealand sea pens including illustrations highlighting technical terms and sea pen morphology. New Zealand Aquatic Environment and Biodiversity Report No. 135: 22.

Williams, J., et al. (2013). Review of factors affecting the abundance of toheroa (*Paphies ventricosa*). New Zealand Aquatic Environment and Biodiversity Report No. 114: 76.

Wing, S. (2005). Fiordland Biodiversity Research Cruise. Unpublished Final Research Report for ZBD2003-04: xx.

Zemke-White, W. L., et al. (2005). Beach-cast seaweed: a review. New Zealand Fisheries Assessment Report 2005/44: 47.

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