Ministry for Primary Industries
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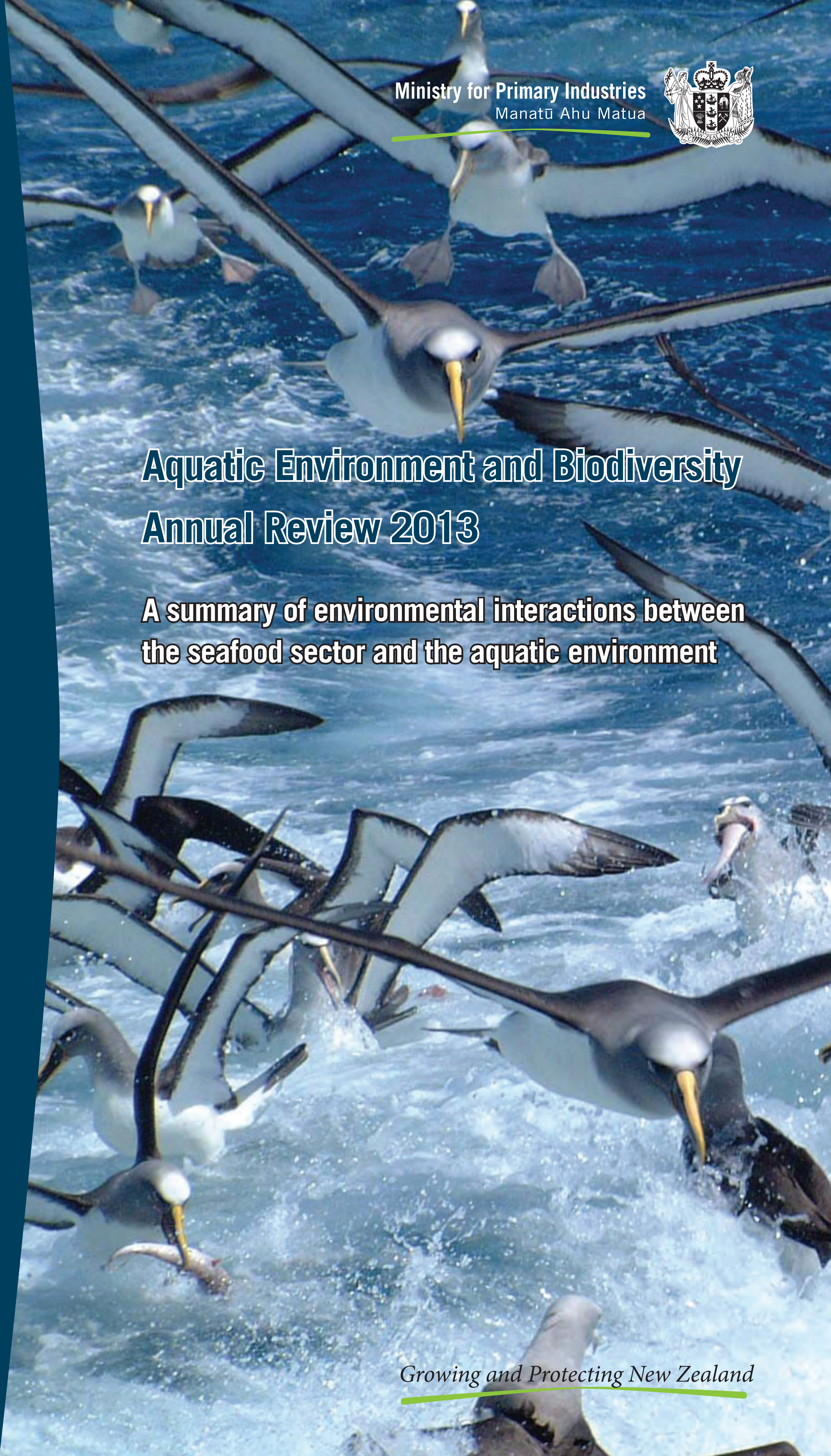

Aquatic Environment and Biodiversity Annual Review 2013

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 (2013)

Fisheries Management Science Team

Acknowledgements

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Disclaimer

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PREFACE

This, the 2013 edition of the Aquatic Environment and Biodiversity Annual Review, expands and updates the 2012 edition. 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 the Aquatic Environment and Biodiversity Annual Review is anticipated and additional chapters will be developed to provide increasingly comprehensive coverage of the issues. New chapters are included this year for sharks, Hector's and Maui's dolphins, and the effects of aquaculture, and an appendix summarising aquatic environment and marine biodiversity research since 1998 has been expanded. 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, Rich Ford and Mary Livingston) 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 2013.

Pamela Mace

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Principal Advisor Fisheries Science
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Contents

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 2012, and the May plenary, MPI 2013) 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 Resource Management and Programmes branch, Ministry for Primary Industries (MPI). It does not cover all issues but, as anticipated, includes more chapters than in 2011 and 2012. 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 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 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 2012 and 2013 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 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 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 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.

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.

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.

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.

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[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.

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.

1.3. Policy Setting

1.3.1. Our Strategy 2030 and MPI’s Statement of Intent 2012/15

The Ministry for Primary Industries’ Statement of Intent, SOI, is an important guiding document for the short to medium term. That for 2013–18 is available on the Ministry’s website at:

http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1767

The SOI sets out the Ministry’s strategic direction for the coming three years, primarily through implementation of Our Strategy 2030 (Appendix 15.7). 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 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 the single key adviser to the Government across all aspects of the primary industries, food production and related trade issues. MPI 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.

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;
- biodiversity 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 subsequent links in this document will eventually change as the new Ministry's systems are progressively merged).

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 have been approved by the Minister and a suite of three plans for inshore species has been released in prototype form. 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
The 2013/14 Annual Operating Plan for deepwater fisheries is available on MPI's website with an ISBN Online number: 978-0-478-40515-9.

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 (including annual operating plans for 2013/14) have been made available at MPI's publications page at: http://www.mpi.govt.nz/news-resources/publications.aspx.

Certain research areas (aquatic environment, recreational and biodiversity) are not entirely covered by fisheries plans, as many of these issues 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 drivers in Tables 1.1, 1.2 and Fisheries 2030.

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 15.8 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 15.5. 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.

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 15.1 and 15.3 for the 2012 Terms of Reference for AEWG and BRAG, respetively).

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 2013 are listed in Appendix 15.2).

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. Increasingly, reports will be available from the MPI website at: http://www.mpi.govt.nz/news-resources/publications.

1.5. References

Ministry of Agriculture and Forestry (2011). Aquatic Environment and Biodiversity Annual Review 2011: a summary of environmental interactions between fisheries and the aquatic environment. Compiled by the Fisheries Science Group, Ministry of Agriculture and Forestry, Wellington, New Zealand. 199 p.

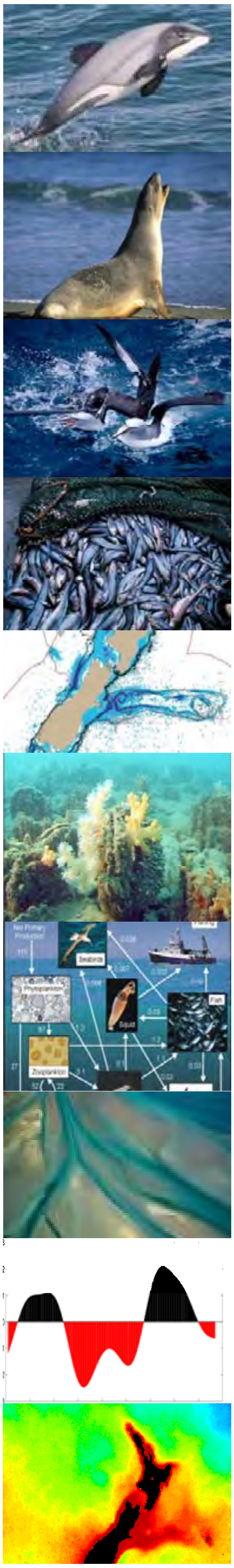
Ministry for Primary Industries (2012a). Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1194 p.

Ministry for Primary Industries (2012b). Fisheries Assessment Plenary, November 2012: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 531 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.

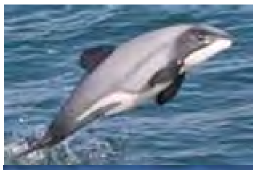
Our understanding is not uniform across these themes and, for example, our knowledge of the quantum and consequences of fishing-related mortality of protected species is much better developed than our knowledge of the consequences of mortalities of non-target fish, bottom trawl impacts, or land management 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.



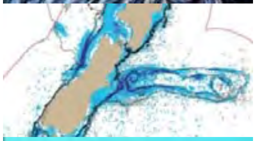
THEME	RESEARCH QUESTIONS	CURRENT WORK
1.PROTECTED SPECIES • Marine mammals • Seabirds • Turtles • Protected fish • Corals	• How many of each NZ-breeding protected species are caught and killed in our fisheries (and out of zone)? • How many unobserved deaths are caused? • What is the likely effect of fishing-related mortality on protected species populations? • 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? • What levels of fatalities would lead to different population outcomes?	• Estimation of annual captures of protected species by fishery • Abundance and productivity of key seabird populations • Abundance and productivity of Hector's & Maui's dolphins • Semi-quantitative risk assessment for all seabirds • Semi-quantitative risk assessment for all marine mammals • Full quantitative risk assessment for selected at-risk populations • Modelling to assess robust links between observed fatalities and population outcomes
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 cycle for deepwater and highly migratory • Risk assessment for tier 3 deepwater bycatch species
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?	• Testing of habitat classifications • Assessment of sensitivity and recovery rate of key habitats • Monitoring the deepwater trawl footprint • Developing means to monitor the inshore trawl footprint • Mapping of biogenic habitats
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? • What is "habitat of particular significance for fisheries management"? • 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?	• Habitat of significance: Kaipara Harbour fish habitats (SNA) • Habitat of significance: review of information for inshore finfish • Habitat of significance: coastal shark nursery areas • Multi-impact risk assessment • Monitoring and indicators of environmental change for deepwater fisheries • Ecotrophic factors affecting highly migratory species • Review and summary of the effects of aquaculture
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 • Ocean acidification in fish habitat • 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 2013.

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 underway. • The full impact of fishing-related mortality on most protected species remains uncertain because of some key knowledge gaps and we rely heavily on risk assessment approaches. • 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 first for seabirds and subsequently applied to 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 waters and developing in coastal waters, although information for most 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 (this needs finalising for inshore species). • 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 (funding from MBIE), 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 (Fiordland, Spirits Bay, seamounts) and larger fishery scale (Norfolk ridge, Chatham Rise, Challenger Plateau, BOI). • 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 ongoing. • 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







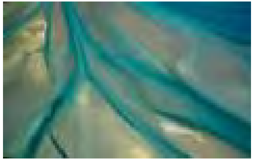
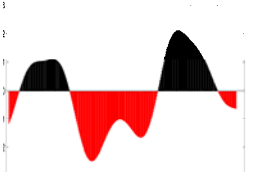
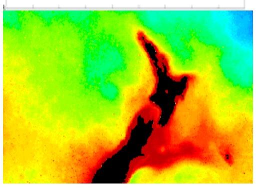




Figure 2.1 *continued*: Summary of Themes in the Aquatic Environment & Biodiversity Review 2013

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.
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; External review of the Breen-Fu-Gilbert model* (SRP2011-04).
Other Govt Research (current)	DOC Marine Conservation Services Programme (CSP): 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*; POP2013-01 *To provide information on the population level and dynamics of the New Zealand sea lion at the Auckland Islands relevant to assessing the impacts of commercial fishing impacts on this population*; POP2012-02 *To determine the key demographic factors driving the observed population decline of New Zealand sea lions at the Auckland Islands*. 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 issues/chapters	See the New Zealand fur seal chapter.

Note: this chapter has been updated for the AEBAR 2013.

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

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[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.

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:

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.

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 and Gales 1998, Gill 1998). 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 and 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

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[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.

[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."

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 and Wilkinson 2008).

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 and Wilkinson 2009), as well as throughout the Auckland Islands and the Otago Peninsula (see Augé et al 2011a, b, 2013 and Chilvers et al 2011). Work also is underway at Campbell Island under NIWA project TMMA103, *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). 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).

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 and 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 and Wilkinson 2009).

The differences in dive profiles have further implications for the animals' estimated aerobic dive limits (ADL; Gales and 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 and 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 environment between the Auckland Islands and the Otago peninsula, a founder effect, or a combination of these or other factors.

Table 3.1: Comparison of select 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 fish (rattail, red cod, opalfish, hoki), cephalopods (octopus, squid), crustaceans (lobster krill, scampi), and salps (Cawthorn et al 1985; Childerhouse et al 2001; Meynier et al 2009). 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 tends to include proportionally more arrow squid (*Nototodarus sloanii*) and proportionally fewer red cod (*Pseudophycis bachus*) and scampi (*Metanephrops challengeri*) than for male NZ sea lions, while lactating and non-lactating females do not differ in their diet (Meynier et al 2008; Meynier 2010).

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 and 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 and 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 and 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 at birth weigh 8–12 kg with parental care restricted to females (Walker and Ling 1981, Cawthorn et al 1985, Chilvers et al 2006). Females remain ashore for about 10 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 and 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 (Riet-Sapriza et al 2012, Chilvers 2008). Pups are weaned after about 10–12 months (Marlow 1975, Gales and 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 and Chilvers 2011). The data show a decline in pup production from a peak of 3021 in 1997/98 to a low of 1501 ± 16 pups in 2008/09 (Chilvers and Wilkinson 2011, Robertson and Chilvers 2011; Table 3.2), with the largest single-year decline (31%) occurring between the 2007/08 and 2008/09 counts. The most recent estimate of pup production for the Auckland Islands population was 1931 pups in 2012/13, of which 357 ± 4 were counted at Sandy Bay and 1364 ± 46 were counted at Dundas Island, using the mark-recapture method. A direct ground count at Figure of Eight Island resulted in 70 ± 1 live pups (Childerhouse et al 2013). An aerial survey made during the same time as the ground surveys for Sandy Bay and Dundas Island resulted in 349 for Sandy Bay and 1398 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). No pups were counted at South East Point using either method.

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 and Kim 2006a, Breen and Kim 2006b, Breen et al 2010). Although other abundance estimates are available (e.g. Gales and 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.

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 (2013), noting that dead pus were not counted in these surveys, leading to some negative bias. 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	1 683	16		
2013	1 931			

For the Campbell Island population, pup production was estimated at 681–726 pups in 2010 (Robertson and Chilvers 2011, 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). The observed increase is not expected to continue (Maloney et al 2012). 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 and 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 7 pups since the 1994/95 breeding season, with five pups recorded in 2010/11 and five recorded in 2012/13 (McConkey et al 2002, Augé 2011, J. Fyfe pers comm). A modelling exercise suggested that this population can

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[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 and Wilkinson 2011).

expand to 9–22 adult females by 2018 (Lalas and Bradshaw 2003). 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 been found at Stewart Island, where 25 pups were tagged during a DOC hut and track maintenance trip in March 2012. Twenty-six pups were tagged at Stewart Island in 2013 (L. Chilvers pers comm).

Established anthropogenic sources of mortality in NZ sea lion include: historic subsistence hunting and commercial harvest (Gales 1995, Childerhouse and Gales 1998); pup entrapment in rabbit burrows prior to rabbit eradication from Enderby Island in 1993 (Gales and 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 and 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 and 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 and Chilvers 2011) and *Klebsiella pneumoniae* that killed 33% and 21% of pups on the Auckland Islands in 2001/02 and 2002/03 respectively (Wilkinson et al 2006). The 1998 epizootic event may have affected the fecundity of the surviving pups, reducing their breeding rate relative to other cohorts (Gilbert and Chilvers 2008). There are also occurrences of predation by sharks (Cawthorn et al 1985, Robertson and Chilvers 2011), starvation of pups if they become separated from their mothers (Walker and Ling 1981, Castinel et al 2007), drowning in wallows and male aggression towards females and pups (Wilkinson et al 2000, Chilvers et al 2005b).

Analysis of tag-resight data on Enderby Island 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, with no indication of a systematic change in survival during the period 1997/98 to 2010/11 (MacKenzie 2011). Further analysis of tag-resight data is being conducted under DOC project POP2012-02 to determine the key demographic factors driving the observed population decline of New Zealand sea lions at the Auckland Islands. This project is due to be completed in June 2014.

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 and Chilvers 2011).

3.2.6. 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 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

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[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

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).

3.3. Global understanding of fisheries interactions

Reviews of fisheries interactions among pinnipeds globally can be found in Read et al (2006), Woodley and 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 3.1); 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 and 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 lionsare 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 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.

(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).

[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.

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).

NZ sea lions	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Breeding males	Dispersed at sea or at haulouts		At breeding colony			Dispersed at sea or at haulouts						
Breeding females	At sea			At breeding colony		At breeding colony and at-sea foraging and suckling						
New Pups				At breeding colony								
Non-breeders	Dispersed at sea, at haulouts, or breeding colony periphery											
Major fisheries	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Hoki trawl		Chatham Rise and Stewart-Snares Shelf								Cook Strait, west coast South Island, Puysegur		
Squid				Stewart-Snares Shelf		Auckland Islands and Stewart-Snares Shelf						
Southern blue whiting	Pukaki Rise and Campbell Rise											Bounty Islands
Scampi	Auckland Islands											

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. In the SQU6T fishery, observer effort was generally around 20–40% in the same period, but reached almost 100% during the 2000/01 season (see 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). 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, while observers reported 196 captures over the same period (Abraham and 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). This approach is currently being applied using information collected under DOC project INT2012-01 and analysed under MPI project PRO2010-01 (Thompson et al 2011, 2013). 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 Table 3.4; and detailed information in Thompson et al 2013). 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 and Baird 2007b, Thompson and Abraham 2010, Thompson et al 2013). Interactions are defined as the number of sea lion 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, both the observed and estimated numbers of NZ sea lion captures have generally declined (Table 3.4). 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. For the other fisheries where SLEDs were not deployed, observed and estimated numbers of NZ sea lion captures increased in the Campbell Island southern blue whiting fishery to a peak in 2010, with a subsequent decrease (Table 3.4). 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 3.4).

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 and 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 and Baird 2005).

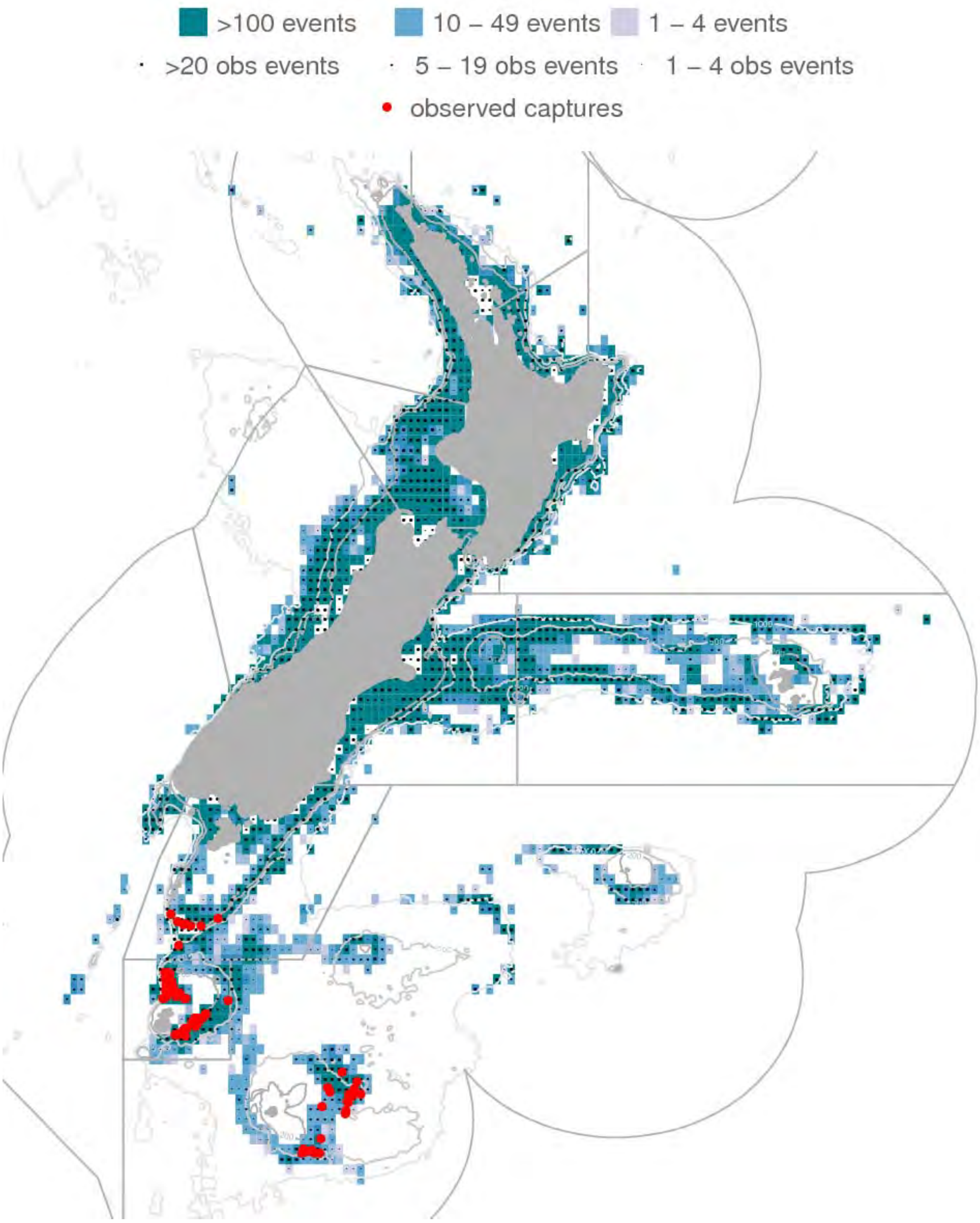


Figure 3.1: Distribution of trawl fishing effort and observed NZ sea lion captures, 2002-03 to 2011-12 (http://data.dragonfly.co.nz/psc/). Fishing effort is mapped into 0.2-degree cells, with the colour of each cell indicating the amount of effort (number of fishing events). Observed fishing events are 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, 96.0% of the effort is shown.

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 3.2), 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 3.5; Robertson and Chilvers 2011).

Table 3.4a: Sea lion captures in all commercial trawl fisheries in New Zealand's Exclusive Economic Zone between 1995 and 2012 (http://data.dragonfly.co.nz/psc/). 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) 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	10 108	10	16	1.5	Both	143	80–241	144	80–243	1.4	0.8–2.4
1996–97	10 975	15	28	1.7	Both	153	104–225	153	100–226	1.4	0.9–2.1
1997–98	9977	14	14	1.0	Both	74	46–118	75	44–121	0.7	0.5–1.2
1998–99	10 559	16	6	0.4	Both	32	19–48	32	18–49	0.3	0.2–0.5
1999–00	9046	23	28	1.4	Both	88	61–127	88	59–130	1.0	0.7–1.4
2000–01	8932	40	46	1.3	Both	60	52–70	82	57–113	0.7	0.6–0.8
2001–02	9946	19	23	1.2	Both	63	45–85	93	60–137	0.6	0.5–0.9
2002–03	8311	19	11	0.7	Both	32	22–46	60	36–93	0.4	0.3–0.6
2003–04	10 036	23	21	0.9	Both	60	43–82	219	117–389	0.6	0.4–0.8
2004–05	11 118	23	14	0.5	Both	53	35–76	186	93–342	0.5	0.3–0.7
2005–06	9316	21	14	0.7	Both	50	34–72	172	86–331	0.5	0.4–0.8
2006–07	6736	24	15	0.9	Both	46	32–65	120	57–233	0.7	0.5–1.0
2007–08	6545	33	8	0.4	Both	28	17–41	132	35–507	0.4	0.3–0.6
2008–09	6677	27	3	0.2	Both	20	11–33	110	24–455	0.3	0.2–0.5
2009–10	5541	34	15	0.8	Both	45	30–64	157	51–543	0.8	0.5–1.2
2010–11	6460	31	6	0.3	Both	28	17–42	85	25–299	0.4	0.3–0.7
2011–12	5456	42	1	0.0	Both	12	5–21	52	11–216	0.2	0.1–0.4

Table 3.4b: Sea lion captures in the Auckland Islands squid trawl fishery between 1995 and 2012 (http://data.dragonfly.co.nz/psc/). 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) 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	4466	12	13	2.4	Model	127	64–224	127	64–223	2.9	1.5–4.9
1996–97	3716	19	28	3.9	Model	140	92–212	140	89–213	3.8	2.6–5.5
1997–98	1441	22	13	4.2	Model	59	32–102	59	30–105	4.1	2.4–6.9
1998–99	402	39	5	3.2	Model	14	7–26	14	4–28	3.5	2.1–5.9
1999–00	1206	36	25	5.7	Model	70	45–108	70	42–111	5.8	4.0–8.7
2000–01	583	99	39	6.7	Model	39	39–40	61	38–90	10.5	8.7–13.3
2001–02*	1648	34	21	3.7	Model	42	29–62	73	42–116	4.4	2.9–6.6
2002–03	1470	29	11	2.6	Model	19	13–28	46	24–77	3.2	1.9–4.9
2003–04	2594	30	16	2.0	Model	40	26–60	200	98–370	7.7	4.0–14.2
2004–05^	2706	30	9	1.1	Model	31	17–53	165	73–320	6.1	2.8–11.7
2005–06	2462	28	9	1.3	Model	27	15–45	149	63–309	6.1	2.6–12.5
2006–07	1320	41	7	1.3	Model	16	9–26	89	28–200	6.8	2.4–15.2
2007–08	1265	47	5	0.8	Model	12	6–21	116	21–489	9.2	1.8–38.9
2008–09	1925	40	2	0.3	Model	7	2–16	97	12–441	5.0	0.7–22.6
2009–10	1190	25	3	1.0	Model	13	5–26	124	19–508	10.4	1.7–43.1
2010–11	1586	34	0	–	Model	4	0–11	60	4–278	3.8	0.3–17.4
2011–12	1281	44	0	–	Model	2	0–7	43	2–206	3.3	0.2–16.2

* SLEDs introduced. ^ SLEDs standardised and in widespread use.

Table 3.4c: Sea lion captures in trawl fisheries targeting scampi and targeting other speciesadjacent to the Auckland Islands between 1995 and 2012 (http://data.dragonfly.co.nz/psc/). 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) 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	1306	5	2	3.1	Ratio	10	4–18
1996-97	1224	15	0	–	Ratio	7	2–14
1997-98	1107	12	0	–	Ratio	6	1–14
1998-99	1254	2	0	–	Ratio	8	2–17
1999-00	1383	5	0	–	Ratio	9	2–17
2000-01	1417	6	4	4.8	Ratio	13	6–21
2001-02	1604	9	0	–	Ratio	10	3–19
2002-03	1351	11	0	–	Ratio	8	2–16
2003-04	1363	12	3	1.8	Ratio	11	5–19
2004-05	1275	0	NA	NA	Ratio	8	2–17
2005-06	1331	9	1	0.9	Ratio	9	3–17
2006-07	1328	7	1	1.1	Ratio	9	3–17
2007-08	1327	7	0	–	Ratio	8	2–17
2008-09	1457	4	1	1.6	Ratio	10	4–19
2009-10	940	10	0	–	Ratio	6	1–12
2010-11	1401	15	0	–	Ratio	8	2–16
2011-12	1244	10	0	–	Ratio	7	2–15
Auckland Islands other							
1995–96	406	6	1	4.0	Ratio	3	1–6
1996–97	296	4	0	–	Ratio	1	0–4
1997–98	684	17	1	0.9	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

Table 3.4d: Sea lion captures in Campbell Island southern blue whiting (SBW) and in Stewart-Snares shelf trawl fisheries between 1995 and 2012 (http://data.dragonfly.co.nz/psc/). 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) for details).

Fishing year	**Fishing effort**		**Observed captures**				**Estimated captures**
	All effort	**% observed**	**Number**	**Rate**	**Method**	**Mean**	**95% c.i.**
Campbell Island SBW							
1996	474	27	0	–	Model	0	0–3
1997	641	34	0	–	Model	0	0–3
1998	963	29	0	–	Model	1	0–5
1999	788	28	0	–	Model	1	0–5
2000	447	52	0	–	Model	0	0–2
2001	672	60	0	–	Model	0	0–2
2002	980	28	1	0.4	Model	3	1–11
2003	599	43	0	–	Model	0	0–3
2004	690	34	1	0.4	Model	3	1–9
2005	726	37	2	0.7	Model	5	2–12
2006	521	28	3	2.1	Model	9	3–21
2007	544	32	6	3.5	Model	15	5–29
2008	557	41	2	0.9	Model	8	5–14
2009	627	20	0	–	Model	1	0–6
2010	550	43	11	4.7	Model	24	15–36
2011	886	39	6	1.7	Model	14	8–25
2012	575	76	0	–	Model	1	0–3
Stewart-Snares (mainly squid)							
1995–96	3456	8	0	–	Ratio	3	0–7
1996–97	5098	10	0	–	Ratio	4	0–10
1997–98	5782	10	0	–	Ratio	5	1–11
1998–99	7590	16	0	–	Ratio	6	1–12
1999–00	5260	23	3	0.2	Ratio	7	3–12
2000–01	5682	43	3	0.1	Ratio	6	3–10
2001–02	5125	18	1	0.1	Ratio	5	1–10
2002–03	4348	16	0	–	Ratio	3	0–8
2003–04	5100	21	1	0.1	Ratio	5	1–10
2004–05	6241	24	3	0.2	Ratio	7	4–13
2005–06	4963	19	1	0.1	Ratio	5	1–9
2006–07	3506	24	1	0.1	Ratio	3	1–7
2007–08	3249	36	1	0.1	Ratio	3	1–6
2008–09	2547	31	0	–	Ratio	2	0–5
2009–10	2784	43	1	0.1	Ratio	2	1–5
2010–11	2456	36	0	–	Ratio	1	0–4
2011–12	2299	50	1	0.1	Ratio	2	1–4

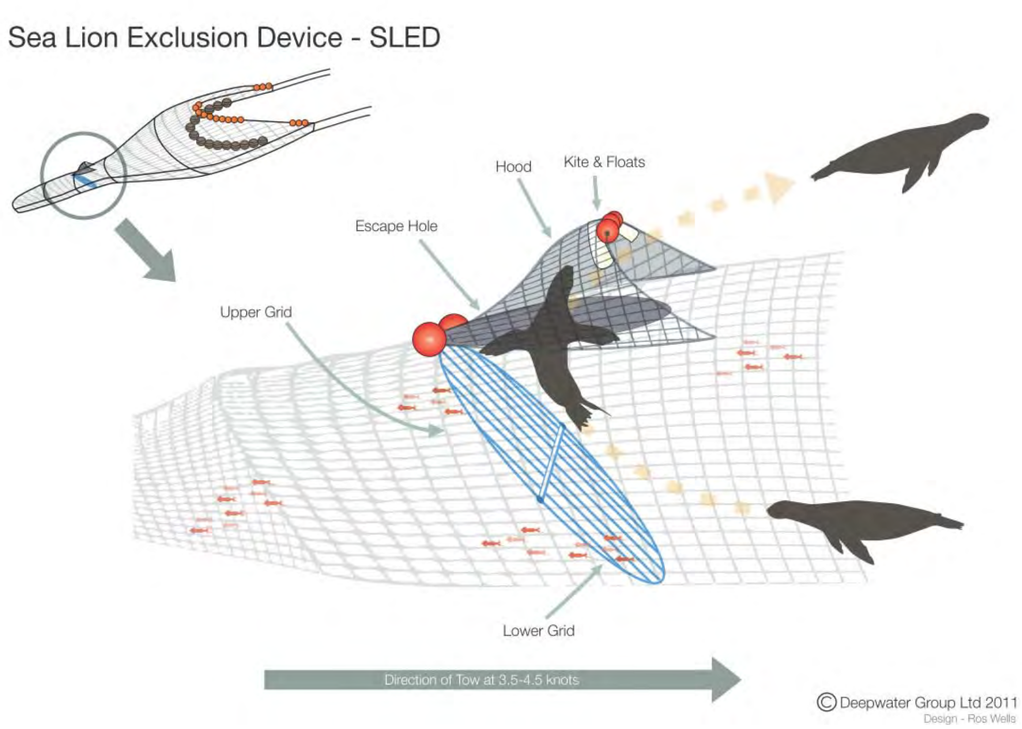


Figure 3.2: Diagram of a NZ sea lion exclusion device (SLED) inside a trawl net. Image courtesy of the Deepwater Group.

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 3.3.3). A strike rate of 5.89 will be assumed for the 2012-13 season, 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 and Abraham 2010, see Table 3.5). 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 3.5: Maximum allowable level of fisheries-related mortality (MALFiRM) or fisheries-related mortality limit (FRML) from 1991 to 2013. Note, however, that direct comparisons among years of the limits in Table 3.5 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%	

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. 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 and 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.

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 and Kim 2006a, Breen and Kim 2006b, and Breen, Fu and 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 and 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 and 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 and 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 and 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 and 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 and 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 and 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 and 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. 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 stike 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).

The density dependent response for this population of NZ sea lions is largely unknown, although there is presently no evidence of a density dependent response in life-history traits such as pup mass, pup survival or female fecundity (Chilvers 2012b). Ecological principles suggest that, as numbers in a population decline, 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 and 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 3.6), or by some other factor, then this would make the simulations optimistic.

Table 3.6: Tow duration in the SQU6T fishery (i.e. for trawl fishers targeting SQU in statistical areas 602, 603, 617 and 618). Years are calendar years. Data from MPI databases.

			Percentage of tows		
Year	**No. of tows**	**Mean tow duration (hours)**	**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

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

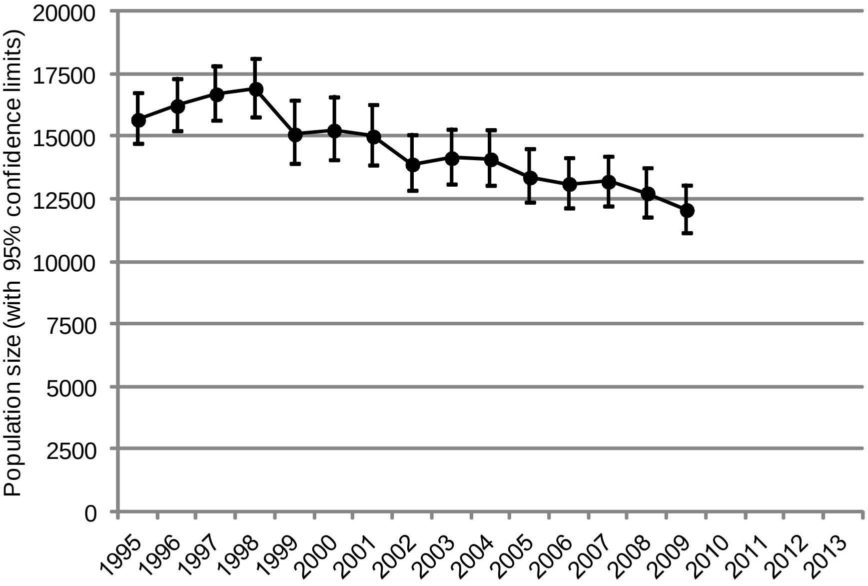
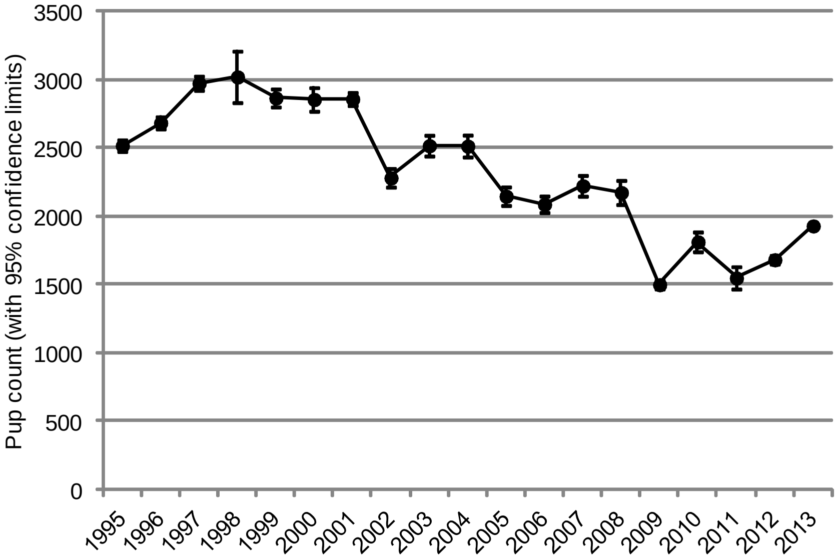
- consideration of a female-only model and other structural changes
- sensitivity to the choice of time series of incidental captures, including before 1980

The panel made several suggestions for further testing and modification of the model and expected these to resolve many of the issues identified. 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.

3.4.5. 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 and 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 may indicate that the nutritional content of prey species is not limiting the metabolic activity of NZ sea lions, although vitamin and mineral content were not considered. 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 (Project SA123098). 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

Population size	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] 1 931 pups at the Auckland Islands in 2012/13[11] 681–726 pups at Campbell Island in 2010[12] 26 pups tagged at Stewart Island in 2013[12] 5 pups at the Otago Peninsula in 2011/12
Population trend	Estimated abundance at the Auckland Islands:  Pup production at the Auckland Islands:  The Campbell Island population is probably increasing based on substantial increases in pup counts (although methodology has changed over time). The Otago Peninsula population is increasing through a combination of reproduction and immigration.

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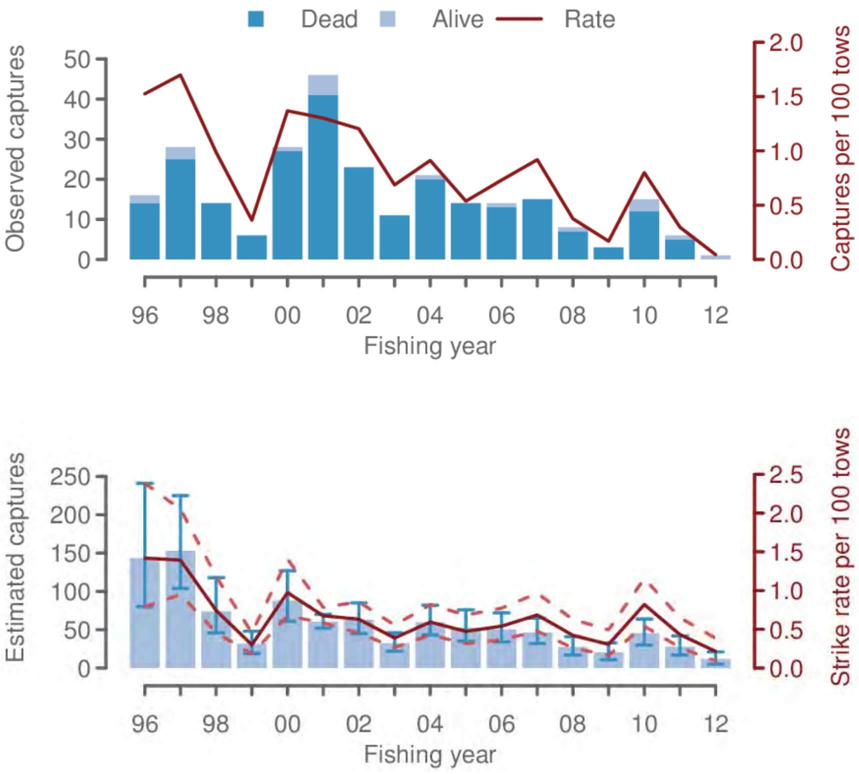
[10] Breen et al (2010).

[11] Childerhouse et al 2013

[12] Robertson and Chilvers (2011), Maloney et al (2012).

[12] L. Chilvers pers. comm. to R Mattlin.

Threat status	NZ: Nationally Critical, Criterion C[13], Range Restricted[14], in 2010[15] IUCN: Vulnerable, A3b[16], in 2008[17]
Number of interactions[18]	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
Trend in interactions	Observed and estimated captures in all trawl fisheries: 

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[13] 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).

[14] 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).

[15] Baker et al (2010).

[16] 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).

[17] Gales (2008).

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

3.6. References

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New Zealand fur seal (*Arctophoca australis forsteri*)

Scope of chapter	This chapter outlines the biology New Zealand fur seals (*Arctophoca australis forsteri*), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty. The taxonomy of the New Zealand fur seal (previously described as a species — *Arctocephalus forsteri*) has recently been revised (Berta & Churchill 2012, Committee on Taxonomy (2012), as reflected above.
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.
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)	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*.
Other Govt Research (current)	DOC Marine Conservation Services Programme (CSP): 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*.
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 New Zealand sea lion chapter.

Note: this chapter has been updated for the AEBAR 2013.

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.

In 2004, DOC approved the *Department of Conservation Marine Mammal Action Plan for 2005–2010*[19] (Suisted and 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)."*

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 seals 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 foodchain 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.

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

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.

Biology

4.1.1. Taxonomy

The NZ fur seal (previously known as *Arctocephalus forsteri* (Lesson, 1828)) is currently recognised as a subspecies (*Arctophoca australis forsteri*, Lesson, 1828), based on genetic and morphological data (Berta & Churchill 2012, Committee on Taxonomy 2012). Thisotariid seal (Family Otariidae – eared seals, including fur seals and sea lions) is one of two native to New Zealand, the other being the New Zealand sea lion (*Phocarctos hookeri* (Gray, 1844)).

4.1.2. 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 40° S to Macquarie Island. On land, NZ fur seals are distributed around the New Zealand coastline, on offshore islands, and on sub-Antarctic islands (Crawley and 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 and 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 and 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 and Wilson 1976).

4.1.3. 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 and 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).

4.1.4. Reproductive biology

NZ fur seals are sexually dimorphic and polygynous (Crawley and 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 and Dawson 2003). The maximum age recorded for NZ fur seals in New Zealand waters is 22 years for females (Dickie and 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 and 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 and 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 and 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 and 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 and 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 and Shaughnessy (1994) for a South Australian colony.

Newborn pups are about 55 cm long and weigh about 3.5 kg (Crawley and Wilson 1976). Male pups are generally heavier than female pups at birth and throughout their growth (Crawley and 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).

4.1.5. 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 estimate is 20,000–30,000 animals (Lalas 2008). A 20-

year plus time series of pup counts exists for three west coast South Island colonies (Cape Foulwind, Wekekura Point, and Open Bay Islands; Best 2011). Recent Kaikoura work by Boren (2005) covered four seasons and unpublished data are available for the subsequent seasons.

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 and Harcourt 1995, Lalas and Murphy 1998, Lalas 2008), 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[20].

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 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 and Bradshaw 2001, Boren 2005, Boren et al 2006, 2008); and mortality through shooting, bludgeoning, and dog attacks. NZ fur seals are vulnerable to certain

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[20] 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.

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 and 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 and Gemmell (2005). Lento et al (1994) described the geographic distribution of mitochondrial cytochrome *b* DNA haplotypes. Robertson and 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.

4.1.6. 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 and 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).

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).

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 and 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 and 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 and Bradford 2000, Mormede et al 2008, Smith and 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 Figures 4.1 and 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 and Smith 2007, Abraham et al 2010a). 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 and 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 and Smith 2007, Thompson and 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.

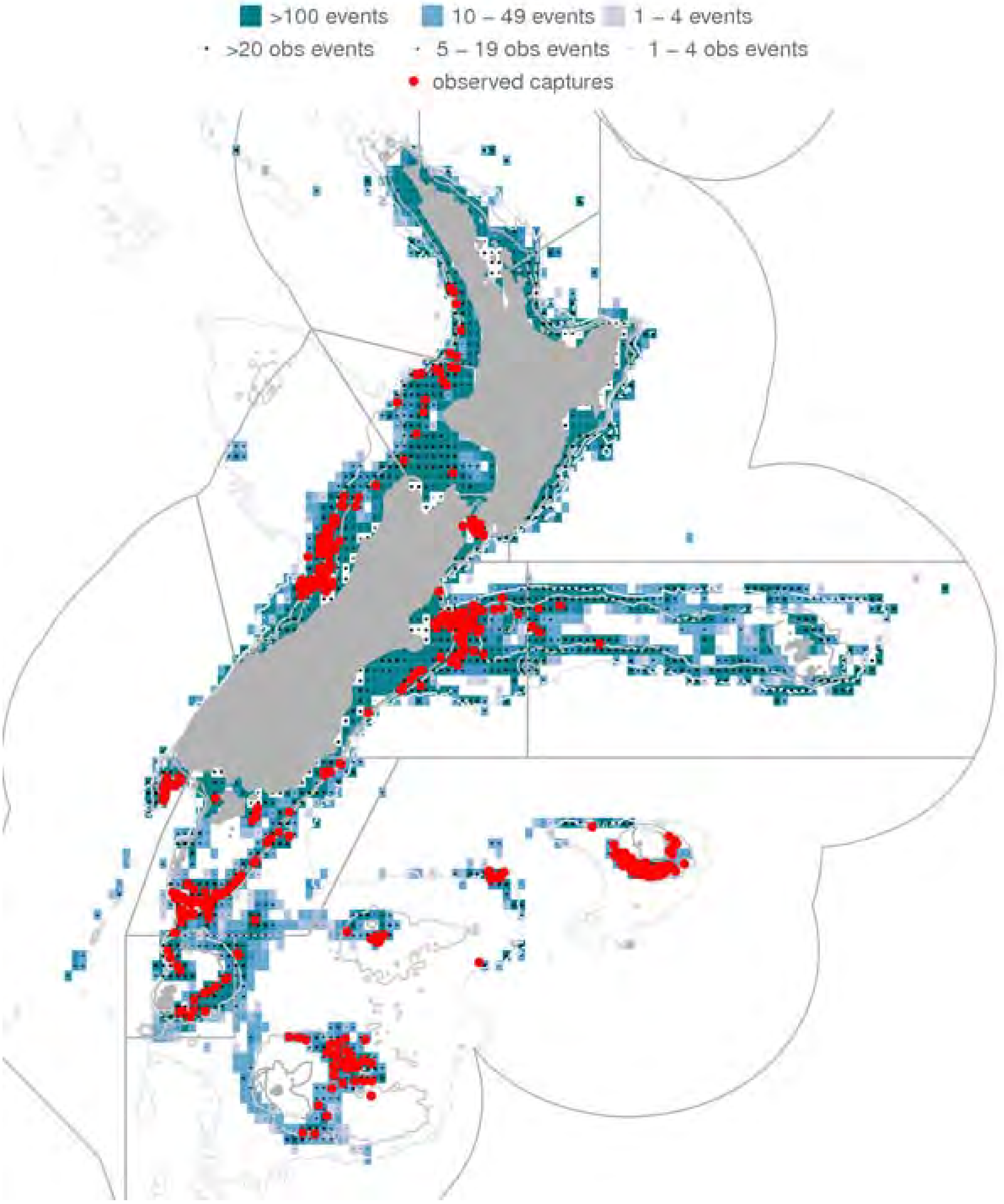


Figure 4.1: Distribution of trawl fishing effort and observed NZ fur seal captures, 2002-03 to 2011-12 (for more information see MPI data analysis at http://data.dragonfly.co.nz/psc/). Fishing effort is mapped into 0.2-degree cells, coloured to represent the amount of effort. Observed fishing events 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. For these years, 96.1% of the effort is shown.

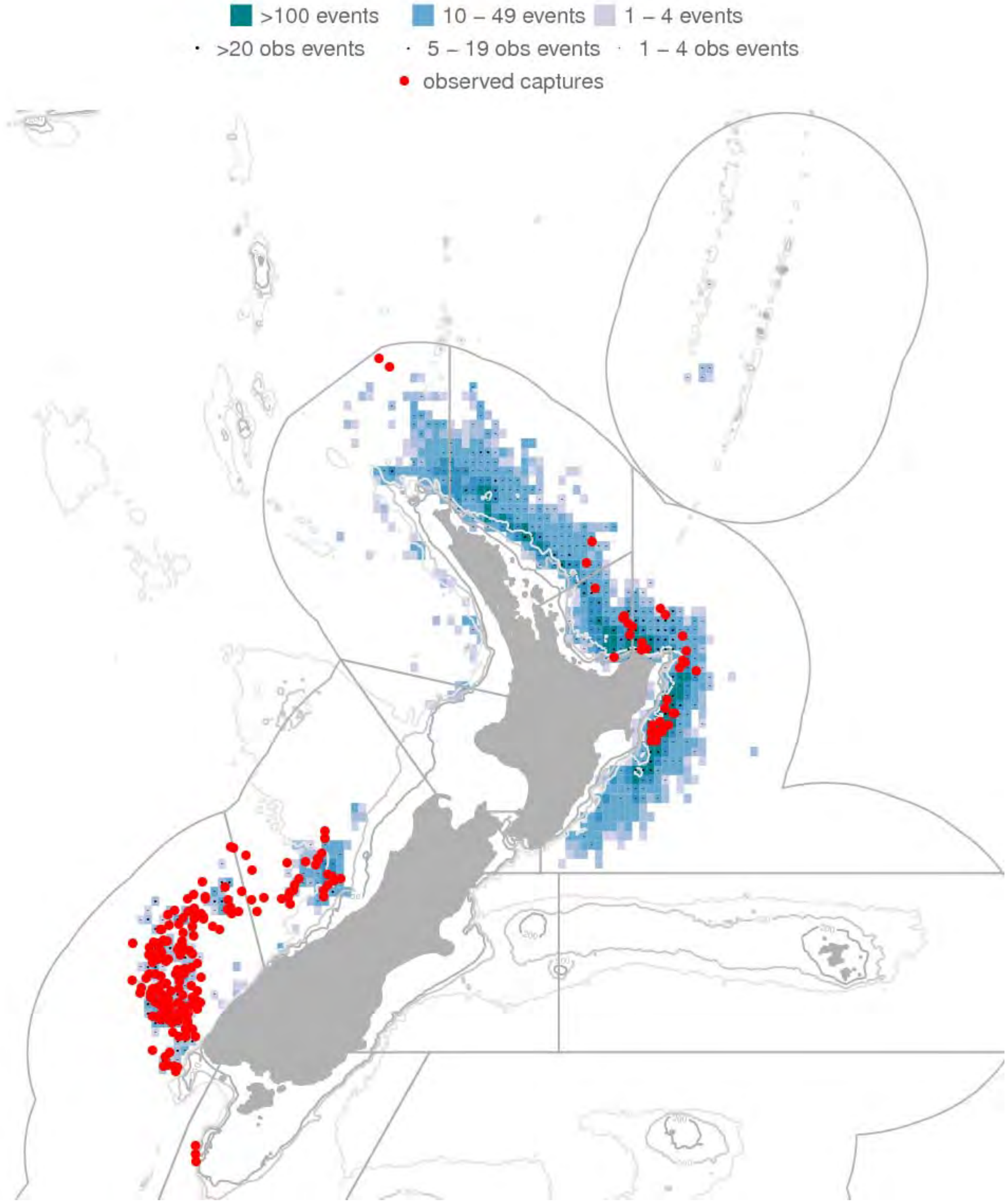


Figure 4.2: Distribution of surface longline fishing effort and observed NZ fur seal captures, 2002-03 to 2011-12 (for more information see MPI data analysis at http://data.dragonfly.co.nz/psc/). Fishing effort is mapped into 0.2-degree cells, coloured to represent the amount of effort. Observed fishing 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 fished within a cell. For these years, 75.0% of the effort is shown.

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.

NZ fur seals	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Breeding males	Dispersed at sea or at haulouts	At breeding colony				Dispersed at sea or at haulouts						
Breeding females	At sea		At breeding colony		At breeding colony and at-sea foraging and suckling							
New Pups	At sea			At breeding colony								
Non-breeders	Dispersed at sea, at haulouts, or breeding colony periphery											
Major fisheries	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Hoki trawl		Chatham Rise and Stewart-Snares Shelf								Cook Strait, west coast South Island, Puysegur		
Squid				Stewart-Snares Shelf		Auckland Islands and Stewart-Snares Shelf						
Southern blue whiting	Pukaki Rise and Campbell Rise											Bounty Islands
Scampi	Auckland Islands											
Southern bluefin tuna longline							SouthWest SI					

4.3.1. Quantifying fisheries interactions

Observer data and commercial effort data have been used to characterise the incidental captures and estimate the total numbers caught (Baird and Smith 2007, Smith and Baird 2009, Thompson and Abraham 2010, Abraham and 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, Thompson 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).

In the last 10 years, model-based estimates of captures have been developed for all trawl fisheries in waters south of 40° S (Baird and Smith 2007, Smith and Baird 2009, Thompson and Abraham 2010, Abraham and Thompson 2011, Thompson et al 2011, Thompson et al 2012, Thompson 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 7 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 and Baird 2009, Thompson and Abraham 2010, Abraham and Thompson 2011, Thompson et al 2011, Thompson et al 2012, Thompson et al in prep., Figure 4.3). This may reflect efforts to reduce bycatch (see section 4.4.1) 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 2011-12, about 11% of the 84 179 tows were observed, with a capture rate of 0.91 fur seal per 100 tows, to give an annual mean total of 442 captures (95% c.i. 256–789) (Table 4.2, See Figure 4.3). Most annual captures are generally observed in Cook Strait. Note these capture rates include animals that are released alive; 14% of 440 observed trawl captures in the 2007/08 to 2011/12 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 2010a). 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 numbers range from 127 (95% c.i. 121–133) in 1998–99 to 25 (14–39) in 2007–08 during southern bluefin tuna fishing by chartered and domestic vessels (Abraham et al 2010a). These capture rates include animals that are released alive (100% of observed surface longline captures in 2008-09, Thompson and Abraham 2010).

Captures of NZ fur seals have also been recorded in other fisheries; 8 in setnets and 2 in bottom longline fisheries since 2002-03 (Thompson et al 2012). Captures associated with recreational fishing activities are poorly known (Abraham et al 2010b).

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 (Thompson 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	1454–1744
1999–2000	139 057	5.5	203	2.65	Ratio	1 539	1400–1693
2000–2001	134 243	6.8	170	1.87	Ratio	1 490	1348–1649
2001–2002	127 883	6.0	157	2.03	Ratio	1 273	1164–1394
2002–2003	129 757	5.2	68	1.00	Model	877	529 – 1419
2003–2004	120 819	5.4	84	1.29	Model	1 071	644 – 1754
2004–2005	120 177	6.4	200	2.61	Model	1 514	943 – 2459
2005–2006	109 925	6.2	143	2.10	Model	955	591 – 1561
2006–2007	103 328	7.6	73	0.92	Model	547	333 – 916
2007–2008	89 432	10.1	141	1.56	Model	778	477 – 1355
2008–2009	87 489	11.2	72	0.74	Model	549	307 – 955
2009–2010	92 802	9.7	72	0.80	Model	484	272 – 911
2010–2011	85 982	8.6	73	0.98	Model	427	246 – 743
2011–2012	84 179	10.7	82	0.91	Model	442	256 – 789
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	10 764 588	20.4	56	0.03	Ratio	157	138–178
2003–2004	7 380 779	21.8	40	0.02	Ratio	116	99–133
2004–2005	3 676 365	21.3	20	0.03	Ratio	77	63–93
2005–2006	3 687 339	19.1	12	0.02	Ratio	70	55–85
2006–2007	3 738 362	27.8	10	0.01	Ratio	52	40–66
2007–2008	2 244 339	18.8	10	0.02	Ratio	45	34–56
2008–2009	3 115 633	30.1	22	0.02	Ratio	57	46–69
2009–2010	2 992 285	22.3	19	0.03	Ratio	78	64–94
2010–2011	3 185 779	21.2	17	0.02	Ratio	57	45–69
2011–2012	3 069 707	23.7	40	0.05	Ratio	96	81–111

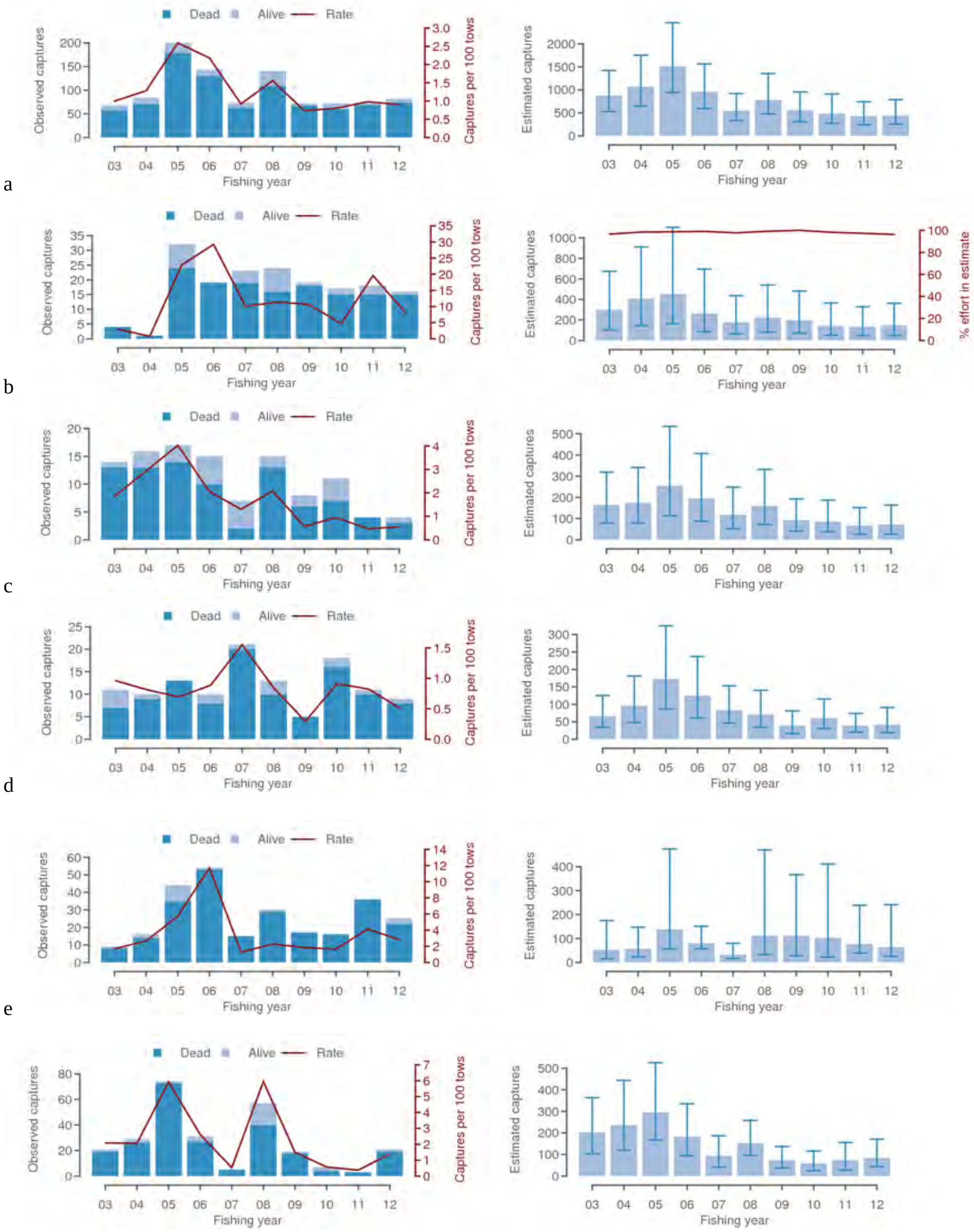


Figure 4.3: Observed captures of NZ fur seals (dead and alive) in trawl fisheries, the capture rate (captures per hundred tows) and the mean number of estimated total captures (with 95% confidence interval) by fishing year for regions with more than 50 observed captures since 2002-03: (a) New Zealand's 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 (Thompson et al *in prep*. and see MPI data analysis at http://data.dragonfly.co.nz/psc/). 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).

4.3.2. 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).

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 proven 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.

4.3.3. 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) 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 et al 2011). In this approach, risk is defined as the ratio of total estimated annual fatalities due to bycatch in fisheries, to the level of Potential Biological Removal (PBR, Wade 1998). The results should be available in 2014.

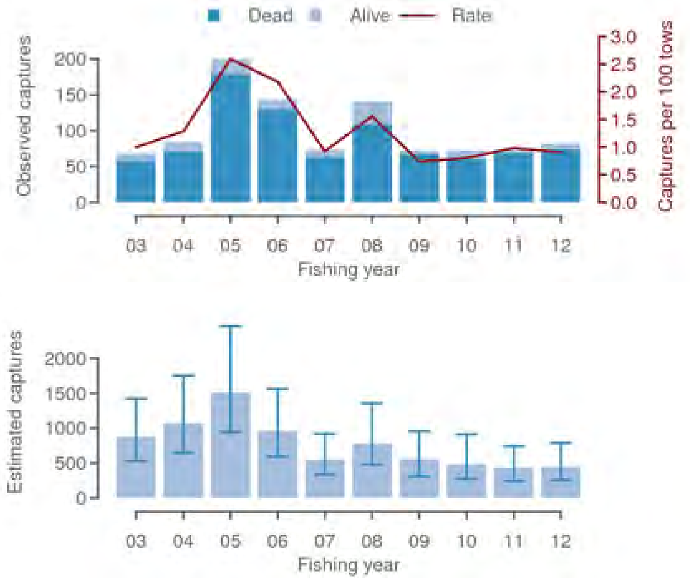
4.3.4. Sources of uncertainty

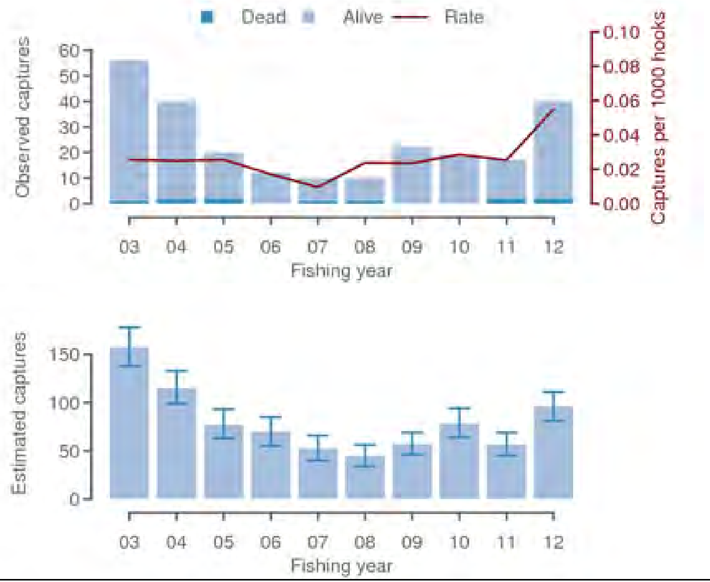
Any measure of the effect of NZ fur seal mortality from commercial fisheries on NZ fur seal populations requires adequate information on the size of the populations at different colonies. Although there is reasonable information about where the main NZ fur seal breeding colonies exist, the size and dynamics 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 and 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.

Indicators and trends

<table>
<tr><td>Population size</td><td>Unknown, but potentially ~100 000 in the New Zealand EEZ[21].</td></tr>
<tr><td>Population trend</td><td>Increasing at some mainland colonies but unknown for offshore island colonies. Range is thought to be increasing.</td></tr>
<tr><td>Threat status</td><td>NZ: Not Threatened, Increasing, Secure Overseas, in 2010[22].
IUCN: Least Concern, in 2008[23].</td></tr>
<tr><td>Number of interactions[24]</td><td>442 estimated captures (95% c.i.: 256–789) in trawl fisheries in 2011–12
96 estimated captures (95% c.i.: 81–111) in surface-longline fisheries in 2011–12
82 observed captures in trawl fisheries in 2011–12
40 observed captures in surface-longline fisheries in 2011–12</td></tr>
<tr><td>Trends in interactions</td><td>Trawl fisheries:


Surface longline fisheries:

</td></tr>
</table>

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

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5. Hector's dolphin (*Cephalorhynchus hectori hectori*) and Maui's dolphin (*C. h. maui*)

Scope of chapter	This chapter outlines the biology of Hector's dolphin (*Cephalorhynchus hectori hectori*) and Maui's 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*.
Other Govt 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[25]	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

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[25] 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).

Related issues/chapters	See the New Zealand sea lion and New Zealand fur seal chapters.

Note: This chapter is new for the AEBAR 2013.

Context

Hector's and Maui's dolphin[26] (*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 Maui's 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 2008; 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 Maui's 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[27] (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 Maui's dolphin and no maximum allowable level of fishing-related mortality has been set. A draft threat management plan (TMP) for Hector's and Maui's 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 Maui's 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*

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[26] 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.

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

- *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 Maui's dolphin TMP consultation paper* published in 2012 (MPI & DOC 2012). The review of the Maui's portion of the TMP provided a comprehensive overview of information relating to the biology, distribution, threats to, and management of Maui's dolphins. To inform the review of the Maui's dolphin TMP, a spatially-explicit, semi-quantitative risk assessment was conducted using an expert panel, to identify, analyse and evaluate all threats to Maui's 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.

Biology

5.2.1. Taxonomy

Hector's and Maui's 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 Maui's dolphin was divided into two sub-species; Hector's dolphin around the South Island (41°S to 47°S) and Maui's dolphin, on the west coast of the North Island (36°S to 40°S; Baker et al 2002). The reproductive isolation of the Maui's 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 in press).

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 2013) 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 2009a). 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 2009a).

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 Maui's 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 Maui's dolphins there is currently no evidence of interbreeding (Hamner et al , in press). 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 (in press) 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.

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

There are reported public sightings of Hector's and Maui's 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 Maui's 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 Maui's dolphins' 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 Maui's 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 Maui's 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 2013; Figures 5.2 & 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. Figures 5.2 & 5.3). Occasional sightings are made beyond the 100 m isobath (e.g. DuFresne & Mattlin 2009; MacKenzie & Clement 2013). Varying bathymetry among these locations meant that all sightings were within 6 nm offshore of the South Island west coast (Rayment et al 2011a), yet extended at least out to 20 nm from the coast at Banks Peninsula (MacKenzie & Clement 2013). 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 2013), a conclusion consistent with nearshore boat-based surveys (e.g. Dawson & Slooten 1988; Bräger 1998) and passive acoustic monitoring (Rayment et al 2009b). However, the furthest offshore sighting distances were similar in summer and winter (Rayment et al 2010; MacKenzie & Clement 2013). 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 Maui's dolphins occurs inshore (within 4 nm 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 nm from the coast, extending at least to 7 nm offshore (Du Fresne 2010; Thompson & Richard 2012). Sightings of Maui's 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 Maui's dolphin distribution[28] was developed as part of the Maui's 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 (2012) investigated the diet of Hector's and Maui's 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 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 <10 cm in length, indicating that the juveniles of some species were targeted (Miller et al 2012). 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 2012). 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 2012). The stomachs of the six smallest dolphins in the sample (standard length <90 cm) contained only milk, while the next largest (99 cm standard length) contained milk and remains of arrow squid (Miller et al 2012). Milk was not found in the stomachs of any dolphins longer than 107 cm (Miller et al 2012).

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 2012), 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).

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[28] 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 2012; 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 the proportion of Hector's dolphins is likely to be small and there was no evidence to suggest 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.

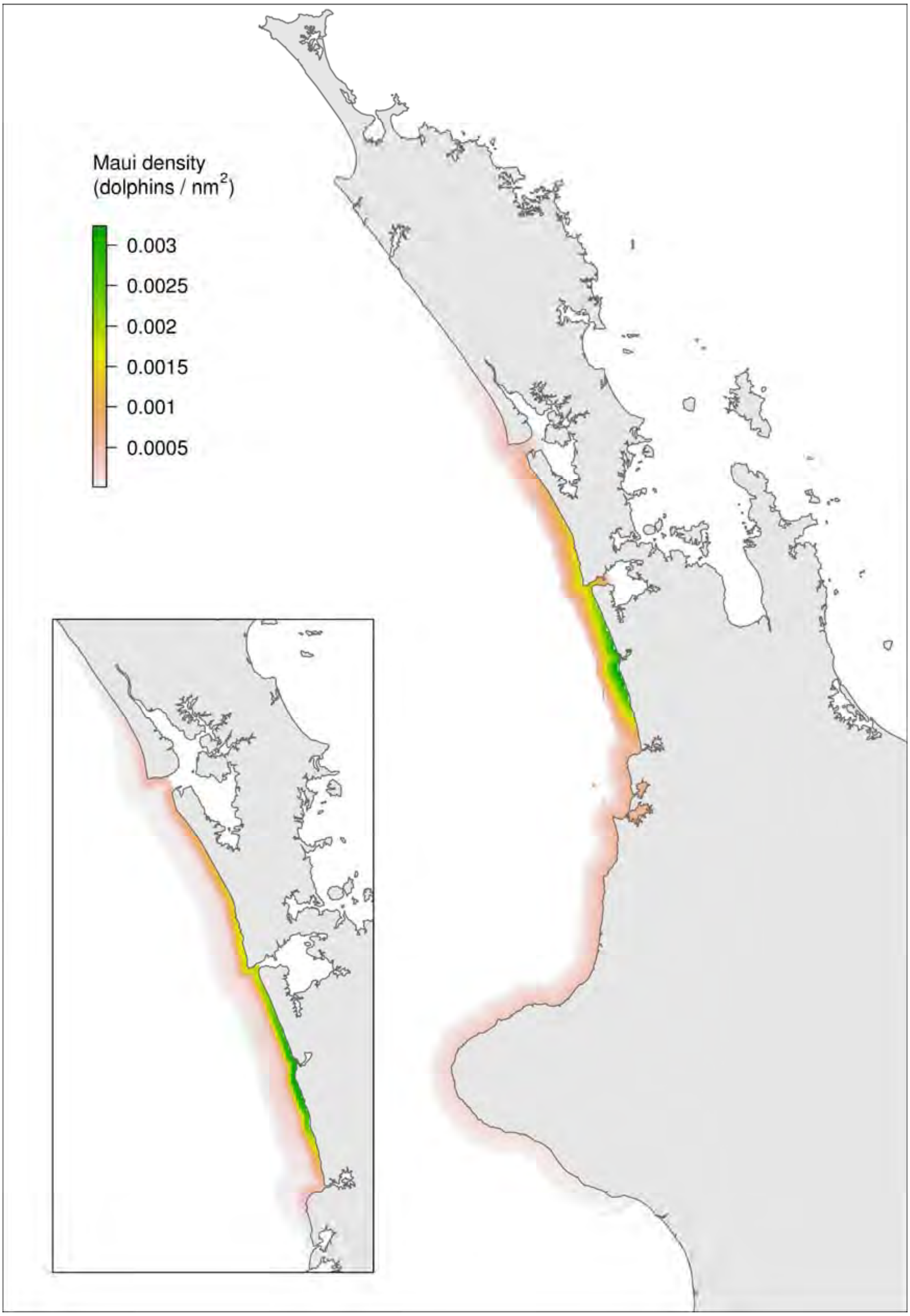
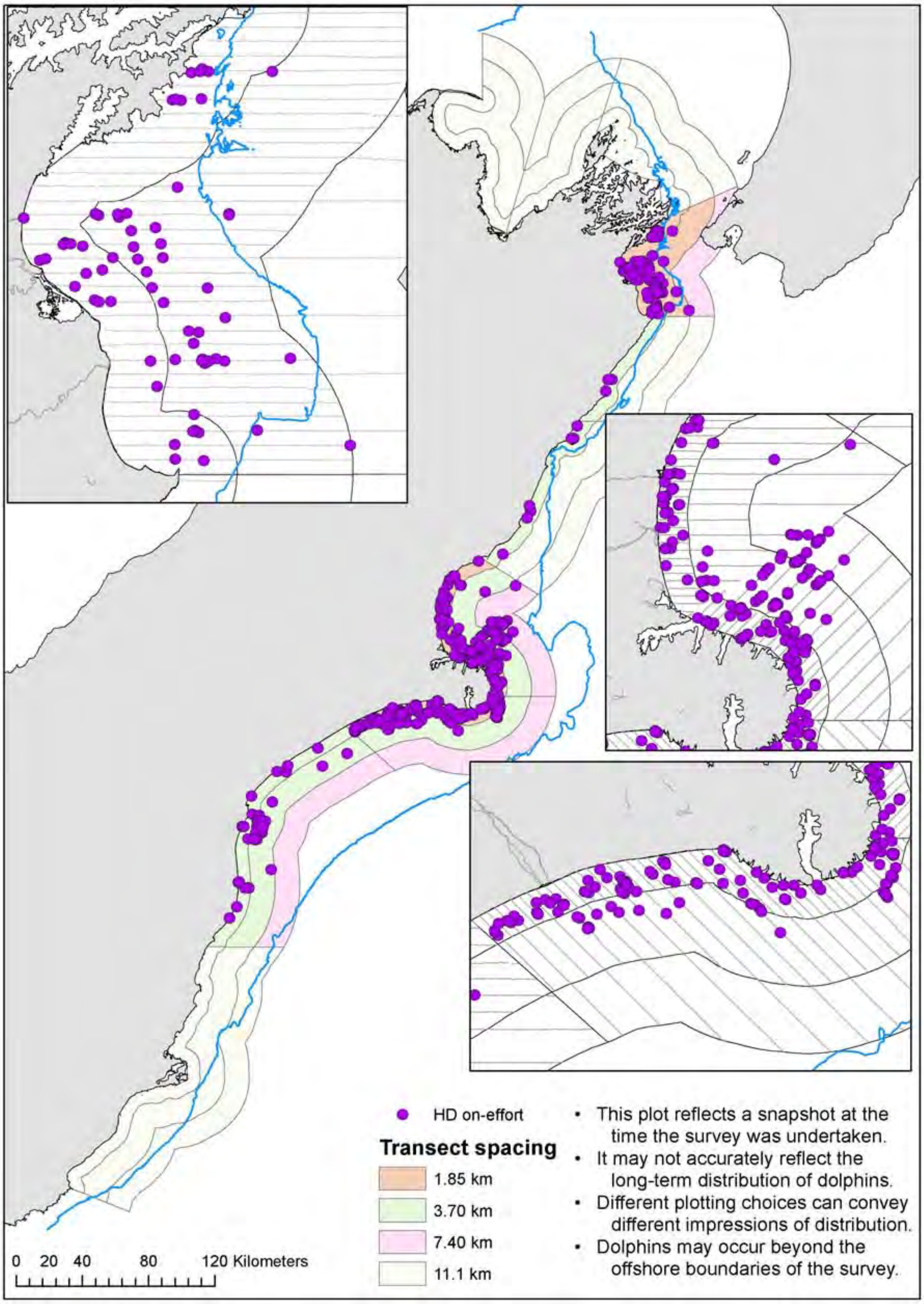
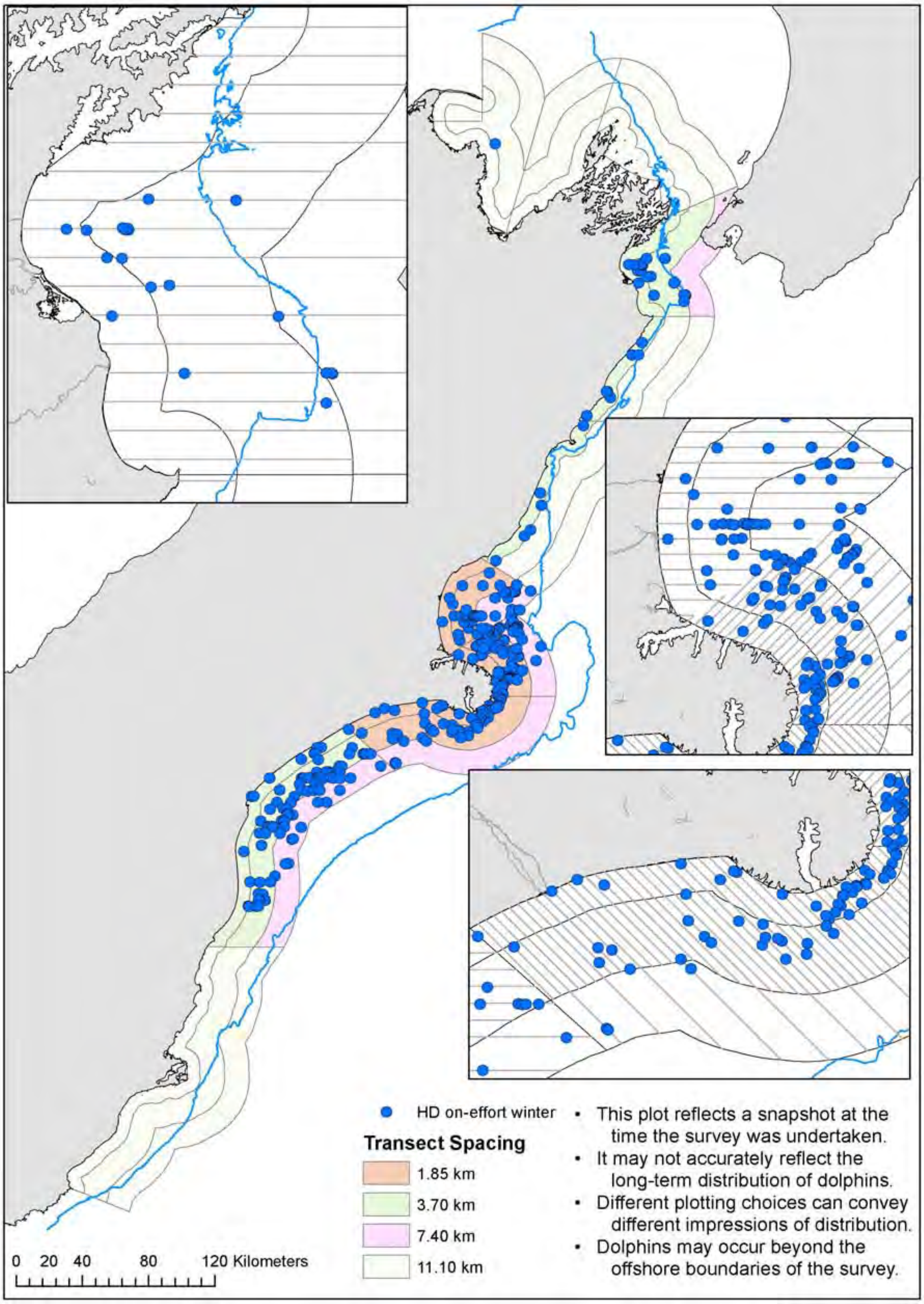


Figure 5.1: Maui's dolphin distribution modelled from systematic survey data collected between 2000 and 2012 and modified to incorporate expert panel feedback (Currey et al 2012). The inset depicts the modelled distribution prior to modification (Thompson & Richard 2012).



- This plot reflects a snapshot at the time the survey was undertaken.
- It may not accurately reflect the long-term distribution of dolphins.
- Different plotting choices can convey different impressions of distribution.
- Dolphins may occur beyond the offshore boundaries of the survey.

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 (2013).



- This plot reflects a snapshot at the time the survey was undertaken.
- It may not accurately reflect the long-term distribution of dolphins.
- Different plotting choices can convey different impressions of distribution.
- Dolphins may occur beyond the offshore boundaries of the survey.

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 (2013).

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 2009a; 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 (2012) 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). Maui's dolphins are significantly longer than Hector's dolphins, with a maximum recorded total length of 162 cm (Russell 1999).

Hector's and Maui's 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 Maui's 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 and 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 Maui's dolphin (3,408 animals with a suggested range of 3,000 to 4,000) 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 800m of shore and calibrated with a limited number of 5 n.mil. offshore transects. Nationwide line transect surveys of Hector's and Maui's 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.mil. of 7270 (CV = 16%; Slooten et al 2004) and for Maui's 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)[29]. 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 Maui's dolphin and Hector's dolphins in Cloudy Bay (Hamner et al 2012b; 2013; Baker et al 2013; Table 5.1). The Maui's dolphin genetic mark-recapture programme has yielded estimates of the number of individuals greater than 1 year old of 59 in 2006 (Baker et al 2013) and 57 in 2011[30] (Hamner et al 2012b; Table 5.1). The genetic mark-recapture data yielded estimates of average annual population change for Maui's 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 Maui's 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 Maui's 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 Maui's 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 2013).The SCSI program involved two aerial surveys undertaken during March 2010 and August 2010 between Puysegur Point and Nugget Point and out to the 100 m depth contour (PRO2009-01A; Clement et al 2011)[31]. 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 2012/2013 and winter 2013 between Farewell Spit and Nugget Point and offshore to 20 nm (covering ~42,677 km^2; PRO2009-01C; MacKenzie & Clement 2013). 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 & 5.3).

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[29] 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.

[30] Two Hector's dolphins were identified in the sample and hence the estimate for Maui's dolphin is frequently cited as 55 (95% CI = 48-69; Hamner et al 2012b).

[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.

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 9,130 dolphins (CV = 19%; 95% CI = 6,342-13,144) in summer 2012/2013 and 7,456 dolphins (CV = 18%; 95% CI = 5,224-10,641) in winter 2013 (MacKenzie & Clement 2013. 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 Maui's 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 Maui's 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 Maui's 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 Maui's 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 installations (DOC & MFish 2007; Currey et al 2012; MPI & DOC 2012).

A comprehensive list of the threats posed to Maui's 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 Maui's dolphins. Working from a previously established list of 47 potential threats to Hector's dolphins from the Hector's and Maui's dolphin TMP (DOC & MFish 2007), the expert panel assessed 23 threats potentially relevant to Maui's 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 Maui's dolphin mortalities per year (Table 5.3).

Table 5.1: Abundance estimates for Hector's and Maui's dolphin. N = estimated population size. * applies to individuals >1 yr of age and includes two individuals genetically identified as Hector's dolphins.

Sampling period	Sub-species	Survey area	Survey method	Analysis method	N	CV	95% CI	Reference
1984-1985	Hector's & Maui's dolphin	North and South Islands	Small boat based strip-transect	Distance sampling	3,408		3,000 – 4,000 (range)	Dawson & Slooten 1988
1989-1997	Hector's dolphin	Banks Peninsula	Photo-ID	Mark-recapture	1119	0.21	744 – 1,682	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 nm)	Boat based line-transect	Distance sampling	1198	0.27	848 – 1,693	Dawson et al 2004
1998-1999	Hector's dolphin	Timaru – Long Point (0 – 4 nm)	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 nm)	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 nm)	Aerial line-transect	Distance sampling	5388	0.21	3,613 – 8,034	Slooten et al 2004
2001-2007	Maui's dolphin	Kaipara Harbour – Tirua Point	Biopsy	Mark-recapture	59		19 - 181	Baker et al 2013
2004	Maui's dolphin	Maunganui Bluff – Pariokariwa Point (0 – 4 nm)	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 – 1,577	DuFresne & Mattlin 2009
					927 (autumn)	0.30	520 – 1,651	
					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 - 1,311	Clement et al 2011
2010-2011	Maui's dolphin	Kaipara Harbour – New Plymouth	Biopsy	Mark-recapture	57*		49 - 71	Hamner et al 2012b
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 nm)	Aerial line-transect	Mark-recapture distance sampling	9,130 (summer)	0.19	6,342 - 13,144	MacKenzie & Clement 2013
					7,456 (winter)	0.18	5,224 - 10,641	

The expert panel's assessment of mortalities can be treated as testable hypothesis (Currey et al , 2012) and evaluated using new information. Roe et al 's (2013) finding that 2 of 3 Maui's 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 Maui's 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 Maui's dolphins are exposed to the greatest level of risk from set net fisheries in the area of the northern Taranaki coastline out to 7 nm offshore, and at the entrance to the Manukau Harbour. Subsequent interim measures restricted set net fishing within 2 nm of the Taranaki coast and required full observer coverage of set net fishing to 7nm. No Maui's dolphins have been captured or sighted by observers in the Taranaki set net fishery to date.

5.2.1. 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 Hector's and Maui's dolphin has been assessed under two threat classification systems: the New Zealand Threat Classification System (Townsend et al 2007) and the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2013).

The IUCN classifies Maui's dolphin as Critically Endangered under criteria A4c,d and C2a(ii)[32] 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[33] 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), Maui's dolphin is classified as Nationally Critical, the most threatened status, under criterion A(1), with the qualifier Conservation Dependent (CD)[34] and Hector's dolphin as Nationally Endangered, the second most threatened status, under criterion C(1/1), with the qualifier Conservation Dependent (CD)[35].

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[32] 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 2010).

[33] 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 2010).

[34] 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).

[35] 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

Table 5.2. Characterisation of threats evaluated as relevant to Maui’s dolphins and likely to affect population trends within the next 5 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 & 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

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population due to existing threats, taken over the next 10 years or three generations, whichever is longer (Townsend et al 2008).

Table 5.3. Estimated number of Maui’s 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 & oil activities	0.03	<0.01-0.17	0.4	<0.1-2.7	26.4
Noise (non-trauma) from mining & oil activities	0.03	<0.01-0.23	0.5	<0.1-3.6	28.6
Noise (trauma) from mining & oil activities	0.01	<0.01-0.13	0.2	<0.1-2.0	8.8
Pollution (discharge) from mining & 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**

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 2013). 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 Maui’s 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.

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 Maui’s dolphins (MFish & DOC 2007; Slooten & Dawson 2010; Currey et al 2012; see Table 5.3). Hector’s and Maui’s 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 5.3) provides only a biased indication of incidental captures. It is clear from this information that incidental captures occur in all areas where Hector's and Maui's 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).

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 Maui's 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[36]	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[37]	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[38]	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

5.4.1. Quantifying fisheries interactions

Prior to 2012, only one observer programme has had 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). An observer programme in statistical areas 018, 020 and 022 (FMA 3) on the east coast of the South Island in the 1997/1998 fishing year 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%)[39] 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 nm 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 2009/2010 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.

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

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

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

[39] 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 1997/1998 (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 and Davies 2011).

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 2003/2004 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 have been deployed in the Timaru set net fishery in 2012/13 and will be deployed again in 2013/14.

Until recently, no attempt to quantify total captures of Maui's dolphins in set nets or trawls using population-specific observer data had been made. However, the likely magnitude of fishing impacts on Maui's dolphin over the coming 5 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.

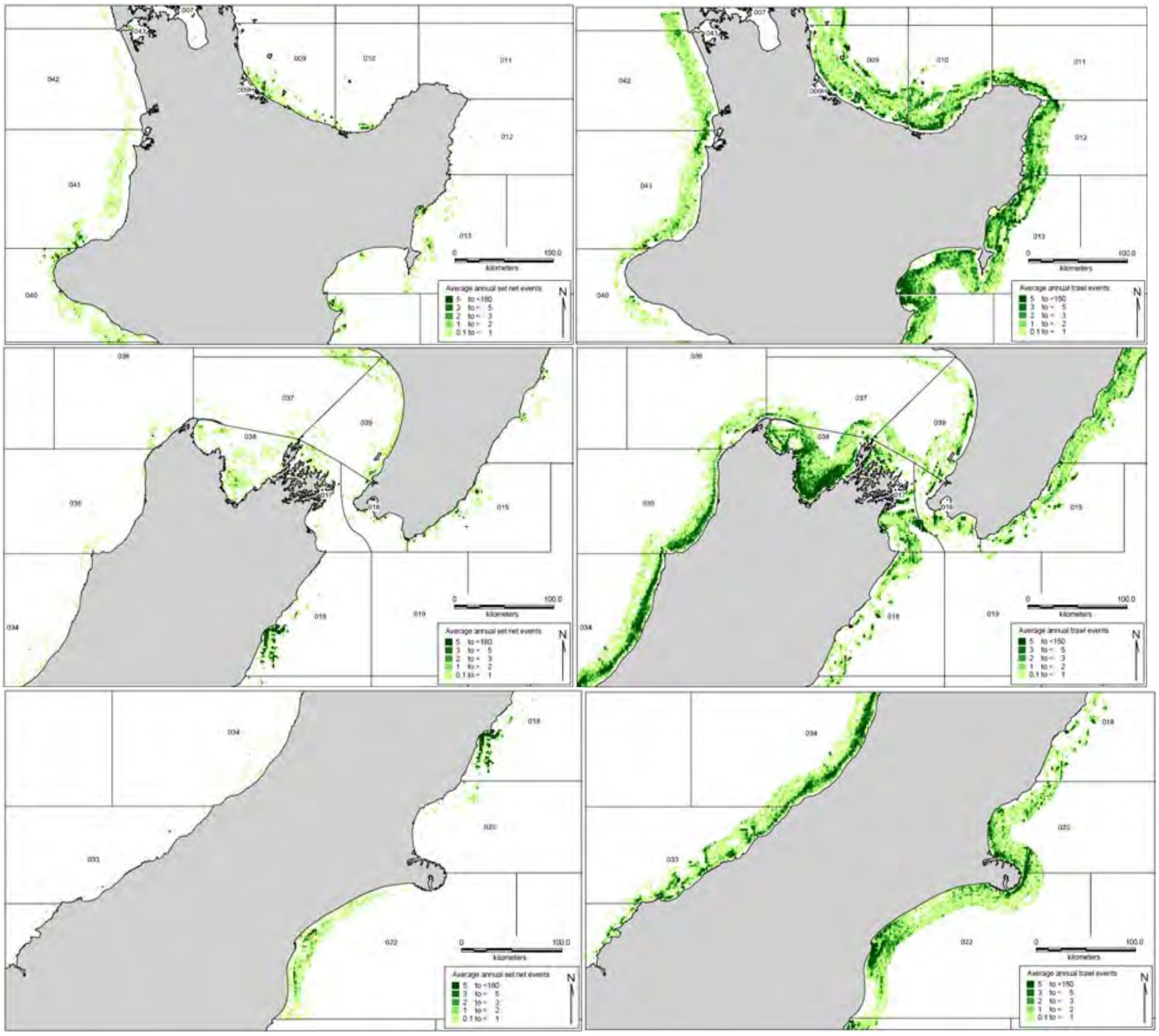

Figure 5.4: The distribution of set net (left) and trawl (right) fishing events 2007/08 to 2009/10 (from www.fish.govt.nz/en-nz/Commercial/About+the+Fishing+Industry/Maps+of+Commercial+Inshore+Fishing+Activity/) to show the general spatial pattern of fishing activity. The annual average number of events (start positions) is shown for each 1 nm 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.

Table 5.5: Summary of observed inshore set net and trawl events, and Hector's and Maui's 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 with and outside Hector's and Maui's dolphin distribution (within: 3, 5, 7, 8 & 9; outside: 1, 2 & 10).

	Set net					**Inshore trawl**			
Fishing year	**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

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 and 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 <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 Maui’s 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 nm 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 nm 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 Maui’s are found and largely superseding the two existing discrete closures. The set net restrictions on the WCNI were extended to 7 nm 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 nm of the coast on the ECSI and SCSI, and recreational set netting was banned on the WCSI within 2 nm of the coast and commercial set netting was subject to a seasonal restriction (Figure 5.5). Trawling was banned on the WCNI to 2 nm offshore between Maunganui Bluff and Pariokariwa Point and 4 nm offshore between Manukau Harbour and Port Waikato, and restricted within 2 nm offshore on the ECSI and SCSI[40](Figure 5.6). In 2012, the set net restrictions on the WCNI were extended further south, banning commercial and recreational set netting to 2 nm offshore from Pariokariwa Point to Hawera and requiring an MPI observer on any commercial set net vessel operating between 2 and 7 nm (Figure 5.5).

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

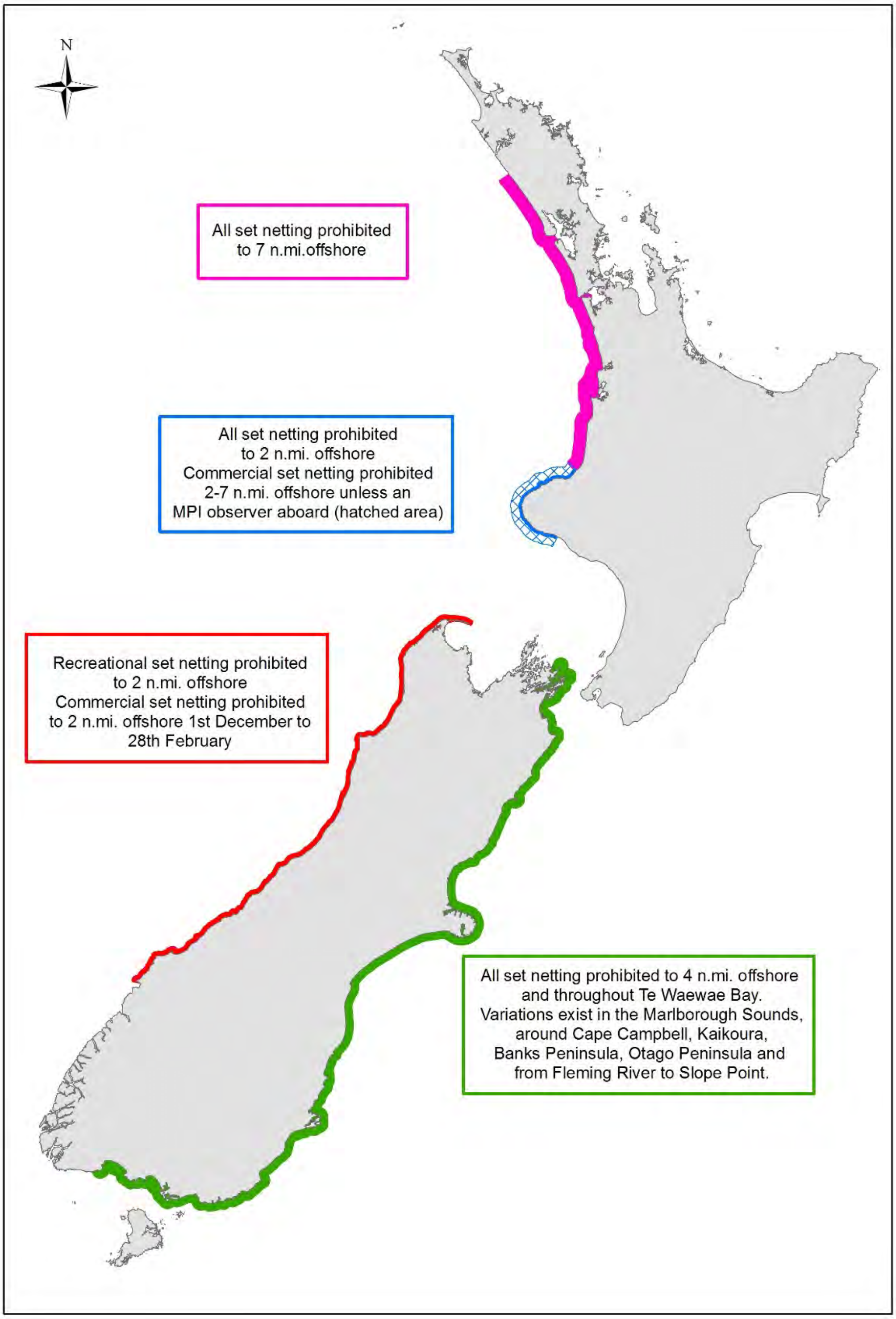


Figure 5.5: Summary of restrictions on commercial and amateur set netting. For a full description of the restrictions, for example in NIWC harbours and variations on ECSI and SCSI, see http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins.

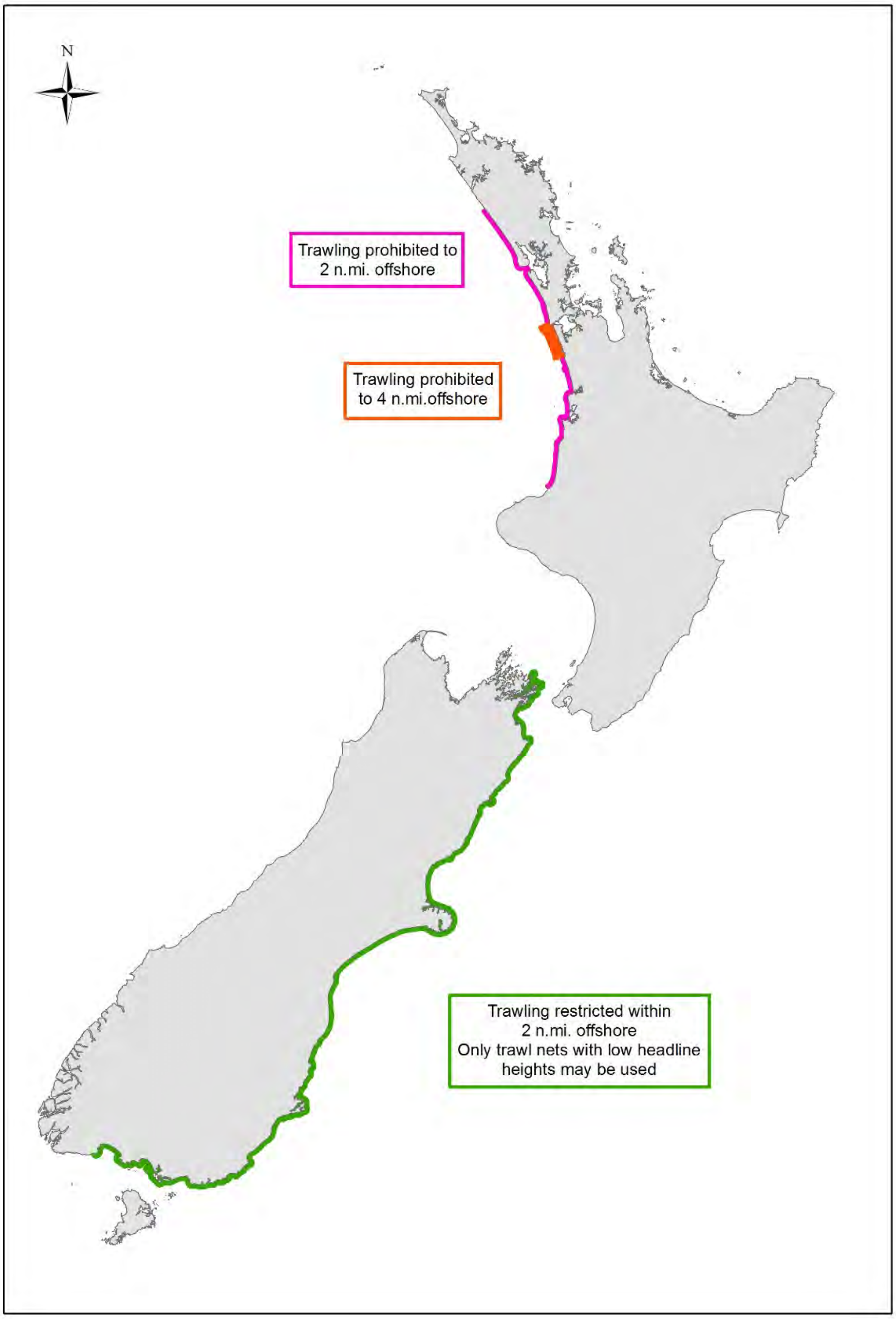


Figure 5.6: Summary of restrictions on trawling. For a full description of the restrictions see http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins.

Assessing the degree of coverage of Hector's and Maui's 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 nm offshore over three summers and winters. A significantly larger proportion of the population was sighted inside the 4 nm 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 2013; Figure 5.8). In the Banks Peninsula (BP) strata, 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) strata, 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 2013), many sightings in summer and most sightings in winter occurred outside these areas.

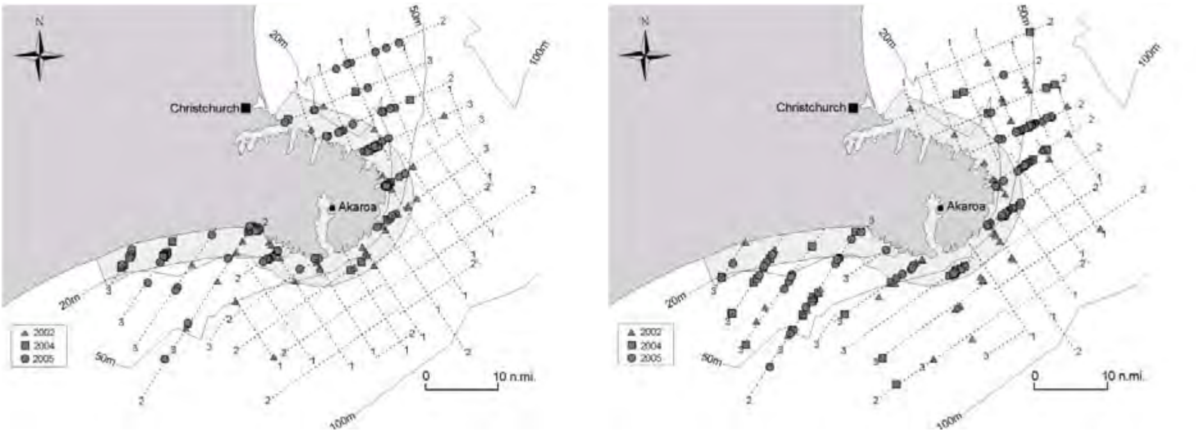
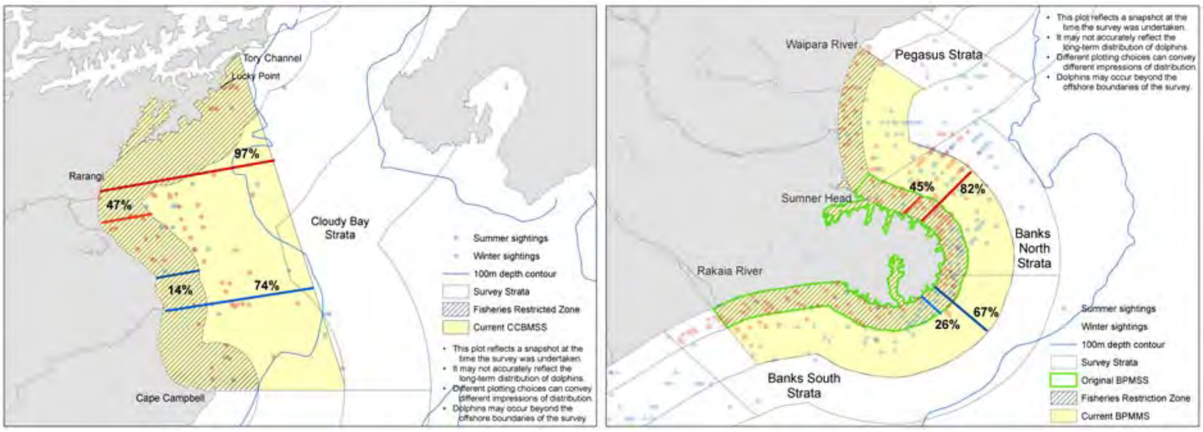


Figure 5.7: Transects and Hector’s dolphin sightings on (left) three summer surveys, and (right) three winter surveys around Banks Peninsula. Numbers at the end of transect lines are the number of years each line was surveyed. Reproduced from Rayment et al (2010).



- This plot reflects a snapshot at the time the survey was undertaken.
- It may not accurately reflect the long-term distribution of dolphins.
- Different plotting choices can convey different impressions of distribution.
- Dolphins may occur beyond the offshore boundaries of the survey.

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, left) and Banks Peninsula (BP, right). Lines and associated percentages represent proportion of the local population found within 4nm and 12nm in summer (red) and winter (blue). Reproduced from MacKenzie & Clement (2013).

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 Maui’s dolphins. Most of this work has been published in science journals (Martien et al 1999; Burkhart and Slooten 2003; Slooten 2007a; Slooten and 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 relate 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 and 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 if 7 077 dolphins across the three populations in 1970, if maximum population growth rate was 4.4%, and 7 957 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 miles 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 and Gilbert (2003) conducted a risk assessment for Maui’s 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 Maui’s 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 Maui’s dolphin and to mode population distribution and abundance off the WCNI. Davies and 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 Maui’s 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 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 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 and 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 (max. one calf per female every 2 yrs). 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 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 Maui's 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 Maui's 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 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 and Dawson (2010) to assess the effect of management options developed for the Hector's and Maui's Dolphin Threat Management Plan (although the options evaluated differed from the final proposals). The input data were similar to those of Slooten (2007a and b). Slooten and 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 and Dawson (2010) suggested that the WCNI population would increase under management pertaining at the time, whereas the other three populations would decline. Slooten and 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 and 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 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 and Dawson 2010). Slooten and 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 Maui's 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 Maui's 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 2014.

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 and Dawson (2010), and Slooten and 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 and Davies 2012). Slooten and 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 Maui's 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 Maui's 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 Maui's 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 Maui's 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 (>10 years) 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 Maui's dolphins other than WCSI (Clement et al 2011; Hamner et al 2012b; MacKenzie & Clement 2013). 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 2009a) and genetic recaptures (Oremus et al 2012; Hamner et al 2012; in press) will improve estimates of movements and dispersal (Rayment et al 2009a; Hamner et al 2012; Pichler 2002; Hamner et al 2012). For example, Hamner et al (in press) suggested that failure to protect the habitat between the North and South Island will reduce the likelihood of dispersal, possibly to the detriment of Maui's dolphin.

Other threats (non-fishing-related, indirect, sub-lethal, cumulative)
Uncertainty exists over the magnitude of impacts faced by Hector's and Maui's 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 Maui's 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 (2012) 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 (2012) suggest that further research is required to investigate the effect on Hector's dolphin populations.

Indicators and trends

Population size	Maui's dolphins: 55 (95% CI = 48-69) in 2010-2011. ECSI Hector's dolphins: 9,130 (CV = 19%; 95% CI = 6,342-13,144) in summer 2012/2013 and 7,456 (CV = 18%; 95% CI = 5,224-10,641) in winter 2013. WCSI Hector's dolphins: 5388(CV = 21%; 95% CI = 3613-8034) in 2000-2001. SCSI Hector's dolphins: 628 (CV = 38.9%; 95% CI = 301-1,311) in 2011.
Population trend	Maui's 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	Maui's 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[41]	Maui's 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: ~2 per annum (Davies et al 2008)
Trends in interactions	Possible reduction from 35 to 50 per annum (Davies et al 2008) to ~23 for ECSI (Slooten & Davies 2012). No estimates for other areas.

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

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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)	PRO2010-01 and 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.*
Other Govt Research (current)	DOC Conservation Services Programme (CSP) projects: INT2013-01, *Observing commercial fisheries*; INT2010-02/INT2013-02, *Identification of seabirds captured in New Zealand fisheries*; POP2011-02, *Flesh-footed shearwater population study trial and at-sea distribution*; POP2013-04, *Black petrel population project*; POP2012-04, *Campbell Island and grey-headed albatrosses population estimates*; POP2013-02, *White-capped albatross population estimate (Auckland Islands)*; POP2012-06, *Salvin's albatross population estimate and at-sea distribution*; POP2013-03, *Gibson's albatross population study (Auckland Islands)*; MIT2012-02, *Inshore trawl warp-strike mitigation analysis of effectiveness*; MIT2012-03, *Review of mitigation techniques in setnet fisheries*; MIT2012-04/MIT2013-02, *Surface longline seabird mitigation*; MIT2012-05, *Protected species bycatch newsletter*; MIT2013-01 *Sea trials of the Kellian line setter*; MIT2013-02 *Characterisation of smaller vessel deep water bottom longline operations in relation to risk factors for seabird capture*; MIT2013-05 *Development of bird baffler design for offshore vessels*
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	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 2013.

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).

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 and 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
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 (Parkinson's) 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
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 Endangered
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 Endangered	Critically Endangered
Grey-backed storm petrel	*Garrodia nereis*	At Risk: Relict	Least Concern
New Zealand white-faced storm petrel	*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 Endangered	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 chathamensis***	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 Endangered	Vulnerable
Snares crested penguin	*Eudyptes robustus*	At Risk: Naturally Uncommon	Vulnerable
Erect-crested penguin	*Eudyptes sclateri*	At Risk: Declining	Endangered

Table 6.1 contd...

Common name	Scientific name	DOC category	IUCN category
Red-tailed tropicbird	*Phaethon rubricauda*	Threatened: Nationally Endangered	Least Concern
Australasian gannet	*Morus serrator*	Not Threatened	Least Concern
Masked booby	*Sula dactylatra tasmani*	Threatened: Nationally Endangered	Least Concern
Black shag	*Phalacrocorax carbo novaehollandiae*	At Risk: Naturally Uncommon	#Least Concern
Pied shag	*Phalacrocorax varius varius*	Threatened: Nationally Vulnerable	#Least Concern
Little black shag	*Phalacrocorax sulcirostris*	At Risk: Naturally Uncommon	Least Concern
Little shag	*Phalacrocorax melanoleucos brevirostris*	Not Threatened	#Least Concern
Stewart Island shag	*Leucocarbo chalconotus*	Threatened: Nationally Vulnerable	Vulnerable
King shag	*Leucocarbo carunculatus*	Threatened: Nationally Endangered	Vulnerable
Chatham Island shag	*Leucocarbo onslowi*	Threatened: Nationally Critical	Critically Endangered
Bounty Island shag	*Leucocarbo ranfurlyi*	Threatened: Nationally Endangered	Vulnerable
Auckland Island shag	*Leucocarbo colensoi*	Threatened: Nationally Vulnerable	Vulnerable
Campbell Island shag	*Leucocarbo campbelli*	At Risk: Naturally Uncommon	Vulnerable
Spotted shag	*Stictocarbo punctatus punctatus*	Not Threatened	Least Concern
Blue shag	*Stictocarbo punctatus oliveri*	At Risk: Naturally Uncommon	#Least Concern
Pitt Island shag	*Stictocarbo featherstoni*	Threatened: Nationally Critical	Endangered
Subantarctic skua	*Catharacta antarctica lonnbergi*	At Risk: Naturally Uncommon	#Least Concern
South Polar skua	*Catharacta maccormicki*	Non-Resident Native: Migrant	Least Concern
Pomarine skua	*Stercorarius pomarinus*	Non-Resident Native: Migrant	Least Concern
Arctic skua	*Stercorarius parasiticus*	Non-Resident Native: Migrant	Least Concern
Long-tailed skua	*Stercorarius longicaudus*	Non-Resident Native: Migrant	Least Concern
Southern black-backed gull	*Larus dominicanus dominicanus*	Not Threatened	#Least Concern
Red-billed gull	*Larus novaehollandiae scopulinus*	Threatened: Nationally Vulnerable	#Least Concern
Black-billed gull	*Larus bulleri*	Threatened: Nationally Critical	Endangered
Caspian tern	*Hydroprogne caspia*	Threatened: Nationally Vulnerable	Least Concern
White-fronted tern***	*Sterna striata striata****	At Risk: Declining	#Least Concern
Southern white-fronted tern***	*Sterna striata aucklandorna****	Threatened: Nationally Vulnerable	#Least Concern
Arctic tern	*Sterna paradisaea*	Non-Resident Native: Migrant	Least Concern
New Zealand Antarctic tern	*Sterna vittata bethunei*	At Risk: Recovering	#Least Concern
Eastern little tern	*Sternula albifrons sinensis*	Non-Resident Native: Migrant	#Least Concern
New Zealand fairy tern	*Sternula nereis davisae*	Threatened: Nationally Critical	#Vulnerable
Sooty tern	*Onychoprion fuscata serratus*	At Risk: Naturally Uncommon	#Least Concern
Black-fronted tern	*Chlidonias albostriatus*	Threatened: Nationally Endangered	Endangered
White-winged black tern	*Chlidonias leucopterus*	Non-Resident Native: Migrant	Least Concern
Brown noddy	*Anous stolidus pileatus*	Non-Resident Native: Coloniser	Least Concern
White-capped (black) noddy	*Anous minutus minutus*	At Risk: Naturally Uncommon	Least Concern
Grey noddy (ternlet)	*Procelsterna cerulea albivittata*	At Risk: Naturally Uncommon	#Least Concern
White tern	*Gygis alba candida*	Threatened: Nationally Critical	#Least Concern

Table 6.1 Notes:
* 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 fails to return to the colony.

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 away 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 (Figures 6.1 and 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.

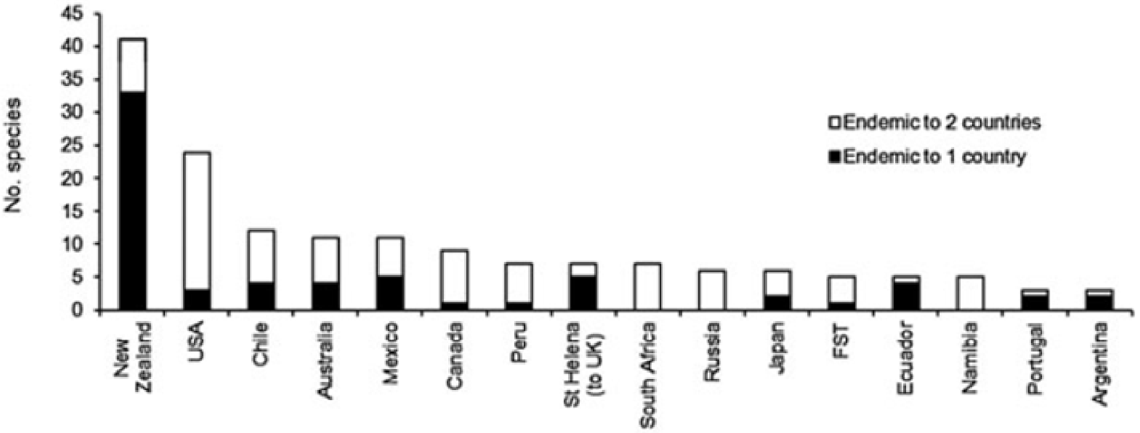


Figure 6.1: (from Croxall et al 2012). Number of endemic breeding seabird taxa by country.

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 2008 ab, 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 petrels, storm petrels, and black petrel.

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.

		World breeding		NZ breeding		NZ visitors,vagrants	
Family	Common name	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

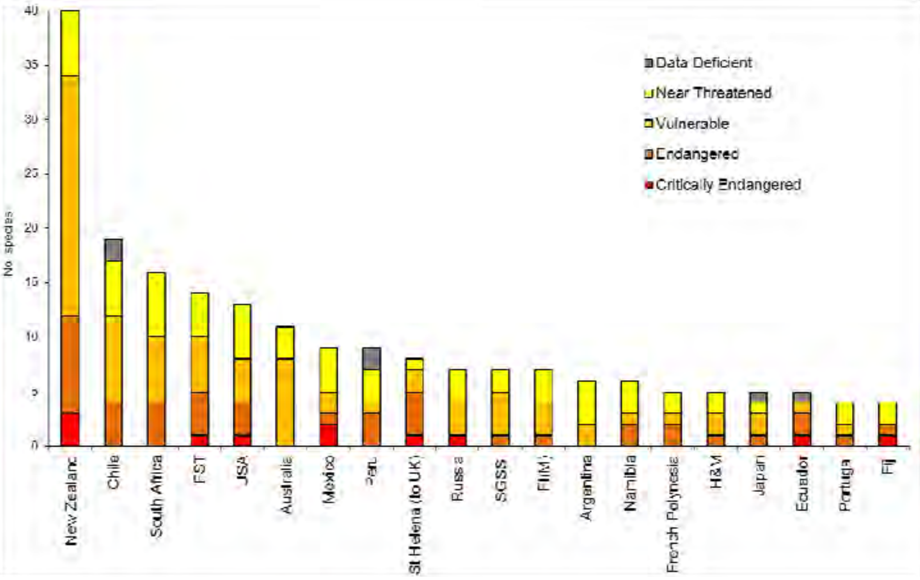


Figure 6.2: (from Croxall et al 2012, supplementary material): The number of breeding and resident seabird species by country in each IUCN category (excluding Least Concern). FST, French Southern Territories; SGSSI, South Georgia and South Sandwich Islands; FI(M), Falkland Islands (Malvinas); H&M, Heard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

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 2008ab, 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 6.4.4.3.

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. 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

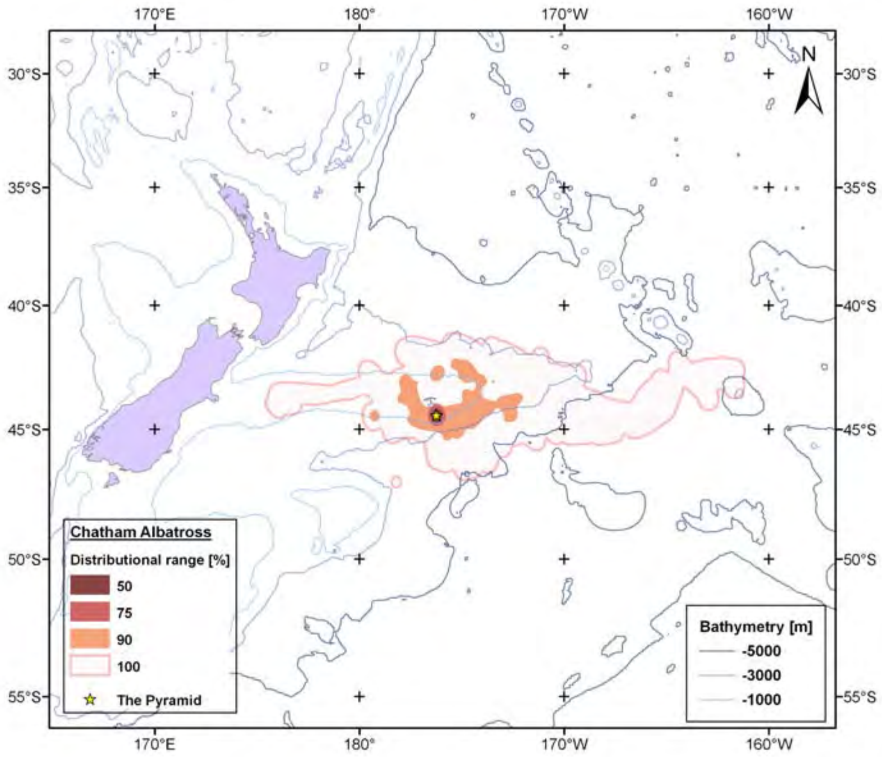


Figure 6.3: (from Fraser et al 2010b) Distributional range of Chatham Island albatross during incubation and early chick rearing as derived from tracking studies in November/December 2007–2009 (n=51 tracks).

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, 2006/07–2009/10.

	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 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 maybe 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.

CSP project POP2012-06 is currently underway and includes a repeat aerial survey at the Bounty Islands in October 2013, with ground truthing, as well as collecting geologger tracking information for the period October 2012 to October 2013.

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.

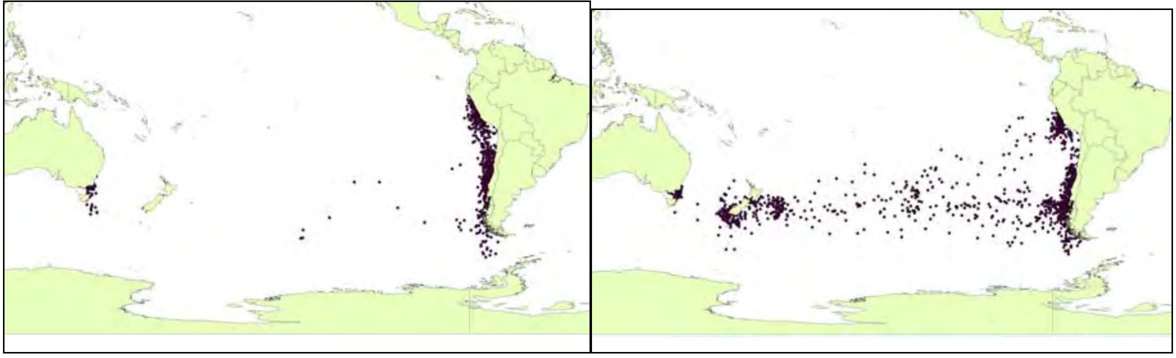
Totals of 1195 and 1116 breeding pairs were counted on Toru and Rima Islets during October 2008 (Charteris et al 2009) and September-October 2009, respectively (Carroll et al 2010) (Table 6.5). Only Toru Island was sampled in 2010.

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

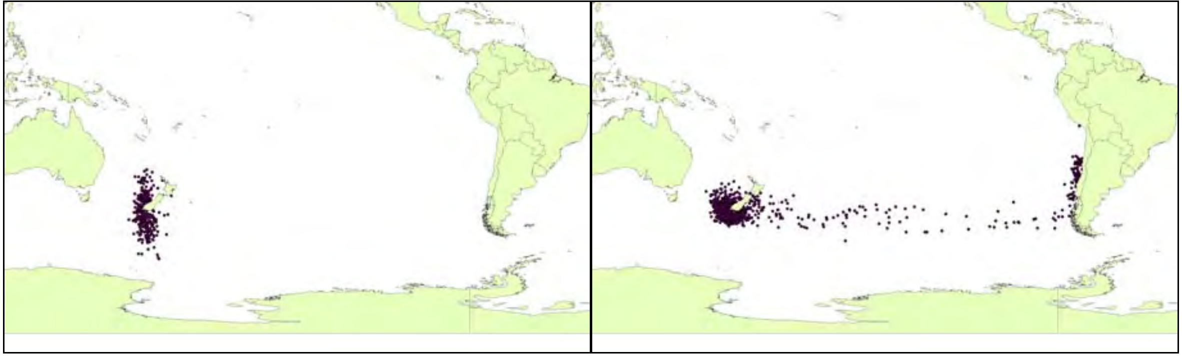
In order to estimate the adult survival of Salvin's albatross, a total of 257 occupied nests were counted within a clearly-defined study area established in October 2008 (Charteris et al 2009). Within this area, 116 birds banded in previous years were recaptured, and a further 20 breeding birds were 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).



April

b) June



c) September

d) December

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).

2012–13: Surveys suggested 99 776 breeding pairs in 2012 and 118 098 breeding pairs 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 -2.19% per year; 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 7 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).

Table 6.6: (after Baker et al 2013) Aerial-photographic counts of breeding pairs of white-capped albatrosses on three islands in the Auckland Islands group in December 2006–2010.

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	100 501

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:

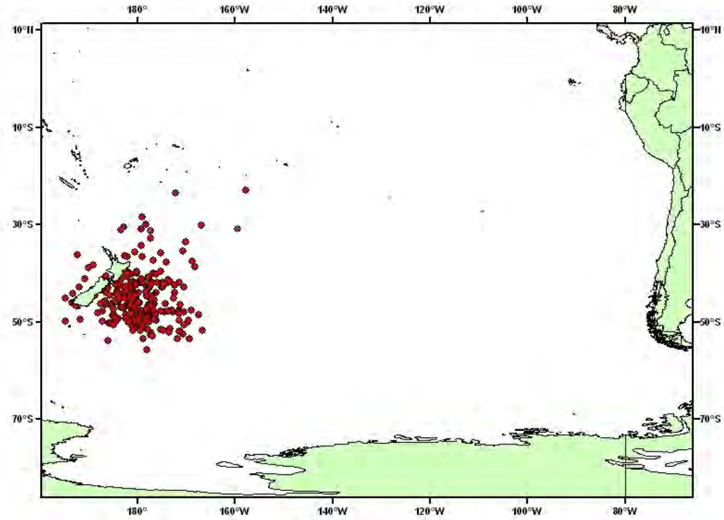
- During the breeding season, the birds foraged within the EEZ, mostly north of Antipodes Island and to the east of the mainland (Figure 6.5a).
- There was movement of birds across the Pacific to the coasts of Chile and Peru during February, presumably by failed breeders (Figure 6.5b).
- In the latter 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 (Sommers et al 2008, 2009, 2010).

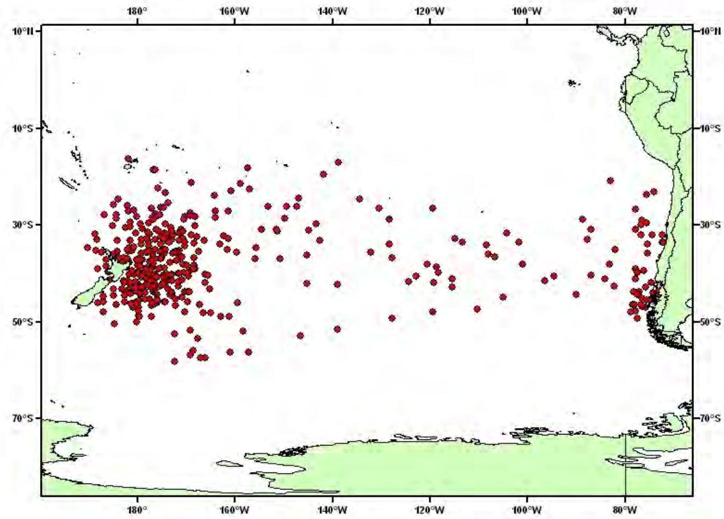
Table 6.8: (from Sommer et al 2010) Results of white-chinned petrel occupancy transects in various habitats spread throughout Antipodes Island.

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

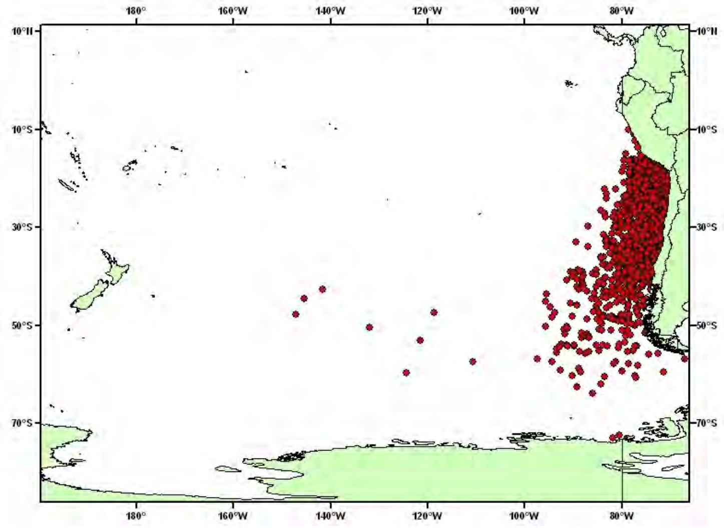


Figure 6.5: (from Sommer et al 2010) Foraging locations of white-chinned petrels from the Antipodes, in a) December, b) February and in c) June-August, after the end of the breeding season.

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 2012.) 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% Cl	Upper 95% Cl	No. Occupied burrows	Lower 95% Cl	Upper 95% Cl
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

CSP project POP2011-02 is currently underway and has objectives to: assess the feasibility of gaining improved estimates of key flesh-footed shearwater population parameters; and to investigate the at-sea distribution of flesh-footed shearwaters.

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 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, 2011 ab, Ayers et al 2004, Baird 1994, 1995, 1996, 1997, 1999, 2000 ab, 2001 ab, 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, available at: http://fs.fish.govt.nz/Doc/22872/AEBR_79.pdf.ashx, updates under review) 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 2011–12 year are shown in Tables 6.10 to 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 42% 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 77% 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 14% of observed captures were albatrosses.

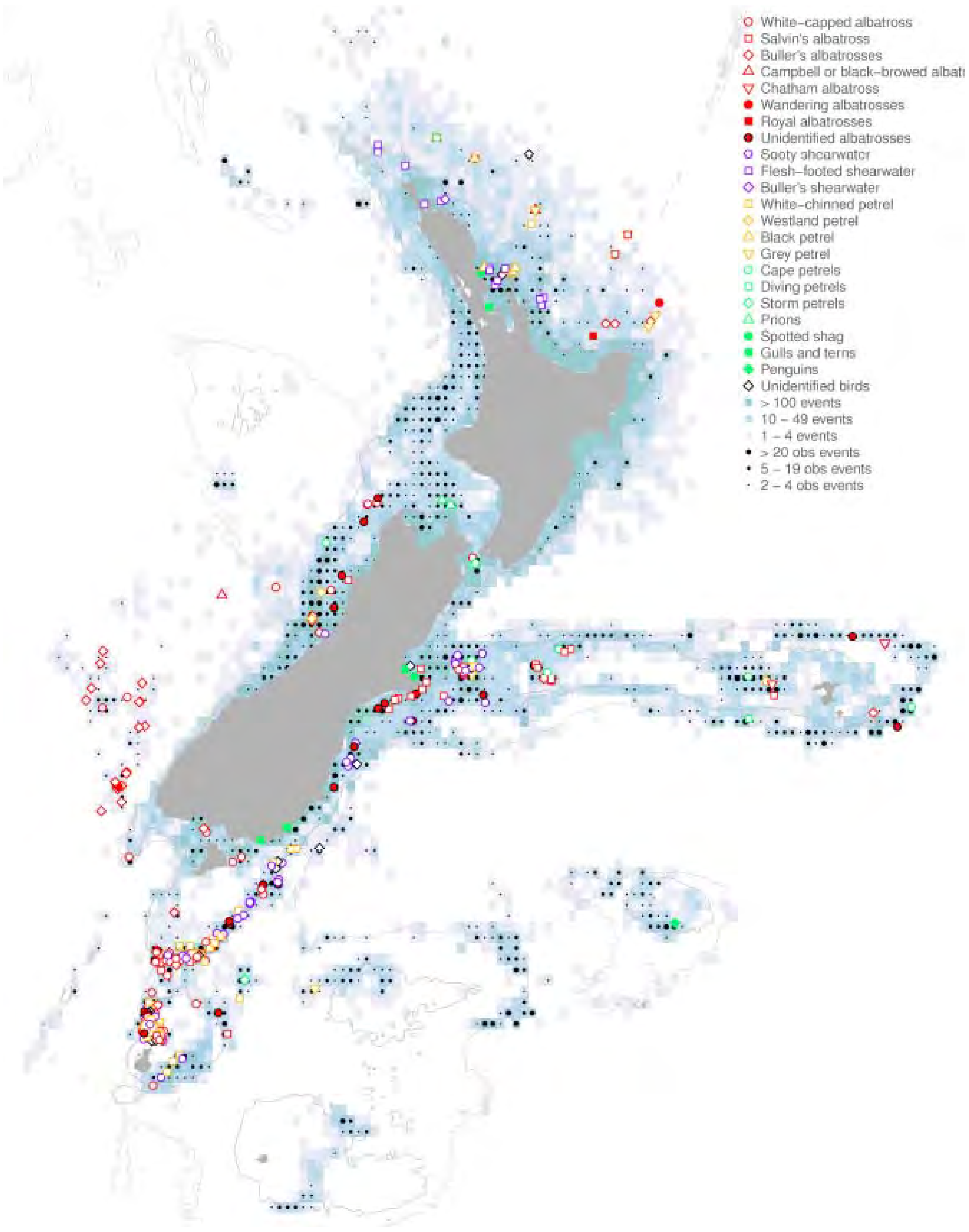


Figure 6.6: (from Abraham & Thompson 2011a): All observed seabird captures in trawl, surface longline, and bottom longline fishing within the New Zealand region, between October 2008 and September 2009. The colour within each 0.2 degree cell indicates the number of fishing events (tows and sets, darker 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.

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 2011–12. 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 v20130304.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002–03	130 338	6 834	5.2	269	3.94	3 462	2 536–4 252	100.0	2.66
2003–04	121 504	6 546	5.4	262	4.00	2 541	2 012–3 247	100.0	2.09
2004–05	120 603	7 709	6.4	483	6.27	4 227	3 296–5 655	100.0	3.50
2005–06	110 237	6 553	5.9	356	5.43	3 344	2 653–4 295	100.0	3.03
2006–07	103 530	7 927	7.7	211	2.66	2 145	1 670–2 776	100.0	2.07
2007–08	89 537	9 047	10.1	234	2.59	1 875	1 493–2 357	100.0	2.09
2008–09	87 589	9 804	11.2	469	4.78	2 463	2 050–2 995	100.0	2.81
2009–10	92 888	9 006	9.7	258	2.86	2 010	1 614–2 583	100.0	2.16
2010–11	86 086	7 442	8.6	376	5.05	2 684	2 146–3 453	100.0	3.12
2011–12	84 287	9 088	10.8	250	2.75	1 904	1 510–2 418	100.0	2.26
Surface longline									
2002–03	10 764 588	2 195 152	20.4	115	0.05	2 033	1 577–2 737	100.0	0.019
2003–04	7 380 779	1 607 304	21.8	71	0.04	1 345	1 044–1 798	100.0	0.018
2004–05	3 676 365	783 812	21.3	41	0.05	601	472–780	100.0	0.016
2005–06	3 687 339	705 945	19.1	37	0.05	790	585–1 137	100.0	0.021
2006–07	3 738 362	1 040 948	27.8	187	0.18	936	720–1 344	100.0	0.025
2007–08	2 244 339	421 900	18.8	37	0.09	513	408–664	100.0	0.023
2008–09	3 115 633	937 496	30.1	57	0.06	593	477–746	100.0	0.019
2009–10	2 992 285	665 883	22.3	135	0.20	921	732–1 201	100.0	0.031
2010–11	3 185 779	674 572	21.2	47	0.07	696	524–948	100.0	0.022
2011–12	3 069 707	728 190	23.7	64	0.09	808	596–1 168	100.0	0.026
Bottom longline									
2002–03	37 688 628	10 774 720	28.6	298	0.03	1 975	1 478–2 523	100.0	0.005
2003–04	43 400 090	5 162 608	11.9	54	0.01	1 322	900–1 765	100.0	0.003
2004–05	41 818 638	2 883 725	6.9	30	0.01	1 377	947–1 827	100.0	0.003
2005–06	37 126 833	3 802 951	10.2	41	0.01	1 176	823–1 559	100.0	0.003
2006–07	38 122 870	2 315 772	6.1	58	0.03	1 604	1 089–2 303	100.0	0.004
2007–08	41 464 276	3 589 511	8.7	40	0.01	1 475	1 059–1 973	100.0	0.004
2008–09	37 389 512	4 024 816	10.8	33	0.01	1 264	882–1 684	100.0	0.003
2009–10	40 413 281	2 271 623	5.6	68	0.03	1 240	876–1 640	100.0	0.003
2010–11	40 831 226	1 732 295	4.2	29	0.02	1 470	1 037–1 936	100.0	0.004
2011–12	37 844 321	2 094 440	5.5	10	0.00	1 144	771–1 542	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 2011–12. 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 v20130304.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002–03	130 338	6 834	5.2	85	1.24	790	599–999	100.0	0.61
2003–04	121 504	6 546	5.4	148	2.26	862	681–1 062	100.0	0.71
2004–05	120 603	7 709	6.4	243	3.15	1133	934–1 399	100.0	0.94
2005–06	110 237	6 553	5.9	69	1.05	566	426–732	100.0	0.51
2006–07	103 530	7 927	7.7	57	0.72	435	317–579	100.0	0.42
2007–08	89 537	9 047	10.1	42	0.46	314	209–434	100.0	0.35
2008–09	87 589	9 804	11.2	96	0.98	439	340–569	100.0	0.50
2009–10	92 888	9 006	9.7	48	0.53	366	263–496	100.0	0.39
2010–11	86 086	7 442	8.6	45	0.60	360	255–488	100.0	0.42
2011–12	84 287	9 088	10.8	66	0.73	391	287–526	100.0	0.46
Surface longline									
2002–03	10 764 588	2 195 152	20.4	2	0.00	68	41–102	100.0	0.001
2003–04	7 380 779	1 607 304	21.8	17	0.01	115	77–161	100.0	0.002
2004–05	3 676 365	783 812	21.3	3	0.00	58	34–89	100.0	0.002
2005–06	3 687 339	705 945	19.1	2	0.00	34	19–54	100.0	0.001
2006–07	3 738 362	1 040 948	27.8	28	0.03	42	32–55	100.0	0.001
2007–08	2 244 339	421 900	18.8	4	0.01	51	31–75	100.0	0.002
2008–09	3 115 633	937 496	30.1	3	0.00	70	44–103	100.0	0.002
2009–10	2 992 285	665 883	22.3	31	0.05	148	102–206	100.0	0.005
2010–11	3 185 779	674 572	21.2	3	0.00	47	28–69	100.0	0.001
2011–12	3 069 707	728 190	23.7	9	0.01	124	81–178	100.0	0.004
Bottom longline									
2002–03	37 688 628	10 774 720	28.6	0	0.00	1	0–4	100.0	0.000
2003–04	43 400 090	5 162 608	11.9	1	0.00	7	2–15	100.0	0.000
2004–05	41 818 638	2 883 725	6.9	0	0.00	7	1–16	100.0	0.000
2005–06	37 126 833	3 802 951	10.2	1	0.00	7	2–15	100.0	0.000
2006–07	38 122 870	2 315 772	6.1	0	0.00	4	0–10	100.0	0.000
2007–08	41 464 276	3 589 511	8.7	0	0.00	6	1–13	100.0	0.000
2008–09	37 389 512	4 024 816	10.8	0	0.00	5	1–12	100.0	0.000
2009–10	40 413 281	2 271 623	5.6	0	0.00	6	1–14	100.0	0.000
2010–11	40 831 226	1 732 295	4.2	0	0.00	5	0–12	100.0	0.000
2011–12	37 844 321	2 094 440	5.5	2	0.00	5	2–11	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 2011–12. 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 v20130304.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002–03	130 338	6 834	5.2	24	0.35	336	156–633	100.0	0.26
2003–04	121 504	6 546	5.4	11	0.17	371	157–725	100.0	0.31
2004–05	120 603	7 709	6.4	37	0.48	1124	534–2 242	100.0	0.93
2005–06	110 237	6 553	5.9	9	0.14	463	199–928	100.0	0.42
2006–07	103 530	7 927	7.7	14	0.18	400	177–772	100.0	0.39
2007–08	89 537	9 047	10.1	11	0.12	253	116–481	100.0	0.28
2008–09	87 589	9 804	11.2	37	0.38	458	264–755	100.0	0.52
2009–10	92 888	9 006	9.7	40	0.44	371	214–627	100.0	0.40
2010–11	86 086	7 442	8.6	22	0.30	525	257–1 000	100.0	0.61
2011–12	84 287	9 088	10.8	25	0.28	427	215–800	100.0	0.51
Surface longline									
2002–03	10 764 588	2 195 152	20.4	1	0.00	45	21–79	100.0	0.000
2003–04	7 380 779	1 607 304	21.8	0	0.00	26	10–47	100.0	0.000
2004–05	3 676 365	783 812	21.3	1	0.00	15	6–28	100.0	0.000
2005–06	3 687 339	705 945	19.1	0	0.00	15	5–29	100.0	0.000
2006–07	3 738 362	1 040 948	27.8	1	0.00	17	6–30	100.0	0.000
2007–08	2 244 339	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	7–27	100.0	0.000
2009–10	2 992 285	665 883	22.3	1	0.00	15	6–28	100.0	0.001
2010–11	3 185 779	674 572	21.2	0	0.00	17	6–31	100.0	0.001
2011–12	3 069 707	728 190	23.7	1	0.00	15	6–27	100.0	0.000
Bottom longline									
2002–03	37 688 628	10 774 720	28.6	15	0.00	122	74–203	100.0	0.000
2003–04	43 400 090	5 162 608	11.9	10	0.00	112	64–191	100.0	0.000
2004–05	41 818 638	2 883 725	6.9	0	0.00	128	57–252	100.0	0.000
2005–06	37 126 833	3 802 951	10.2	1	0.00	109	47–224	100.0	0.000
2006–07	38 122 870	2 315 772	6.1	22	0.01	152	80–285	100.0	0.000
2007–08	41 464 276	3 589 511	8.7	0	0.00	131	56–265	100.0	0.000
2008–09	37 389 512	4 024 816	10.8	1	0.00	128	57–255	100.0	0.000
2009–10	40 413 281	2 271 623	5.6	0	0.00	120	56–232	100.0	0.000
2010–11	40 831 226	1 732 295	4.2	2	0.00	136	59–280	100.0	0.000
2011–12	37 844 321	2 094 440	5.5	0	0.00	116	48–239	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 2011–12. 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 v20130304.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002–03	130 338	6 834	5.2	6	0.09	80	31–172	100.0	0.06
2003–04	121 504	6 546	5.4	9	0.14	95	39–211	100.0	0.08
2004–05	120 603	7 709	6.4	24	0.31	209	106–422	100.0	0.17
2005–06	110 237	6 553	5.9	9	0.14	93	44–176	100.0	0.08
2006–07	103 530	7 927	7.7	5	0.06	59	23–119	100.0	0.06
2007–08	89 537	9 047	10.1	18	0.20	110	59–197	100.0	0.12
2008–09	87 589	9 804	11.2	18	0.18	83	47–144	100.0	0.09
2009–10	92 888	9 006	9.7	11	0.12	71	34–144	100.0	0.08
2010–11	86 086	7 442	8.6	20	0.27	105	56–194	100.0	0.12
2011–12	84 287	9 088	10.8	35	0.39	162	92–309	100.0	0.19
Surface longline									
2002–03	10 764 588	2 195 152	20.4	41	0.02	277	208–361	100.0	0.003
2003–04	7 380 779	1 607 304	21.8	39	0.02	194	148–246	100.0	0.003
2004–05	3 676 365	783 812	21.3	21	0.03	99	73–129	100.0	0.003
2005–06	3 687 339	705 945	19.1	14	0.02	100	72–132	100.0	0.003
2006–07	3 738 362	1 040 948	27.8	49	0.05	158	125–197	100.0	0.004
2007–08	2 244 339	421 900	18.8	21	0.05	99	75–133	100.0	0.004
2008–09	3 115 633	937 496	30.1	30	0.03	107	83–137	100.0	0.003
2009–10	2 992 285	665 883	22.3	69	0.10	158	129–191	100.0	0.005
2010–11	3 185 779	674 572	21.2	28	0.04	106	80–136	100.0	0.003
2011–12	3 069 707	728 190	23.7	31	0.04	109	83–139	100.0	0.004
Bottom longline									
2002–03	37 688 628	10 774 720	28.6	1	0.00	51	17–104	100.0	0.000
2003–04	43 400 090	5 162 608	11.9	0	0.00	39	12–80	100.0	0.000
2004–05	41 818 638	2 883 725	6.9	0	0.00	81	26–165	100.0	0.000
2005–06	37 126 833	3 802 951	10.2	0	0.00	70	23–142	100.0	0.000
2006–07	38 122 870	2 315 772	6.1	0	0.00	118	39–238	100.0	0.000
2007–08	41 464 276	3 589 511	8.7	6	0.00	109	39–217	100.0	0.000
2008–09	37 389 512	4 024 816	10.8	0	0.00	82	26–167	100.0	0.000
2009–10	40 413 281	2 271 623	5.6	0	0.00	85	27–171	100.0	0.000
2010–11	40 831 226	1 732 295	4.2	0	0.00	76	24–153	100.0	0.000
2011–12	37 844 321	2 094 440	5.5	3	0.00	58	20–115	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 2011–12. 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 v20130304.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002–03	130 338	6 834	5.2	13	0.19	147	79–248	100.0	0.11
2003–04	121 504	6 546	5.4	18	0.27	110	64–175	100.0	0.09
2004–05	120 603	7 709	6.4	55	0.71	233	159–339	100.0	0.19
2005–06	110 237	6 553	5.9	70	1.07	374	242–561	100.0	0.34
2006–07	103 530	7 927	7.7	29	0.37	153	88–252	100.0	0.15
2007–08	89 537	9 047	10.1	59	0.65	294	195–433	100.0	0.33
2008–09	87 589	9 804	11.2	104	1.06	327	240–452	100.0	0.37
2009–10	92 888	9 006	9.7	74	0.82	300	204–440	100.0	0.32
2010–11	86 086	7 442	8.6	130	1.75	489	340–732	100.0	0.57
2011–12	84 287	9 088	10.8	58	0.64	246	162–370	100.0	0.29
Surface longline									
2002–03	10 764 588	2 195 152	20.4	4	0.00	93	52–145	100.0	0.001
2003–04	7 380 779	1 607 304	21.8	2	0.00	62	34–97	100.0	0.001
2004–05	3 676 365	783 812	21.3	3	0.00	34	19–55	100.0	0.001
2005–06	3 687 339	705 945	19.1	1	0.00	35	18–58	100.0	0.001
2006–07	3 738 362	1 040 948	27.8	5	0.00	34	19–53	100.0	0.001
2007–08	2 244 339	421 900	18.8	4	0.01	25	14–39	100.0	0.001
2008–09	3 115 633	937 496	30.1	3	0.00	30	15–48	100.0	0.001
2009–10	2 992 285	665 883	22.3	3	0.00	29	15–47	100.0	0.001
2010–11	3 185 779	674 572	21.2	8	0.01	38	23–58	100.0	0.001
2011–12	3 069 707	728 190	23.7	4	0.01	30	16–48	100.0	0.001
Bottom longline									
2002–03	37 688 628	10 774 720	28.6	132	0.01	480	331–691	100.0	0.001
2003–04	43 400 090	5 162 608	11.9	15	0.00	229	125–371	100.0	0.001
2004–05	41 818 638	2 883 725	6.9	11	0.00	258	130–449	100.0	0.001
2005–06	37 126 833	3 802 951	10.2	13	0.00	236	126–386	100.0	0.001
2006–07	38 122 870	2 315 772	6.1	12	0.01	444	194–1 040	100.0	0.001
2007–08	41 464 276	3 589 511	8.7	10	0.00	410	203–745	100.0	0.001
2008–09	37 389 512	4 024 816	10.8	1	0.00	297	141–534	100.0	0.001
2009–10	40 413 281	2 271 623	5.6	1	0.00	235	111–408	100.0	0.001
2010–11	40 831 226	1 732 295	4.2	24	0.01	398	224–629	100.0	0.001
2011–12	37 844 321	2 094 440	5.5	1	0.00	222	105–383	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 2011–12. 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 v20130304.

	Fishing effort			Seabirds		Model estimates			
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl	Rate
Trawl									
2002–03	130 338	6 834	5.2	120	1.76	1260	777–2 032	100.0	0.97
2003–04	121 504	6 546	5.4	54	0.82	440	254–732	100.0	0.36
2004–05	120 603	7 709	6.4	74	0.96	563	347–886	100.0	0.47
2005–06	110 237	6 553	5.9	169	2.58	1208	761–1 905	100.0	1.10
2006–07	103 530	7 927	7.7	84	1.06	582	369–899	100.0	0.56
2007–08	89 537	9 047	10.1	82	0.91	493	310–770	100.0	0.55
2008–09	87 589	9 804	11.2	152	1.55	639	441–932	100.0	0.73
2009–10	92 888	9 006	9.7	43	0.48	266	158–425	100.0	0.29
2010–11	86 086	7 442	8.6	110	1.48	585	381–912	100.0	0.68
2011–12	84 287	9 088	10.8	31	0.34	197	109–337	100.0	0.23
Surface longline									
2002–03	10 764 588	2 195 152	20.4	8	0.00	15	8–30	100.0	0.000
2003–04	7 380 779	1 607 304	21.8	3	0.00	6	3–17	100.0	0.000
2004–05	3 676 365	783 812	21.3	0	0.00	2	0–8	100.0	0.000
2005–06	3 687 339	705 945	19.1	0	0.00	2	0–8	100.0	0.000
2006–07	3 738 362	1 040 948	27.8	2	0.00	4	2–9	100.0	0.000
2007–08	2 244 339	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	2 992 285	665 883	22.3	0	0.00	1	0–6	100.0	0.000
2010–11	3 185 779	674 572	21.2	0	0.00	2	0–8	100.0	0.000
2011–12	3 069 707	728 190	23.7	0	0.00	1	0–6	100.0	0.000
Bottom longline									
2002–03	37 688 628	10 774 720	28.6	32	0.00	92	45–196	100.0	0.000
2003–04	43 400 090	5 162 608	11.9	17	0.00	71	27–175	100.0	0.000
2004–05	41 818 638	2 883 725	6.9	3	0.00	78	19–208	100.0	0.000
2005–06	37 126 833	3 802 951	10.2	3	0.00	40	6–130	100.0	0.000
2006–07	38 122 870	2 315 772	6.1	1	0.00	47	6–146	100.0	0.000
2007–08	41 464 276	3 589 511	8.7	6	0.00	56	17–142	100.0	0.000
2008–09	37 389 512	4 024 816	10.8	0	0.00	49	7–150	100.0	0.000
2009–10	40 413 281	2 271 623	5.6	7	0.00	48	10–145	100.0	0.000
2010–11	40 831 226	1 732 295	4.2	0	0.00	61	6–203	100.0	0.000
2011–12	37 844 321	2 094 440	5.5	0	0.00	64	7–215	100.0	0.000

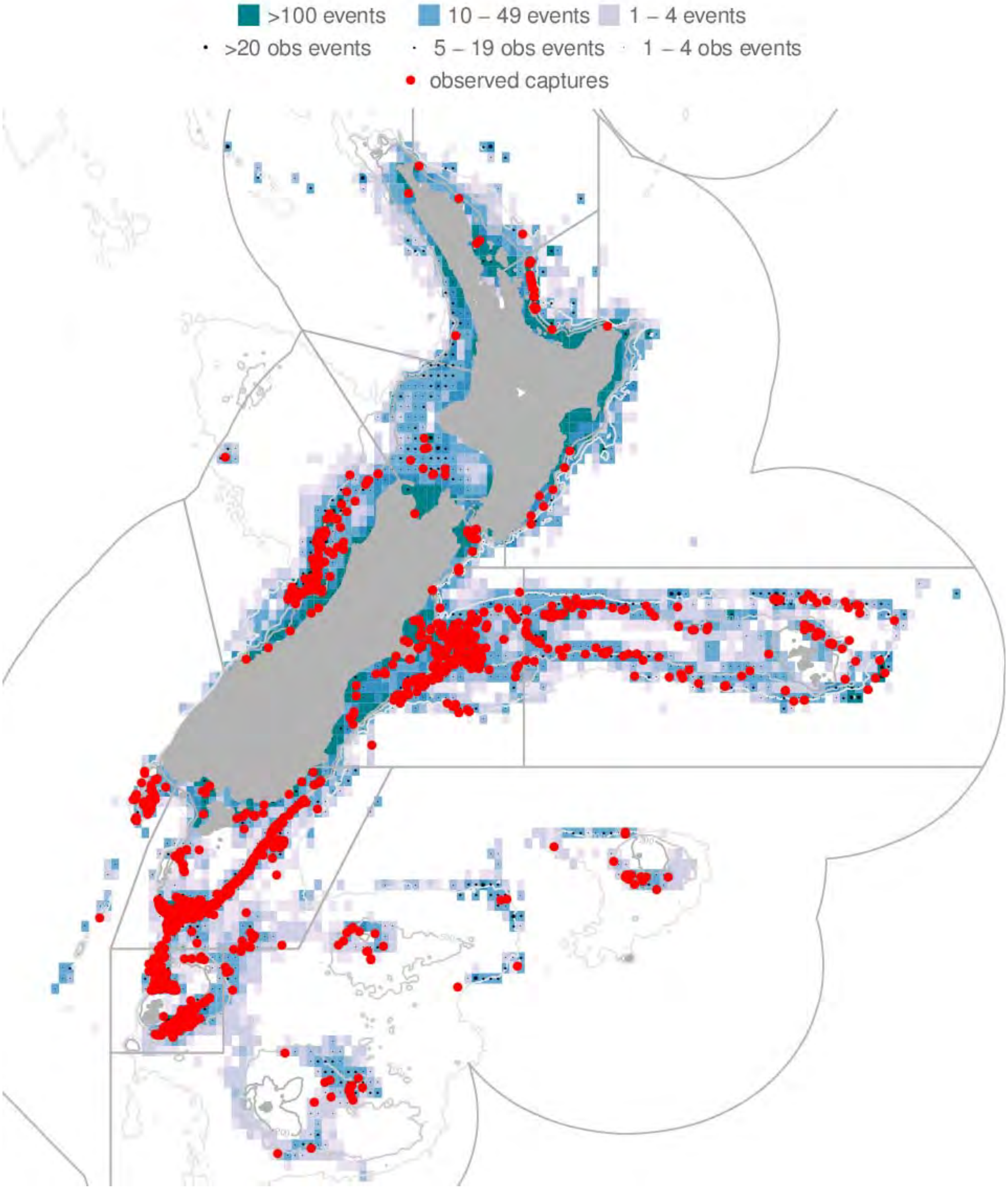


Figure 6.7: Map of trawl fishing effort and all observed seabird captures in trawls, October 2003 to September 2012. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed 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, 96% of effort is displayed).

Table 6.16: Summary of seabirds observed captured in trawl fisheries 2002–03 to 2010–11. 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 v20121101.

	Declared target species									
Species or group	SQU	HOK+	Mid.	SCI	ORH+	SBW	JMA	Ins.	FLA	Total
White capped albatross	679	54	52	15	6	0	1	22	0	829
Salvin's albatross	18	87	25	29	16	2	0	20	0	197
Southern Buller's	49	41	19	4	3	0	1	1	0	118
Campbell albatross	2	5	0	1	0	1	0	0	0	9
Chatham Island albatross	0	0	0	1	8	0	0	0	0	9
Southern royal albatross	5	0	0	0	0	1	0	0	0	6
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
Northern royal albatross	0	0	0	0	1	0	0	0	0	1
Albatross indet.	10	10	1	5	0	4	1	1	0	32
All albatrosses	764	199	97	55	35	8	3	46	0	1207
Sooty shearwater	540	181	119	37	5	0	5	1	0	888
White chinned petrel	387	43	42	48	1	0	9	0	0	530
Cape petrels	1	34	1	3	19	1	2	0	0	61
Flesh footed shearwater	0	1	0	35	0	0	0	2	0	38
Spotted shag	0	0	0	0	0	0	0	0	32	32
Grey petrel	1	2	0	0	3	22	0	0	0	28
Common diving petrel	5	5	0	1	2	0	1	0	0	14
Westland petrel	0	11	1	0	0	0	1	0	0	13
Fairy prion	0	4	0	0	0	0	5	0	0	9
Antarctic prion	7	0	0	0	0	0	0	0	0	7
Northern giant petrel	0	3	1	1	1	0	0	0	0	6
Giant petrel	3	1	0	0	0	0	0	0	0	4
Grey-backed storm petrel	3	1	0	0	0	0	0	0	0	4
Fulmar prion	0	0	0	0	0	0	3	0	0	3
Black petrel	0	0	0	1	0	0	0	1	0	2
Black-bellied storm petrel	1	1	0	0	0	0	0	0	0	2
White-faced storm petrel	0	0	0	0	2	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.	11	5	3	2	1	5	0	2	2	31
All other birds	960	292	168	128	34	28	26	6	35	1677
All observed birds	1724	491	265	183	69	36	29	52	35	2884
Approx. proportion obs.	0.23	0.14	0.06	0.09	0.26	0.35	0.25	0.01	0.01	0.08

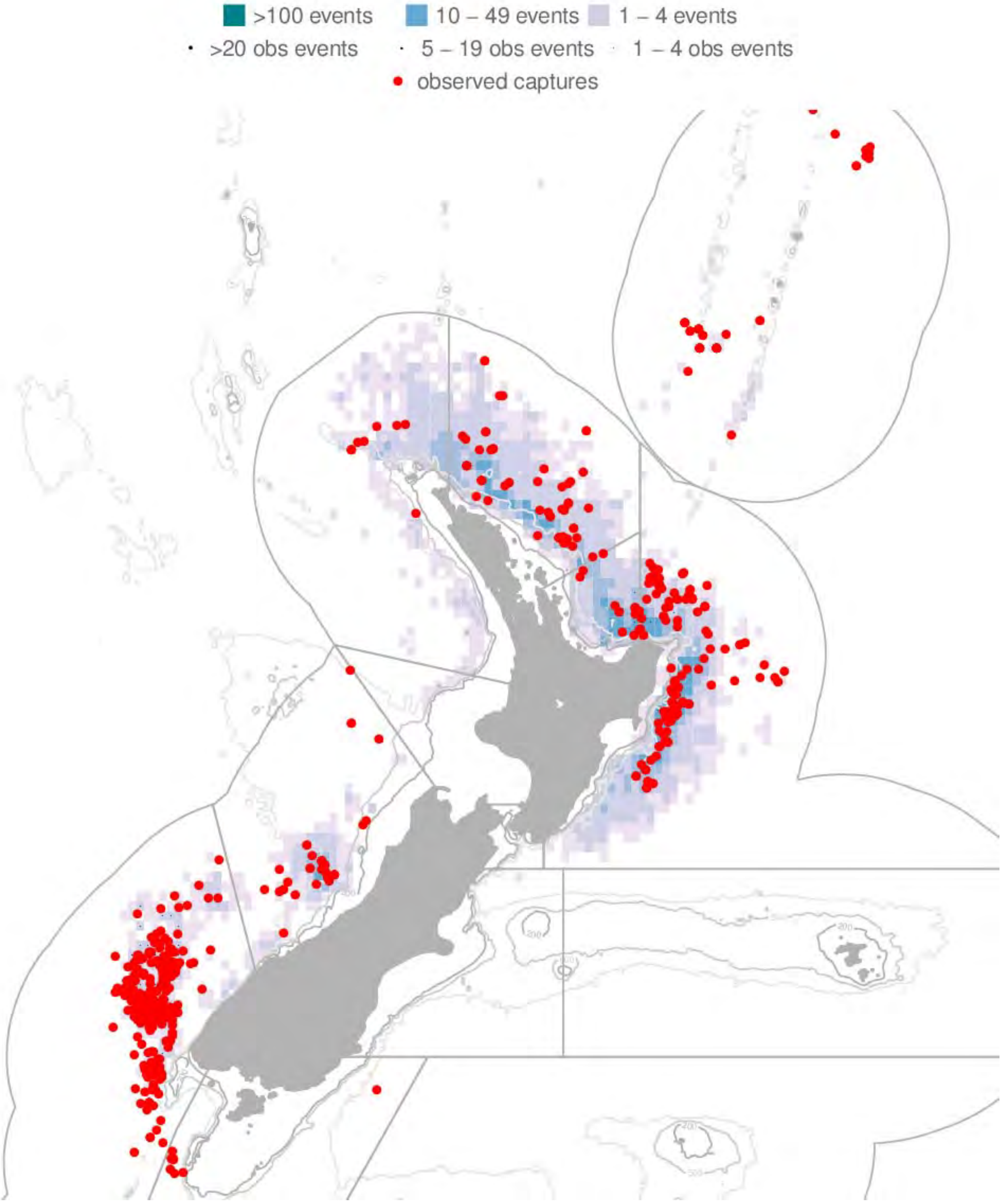


Figure 6.8: Map of surface longline fishing effort and all observed seabird captures by surface longlines, October 2003 to September 2012. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated 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, 94% of effort is displayed).

Table 6.17: Summary of seabirds observed captured in surface longline fisheries 2002–03 to 2010–11. Declared target species are: SBT, southern bluefin tuna; BIG, bigeye tuna; SWO, broadbill swordfish; ALB, albacore tuna. Data version v20121101.

	Declared target species				
Species or group	SBT	BIG	SWO	ALB	Total
Southern Buller's albatross	296	7	1	8	312
White capped albatross	91	1	1	0	93
Campbell albatross	18	3	2	17	40
Antipodean albatross	4	8	15	3	30
Gibson's albatross	8	6	9	7	30
Wandering albatrosses	8	3	0	0	11
Salvin's albatross	3	4	0	1	8
Antipodean / Gibson's	0	2	5	0	7
Black browed albatrosses	0	2	2	0	4
Southern royal albatross	4	0	0	0	4
Southern black-browed	2	0	0	0	2
Light-mantled sooty	1	0	0	0	1
Northern royal albatross	0	1	0	0	1
Pacific albatross	1	0	0	0	1
Albatrosses indet.	2	1	33	0	36
Total albatrosses	438	38	68	36	580
Grey petrel	38	0	3	5	46
White chinned petrel	21	8	2	2	33
Black petrel	0	23	2	1	26
Grey-faced petrel	0	1	2	17	20
Sooty shearwater	4	0	1	8	13
Flesh footed shearwater	0	11	1	0	12
Westland petrel	6	0	0	2	8
Cape petrels	2	0	0	0	2
Southern giant petrel	2	0	0	0	2
White headed petrel	0	0	0	2	2
Petrels indeterminate	0	1	0	0	1
Total other birds	73	44	11	37	165
All observed birds	511	82	79	73	745
Approx. proportion obs.	0.42	0.03	0.10	0.38	0.22

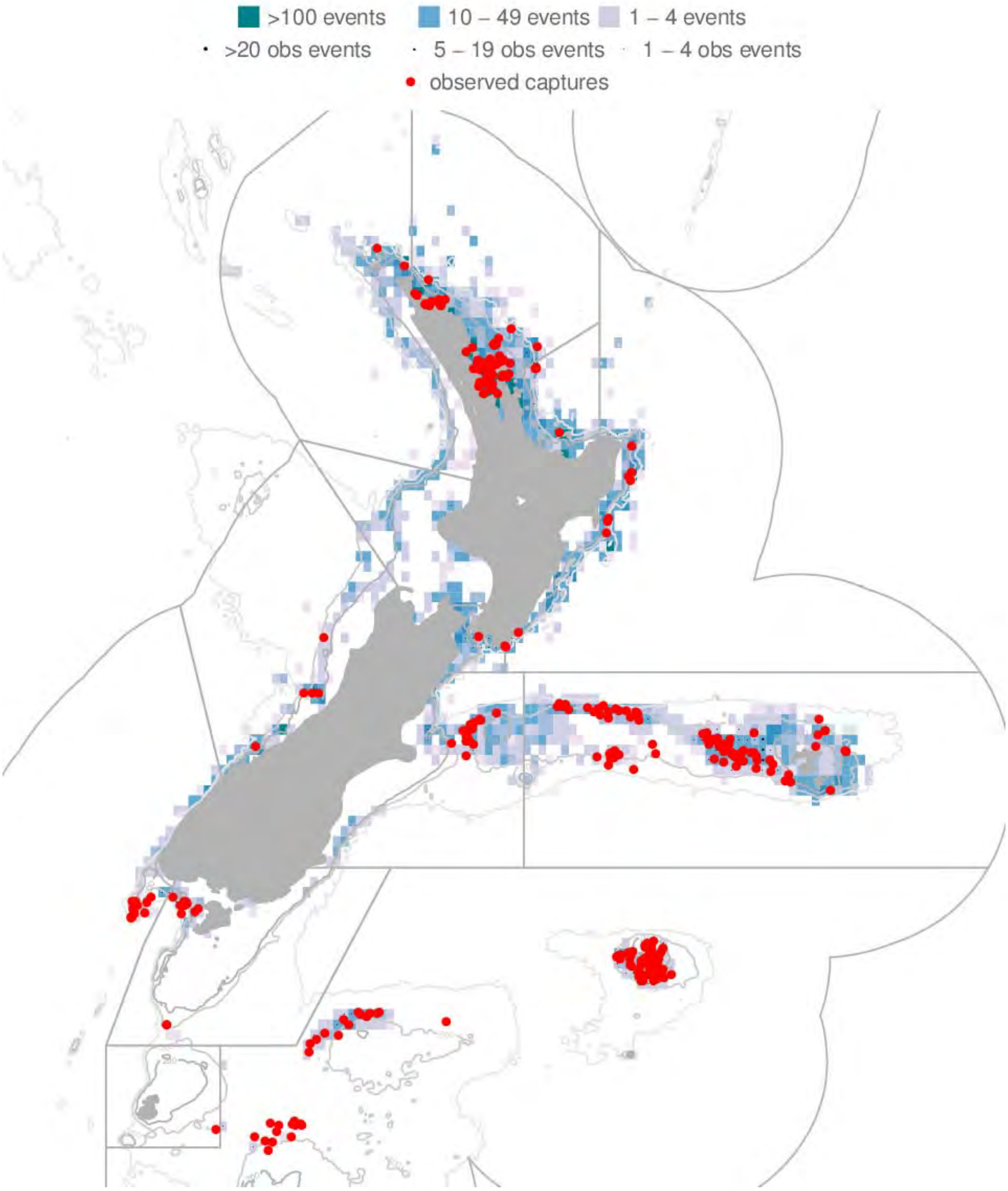


Figure 6.9: Map of bottom longline fishing effort and all observed seabird captures by bottom longlines, October 2003 to September 2012. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by 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, 97% of effort is displayed).

Table 6.18: Summary of seabirds observed captured in bottom longline fisheries 2002–03 to 2010–11. Declared target species are: LIN, ling; SNA, snapper; BNS, bluenose; HPB, hapuku or bass. Data version v20121101.

	Declared target species				
Species or group	LIN	SNA	BNS	HPB	Total
Salvin's albatross	51	0	0	0	51
Chatham Island albatross	18	0	0	0	18
Southern Buller's albatross	4	0	3	0	7
Campbell albatross	0	0	2	1	3
Wandering albatrosses	2	0	1	0	3
White capped albatross	2	0	0	0	2
Black browed albatrosses	1	0	0	0	1
Indian yellow-nosed albatross	1	0	0	0	1
Southern royal albatross	1	0	0	0	1
Albatross indet.	2	0	0	0	2
All albatrosses	82	0	6	1	89
White chinned petrel	217	0	2	0	219
Grey petrel	79	0	0	0	79
Sooty shearwater	68	0	0	1	69
Black petrel	0	28	14	7	51
Flesh footed shearwater	0	36	0	3	39
Cape petrels	24	0	0	0	24
Common diving petrel	23	0	0	0	23
Grey-faced petrel	0	0	0	6	6
Fluttering shearwater	0	4	0	0	4
Northern giant petrel	4	0	0	0	4
Prions	4	0	0	0	4
Storm petrels	3	0	0	0	3
Gannets	0	2	0	0	2
Pied shag	0	2	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
Giant petrel	1	0	0	0	1
Red billed gull	0	1	0	0	1
Other birds indeterminate	1	10	0	0	11
All other birds	425	85	16	17	545
All birds observed	507	85	22	18	634
Approx. proportion obs.	0.20	0.01	0.01	0.01	0.10

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 55%, 21%, and 24% of captures, respectively, but there are substantial differences in these proportions among seabird taxa. A high proportion (87% between 2003 and 2011) of white-capped albatross captures are taken in trawl fisheries with almost all of the remainder taken in surface longline fisheries. The trawl fishery also accounts for 89% of sooty shearwaters captured, with most of the remainder taken by bottom longliners. The proportion captured by trawl fisheries reduces to 53% for all other albatrosses combined, with 30% and 17% taken in surface and bottom longline fisheries, respectively. Bottom longline and trawl take similar proportions of the white-chinned petrels captured (43% and 50%, respectively).

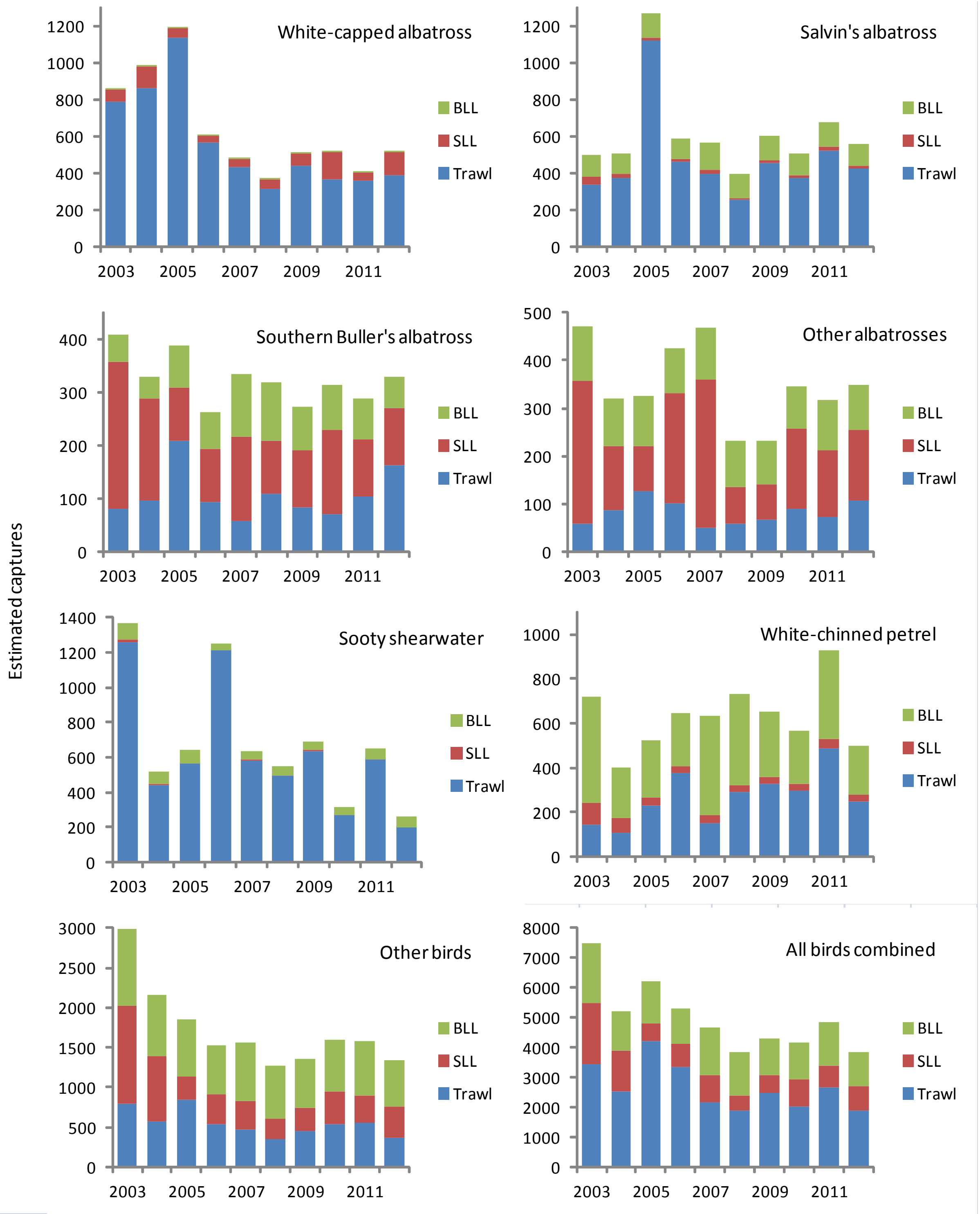


Figure 6.10: Model-based estimates of captures of the most numerous seabird taxa observed captured in trawl, surface longline, and bottom longline fisheries between 2002–03 and 2010/12. For confidence limits see Tables 6.10 to 6.15. Note that this level of aggregation conceals any different trends within a fishing method (e.g., deepwater vs. inshore and flatfish trawl or large vs. small longliners).

Over the 2003 to 2011 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 sooty shearwaters and white-chinned petrel (Figure 6.10). Estimated captures of other albatrosses, sooty shearwaters, 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 the 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 (Figures 6.11 to 6.13).

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 2006–07 (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 2011/12, especially after 2006–07 (Figure 6.12). Capture rates were unusually high in all trawl fisheries in 2004–05. Together, these fisheries account for 71% of all estimated captures of Salvin’s albatross in these years.

For white-chinned petrel, captures rates increased between 2002–03 and 2011/12 in squid and scampi trawlers (Figure 6.13) but showed little trend for bottom longliners targeting ling and bluenose. Together, these fisheries account for 83% of all estimated captures of white-chinned petrel in these years.

For sooty shearwaters, captures rates decreased between 2002–03 and 2011/12 for bottom longliners targeting ling, but fluctuated without apparent trend in squid, middle-depth, and hoki trawlers (Figure 6.14). 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 (23% in trawl fisheries between 2002–03 and 2010–11, 29% in surface longline fisheries, and 25% 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. Second, identifications by observers are not completely reliable and sometimes use generic codes rather than species codes. A high proportion of dead captures are returned for necropsy and formal identification (87% in trawl fisheries between 2002–03 and 2010–11, 83% in surface longline fisheries, and 89% in bottom longline fisheries), but there remains uncertainty in the identity of 11–17% of dead captures and 100% of those released alive during that period (currently, processes are in place to obtain photographs of live-released birds for expert determination of identification). 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.

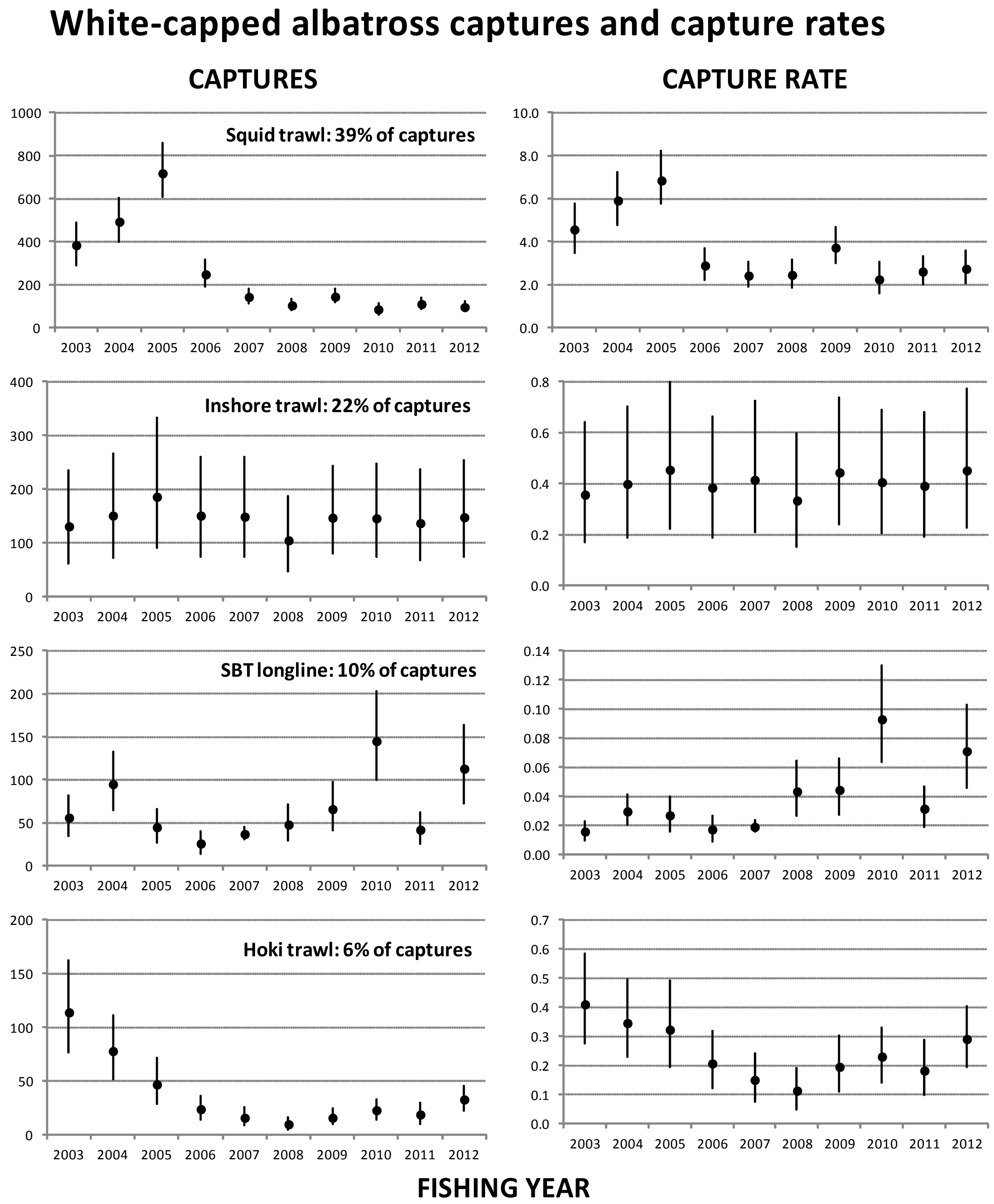


Figure 6.11: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of white capped albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2011–12 (cumulatively, 78% of all white-capped albatross captures). Data version v20130304.

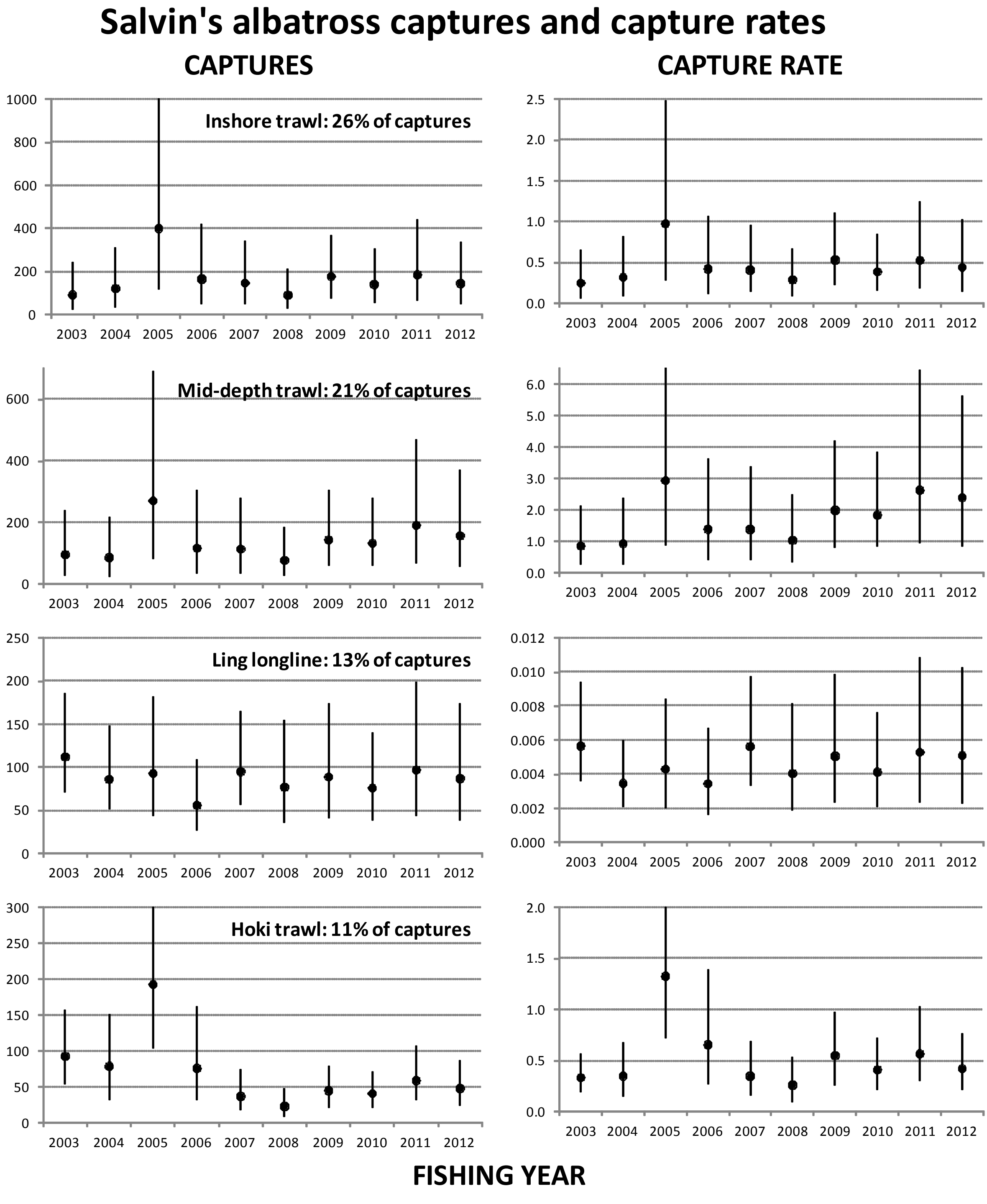


Figure 6.12: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of Salvin's albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2011–12 (cumulatively, 71% of all Salvin's albatross captures). Data version v20130304.

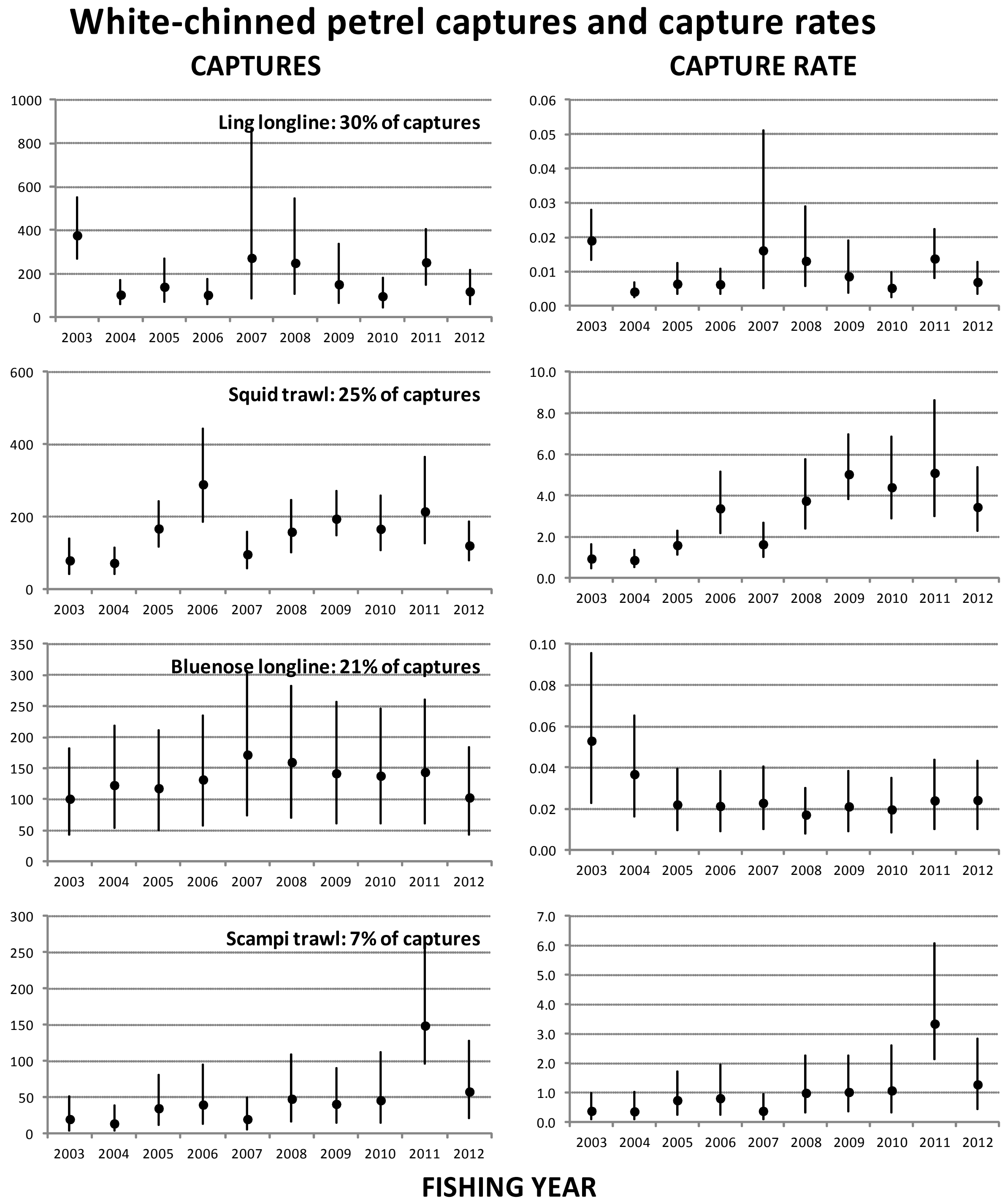


Figure 6.13: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of white chinned petrels in the four fisheries estimated to have taken the most captures between 2002–03 and 2011–12 (cumulatively, 83% of all white-chinned petrel captures). Data version v20130304.

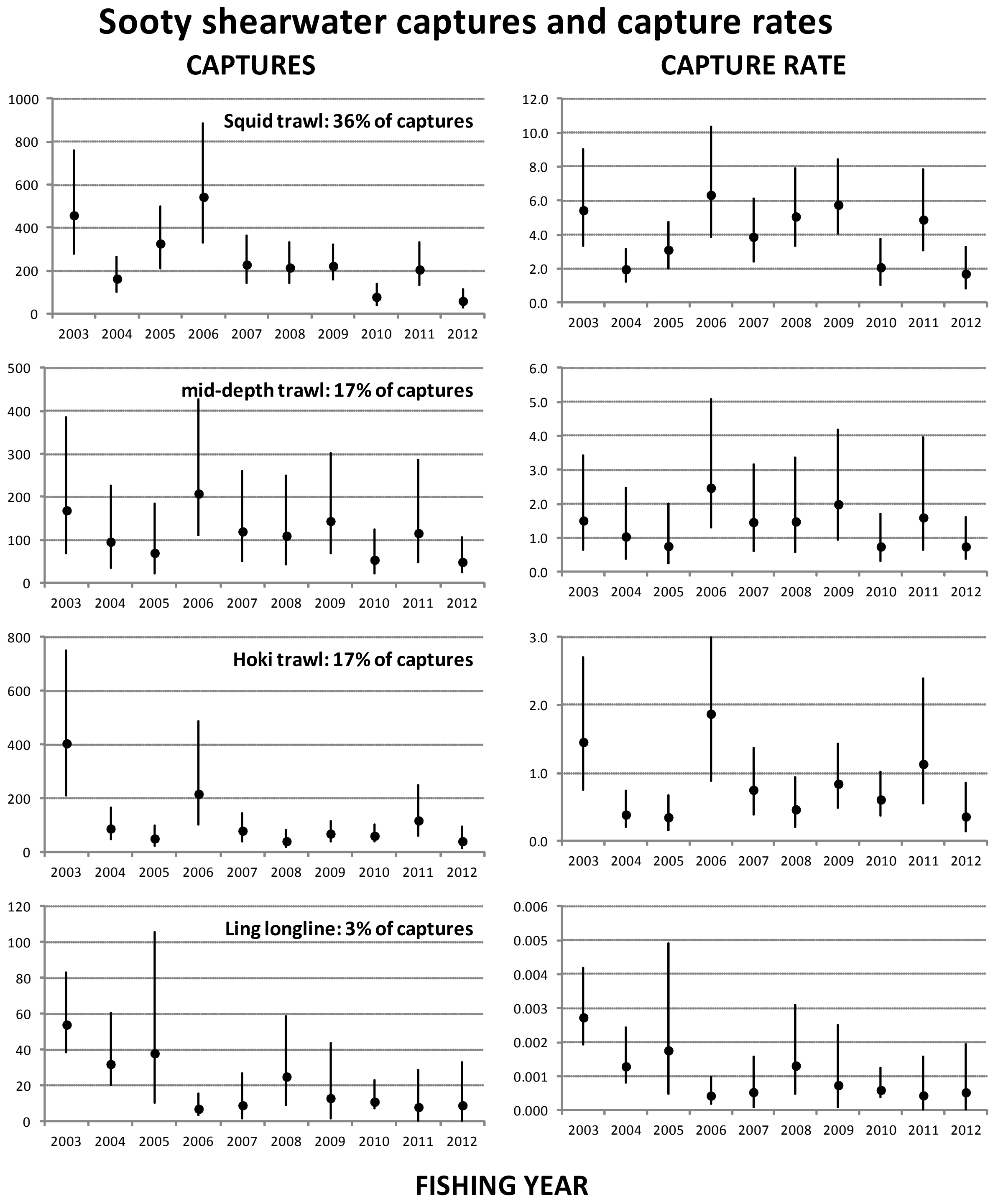


Figure 6.14: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of sooty shearwaters in the four fisheries estimated to have taken the most captures between 2002–03 and 2011–12 (cumulatively, 73% of all sooty shearwater captures). Data version v20130304.

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 6.19.

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.

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[8];
- 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, 2012 ab). 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.

Table 6.19: (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.

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 6.15). 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 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.

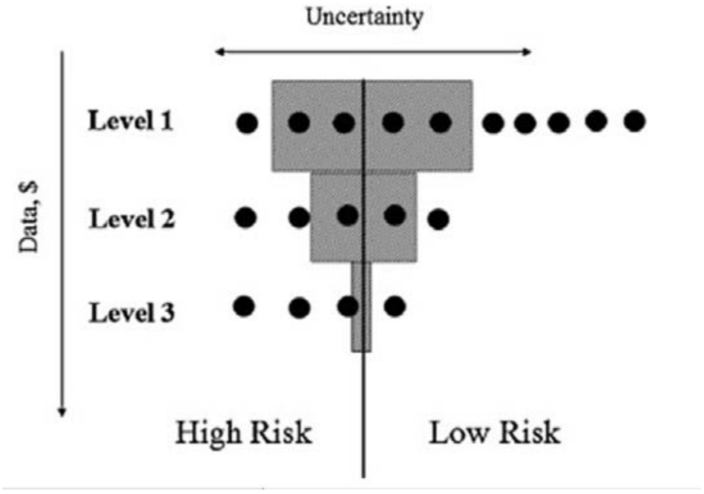


Figure 6.15: (from Hobday et al 2007): Diagrammatic representation of the hierarchical risk assessment process where activities that present low risk are progressively screened out by assessments of increasingly high data content, sophistication, and cost.

6.4.4.2. 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 Tables 6.20 and 6.21 (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 6.22.

Table 6.20: 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 6.21: 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 6.22: Confidence scores used by Rowe (2013) (after Hobday et al 2007).

Score	Descriptor	Rationale for confidence score
1a	Low	Data exists, but is considered poor or conflicting.
1b		No data exists.
1c		Agreement between experts, but with low confidence
1d		Disagreement between experts
2a	High	Data exists and is considered sound.
2b		Consensus between experts
2c		High confidence exposure to impact can not occur (e.g. no spatial overlap of fishing activity and at-sea seabird distribution)

Total potential and residual risk for a seabird taxon was estimated by summing the scores across all fisheries (Table 6.23 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 6.24 shows the results for all 26 fishery groups).

White-chinned petrel, sooty shearwater, black (Parkinson's) 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 6.23: 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 (Parkinson's) 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.

Table 6.24: 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	–

6.4.4.3. 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 2008 ab, 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 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 6.16) and fishing effort distributions (e.g., see Figures 6.7–6.9), and compares these estimates with observed captures from fisheries observer data to estimate vulnerability by taxon (capture rates per encounter) to each fishery group, yielding estimates of total observable captures and population-level potential fatalities from all New Zealand commercial fisheries. Impact estimates are subsequently compared with population estimates and biological characteristics to yield estimates of population-level risk (see method diagram in Figure 6.17).

The current level 2 risk assessment (i.e., as described by Richard & Abraham 2013b) estimated the risk posed to each of 70 seabird taxa by trawl and longline fisheries within New Zealand's TS and EEZ. This iteration of the risk assessment includes several substantial improvements on the 2011 version (Richard et al 2011) including:

- The assessment was extended to include additional seabird species: fluttering shearwater, little black shag, pied shag, and little blue penguin. Inclusion of the latter species encompassed four races of little penguin (northern, southern, white-flippered, and Chatham Island). Black-browed albatross was omitted from the assessment because very few breed in New Zealand waters. These amendments resulted in an increase in the number of populations assessed from 64 to 70.
- The calculation of the PBR was modified to include the calibration factor, ρ (rho).
- The risk ratio was calculated using a PBR with recovery factor, f = 1.
- Vulnerabilities were estimated using a single model, so that the vulnerability was a product of a fisheries-related vulnerability and a species-group specific vulnerability.
- Breeding and non-breeding bird distributions were considered separately to account for the seasonality in the distribution of species and fisheries.
- Multipliers to account for cryptic mortality were re-calculated to include uncertainty in their estimation.
- Potential fatalities were estimated using bycatch data from the most recent period (2006–07 to 2010–11) since the introduction of mandatory mitigation in many fisheries.
- Set-net fisheries were included.
- Population sizes were updated for 14 taxa, and age at first reproduction, survival and the proportion of adults breeding were updated for five albatross taxa.
- Spatial distributions were improved for 13 taxa.

For each taxon, the risk was assessed by dividing the estimated number of annual potential fatalities 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 6.16). 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 (2013a) 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 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).

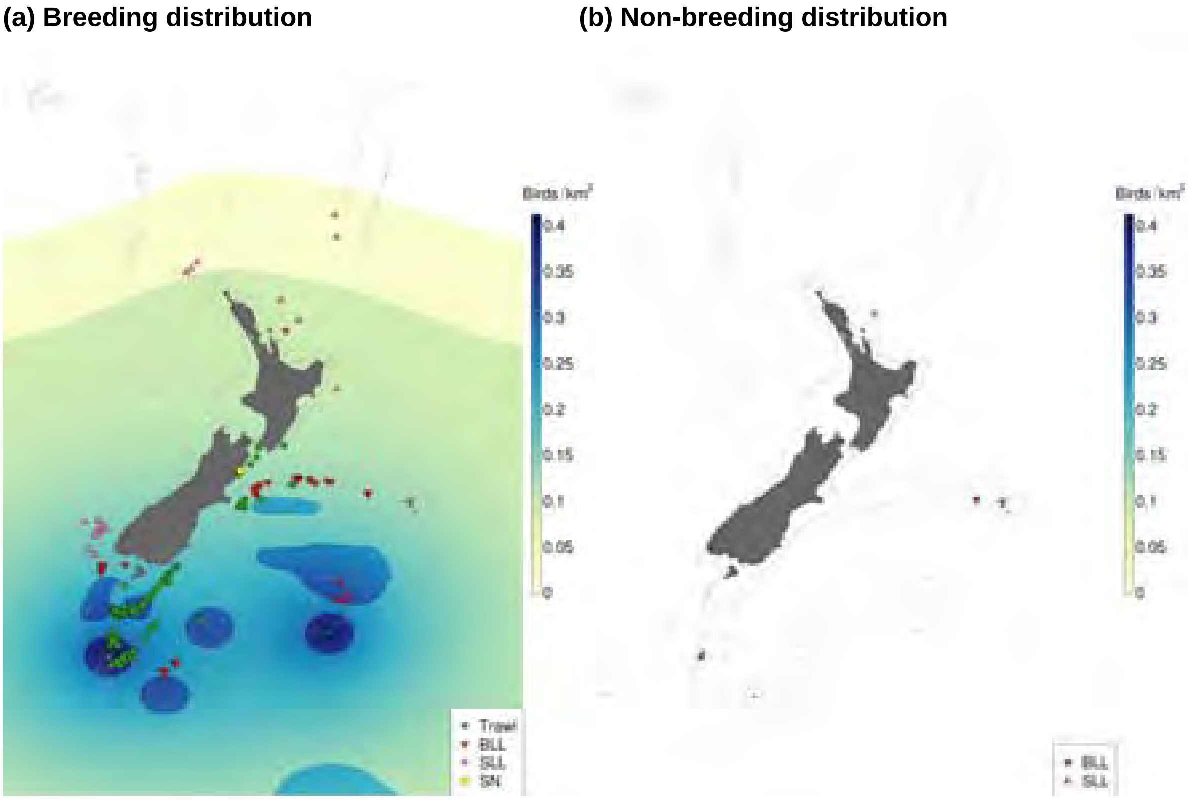
Calculation of the PBR for a seabird species requires specification of the recovery factor, *f*. This factor is typically set between 0.1 and 0.5 and can be used for several purposes (e.g., Lonergan 2011). It can be used to "protect" against errors in the input data used to calculate the PBR, to provide 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) set the recovery factor to $f = 1$ and suggested that appropriate values for each species should be determined at a later stage.

Amongst the 70 studied taxa, two species clearly stood out as at most risk from commercial fishing activities within New Zealand waters (Figure 6.18 and Table 6.25). Even with the recovery factor set to 1, two 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), with black (Parkinson's) petrel having the highest risk ratio (estimated annual potential fishing-related fatalities almost 20 times higher than the PBR: median, 19.9; 95% c.i.: 11.4–32.8). Potential fatalities for Salvin's albatross were nearly three times the PBR (2.88; 1.47–5.41). Another four 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, southern Buller's albatross, Chatham Island albatross, and New Zealand white-capped albatross.

Four species had a median risk ratio above 0.3 or the upper 95% confidence limit above 1 and are classified as at "high risk": northern Buller's albatross; Gibson's albatross; Cape petrel; and Antipodean albatross. The risk ratio of nine species had a median above 0.1 or the upper 95% confidence limit above 0.3 and are classified as at "medium risk": northern and southern royal albatrosses; Westland petrel; northern giant petrel; white-chinned petrel; spotted shag; Campbell black-browed albatross; grey petrel; and the mainland population of yellow-eyed penguin (assuming that all fisheries-related mortalities are of the mainland population) (Richard & Abraham 2013b).

In total, there were 15 100 (95% c.i.: 13 600 – 16 600) estimated annual potential seabird fatalities across the four fishing methods (Table 6.26). The highest number of annual potential fatalities was in trawl fisheries with 9870 (8560–11 300) 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. In bottom-longline fisheries, there were a total of 3560 (3040–4150) estimated annual potential fatalities (Table 6.26), mostly in the small vessel bottom longline sector (1570, 1240–1950). The species with the highest number of estimated potential fatalities in these fisheries were: black petrel with 1340 (980–1780); flesh-footed shearwater with 519 (313–742); and Salvin's albatross with 427 (287–614) (Richard & Abraham 2013b). Annual potential fatalities in surface-longline fisheries totalled 1340 (1170–1570) estimated annual potential fatalities across all seabird species (Table 6.26), over 80% of which were in the small vessel surface-longline sector. The species with the highest number of estimated potential fatalities in these fisheries were: northern and southern Buller's albatross with, respectively, 242 and 106 (170–343 and 87–127); NZ white-capped albatross with 178 (122–240); and Gibson's albatross with 103 (71–143) (Richard & Abraham 2013b).

Set-net fisheries were included in the risk assessment for the first time, and estimated potential fatalities in these fisheries were relatively low, with a total of 317 (95% c.i.: 228 – 460) annual potential fatalities across all species (Table 6.26). Although the total estimate was low, for some species, the highest number of estimated annual potential fatalities occurred in set-net fisheries. In particular, there were 32 (17–49) estimated annual potential fatalities of yellow-eyed penguin, assumed to come from the mainland population, and 50 (2–175) estimated annual potential fatalities of Australasian gannet in set-net fisheries.



(a) Breeding distribution

(b) Non-breeding distribution

Figure 6.16: (from Richard & Abraham 2013b 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 2010–11 in trawl, surface-longline (SLL), bottom-longline (BLL), and set-net (SN) fisheries.

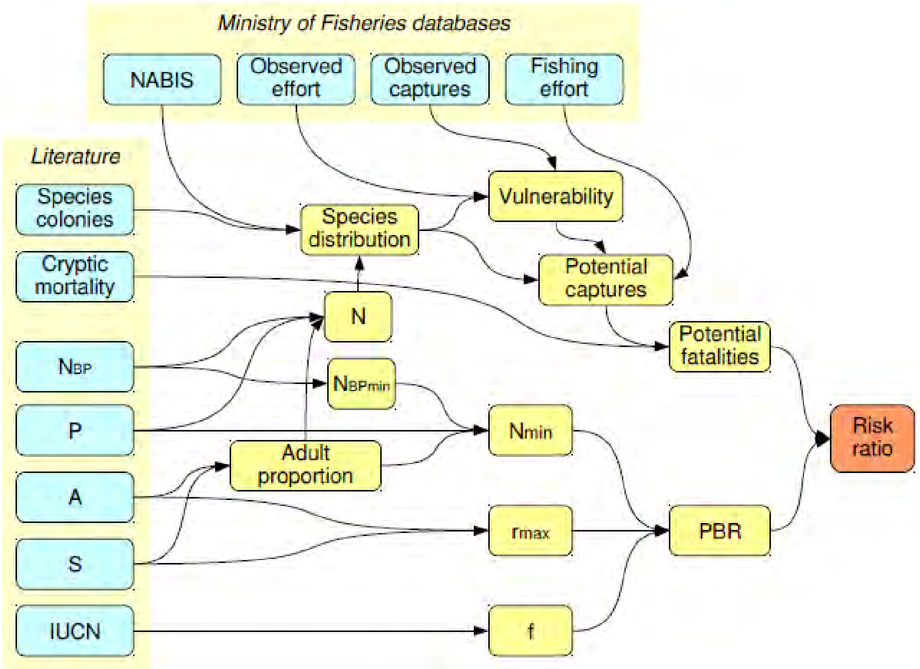


Figure 6.17: (reproduced from Richard et al 2011): Diagram of the modelling approach to calculate the risk index for each taxon. N_{BP}, number of annual breeding pairs; *N*, total number of birds over one year old; N_{BPmin}, lower 25% of the distribution of N_{BP}; *Nmin*, lower 25% of the distribution 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.

Table 6.25: (reproduced from Richard & Abraham 2013b) 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 (P_1, $P_{0.5}$, and $P_{0.1}$ respectively). Species are sorted by decreasing order of the median risk ratio. The risk ratio for the mainland population of yellow-eyed penguin assumes that all estimated fatalities were of that population (600–800 annual breeding pairs). 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. ??, workshop review result Nov 2013.

	PBR_1		APF		Risk ratio				
Taxon / population	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.	P_1	$P_{0.5}$	$P_{0.1}$
Black petrel	74	47–117	1 440	1 070–1 900	19.9	11.40–32.80	1.00	1.00	1.00
Salvin's albatross	975	521–1 740	2 690	2 100–3 420	2.88	1.47–5.41	1.00	1.00	1.00
Flesh-footed shearwater	590	288–1 200	780	523–1 090	1.41	0.59–2.94	0.81	0.99	1.00
Southern Buller's albatross	513	270–831	663	520–839	1.32	0.75–2.58	0.79	1.00	1.00
Chatham Island albatross	159	94–264	205	136–316	1.30	0.68–2.59	0.78	1.00	1.00
NZ white-capped albatross	4 040	908–9 840	2 830	2 080–3 790	0.78	0.28–3.13	0.36	0.77	1.00
Northern Buller's albatross	617	325–1 000	418	312–560	0.69	0.38–1.36	0.17	0.82	1.00
Gibson's albatross	260	132–425	121	86–164	0.48	0.25–1.00	0.03	0.45	1.00
Cape petrel	840	283–1 890	254	175–361	0.33	0.12–0.93	0.02	0.23	0.99
Antipodean albatross	295	203–419	89	63–121	0.30	0.18–0.49	0	0.02	1.00
Northern royal albatross	396	164–782	108	72–160	0.29	0.12–0.70	0	0.12	1.00
Southern royal albatross	441	302–630	116	82–160	0.27	0.16–0.43	0	0	1.00
Westland petrel	241	142–384	63	28–129	0.25	0.10–0.66	0	0.08	0.98
Northern giant petrel	217	66–486	47	18–103	0.23	0.06–0.85	0.01	0.14	0.87
White-chinned petrel	7 920	3 280–15 800	1 670	1 210–2 330	0.22	0.10–0.53	0	0.04	0.97
Spotted shag	3 780	1 730–7 570	745	485–1 100	0.21	0.09–0.48	0	0.02	0.95
Campbell black-browd albatross	1 020	514–1 830	192	111–324	0.19	0.08–0.44	0	0.01	0.94
Yellow-eyed penguin (mainland)	184	122–272	35	19–56	0.19	0.09–0.37	0	0	0.96
Grey petrel	2 170	1 010–3 900	247	169–364	0.12	0.06–0.27	0	0	0.65
Little black shag	120	67–216	8	5–14	0.07	0.03–0.15	0	0	0.18
Yellow-eyed penguin	537	352–805	35	19–56	0.07	0.03–0.12	0	0	0.10
Kermadec storm petrel	4	1–9	0	0–0	0.06	0.02–0.18	0	0	0.26
Pied shag	172	75–329	10	3–24	0.06	0.01–0.20	0	0	0.23
Stewart island shag	269	218–334	13	3–29	0.04	0.01–0.11	0	0	0.04
NZ king shag	16	13–20	1	0–4	0.04	0.00–0.24	0	0	0.12
Light-mantled sooty albatross	237	167–319	7	2–20	0.02	0.01–0.09	0	0	0.02
Chatham petrel	11	5–26	0	0–1	0.02	0.00–0.10	0	0	0.02
Grey-headed albatross	333	157–613	6	1–20	0.01	0.00–0.07	0	0	0.01
Australasian gannet	4 190	1 500–9 770	62	7–222	0.01	0.00–0.07	0	0	0.01
Fiordland crested penguin	488	255–866	6	1–17	0.01	0.00–0.04	0	0	0
Soft-plumaged petrel	171	32–553	1	0–3	0.01	0.00–0.05	0	0	0
Grey-faced petrel	14 000	6 290–31 200	108	51–207	0.01	0.00–0.02	0	0	0
Cook's petrel	2 430	1 140–5 500	17	6–35	0.01	0.00–0.02	0	0	0
Pycroft's petrel	109	48–241	1	0–2	0.01	0.00–0.02	0	0	0
Northern little penguin	1 360	869–2 000	9	2–23	0.01	0.00–0.02	0	0	0
Sooty shearwater	348 000	115 000–751 000	1 760	1 260–2 480	0.01	0.00–0.02	0	0	0
Fluttering shearwater	5 220	1 240–13 700	19	5–54	0	0.00–0.02	0	0	0
White-flippered little penguin	421	263–657	2	0–4	0	0.00–0.01	0	0	0
Mottled petrel	15 300	7 040–33 500	45	17–98	0	0.00–0.01	0	0	0
Southern little penguin	1 360	864–2 030	3	1–9	0	0.00–0.01	0	0	0
Hutton's shearwater	6 370	3 490–10 600	15	4–36	0	0.00–0.01	0	0	0
Black-bellied storm petrel	4 550	2 410–8 220	8	2–17	0	0.00–0.00	0	0	0
Snares crested penguin	4 910	2 520–8 800	8	2–19	0	0.00–0.00	0	0	0
White-headed petrel	18 500	6 760–44 000	23	11–41	0	0.00–0.00	0	0	0
Chatham Island little penguin	1 350	856–2 030	3	0–14	0	0.00–0.01	0	0	0
Common diving petrel	64 600	19 400–152 000	36	15–77	0	0.00–0.00	0	0	0
Buller's shearwater	14 800	5 530–33 800	10	2–32	0	0.00–0.00	0	0	0
Kermadec petrel	336	153–752	0	0–1	0	0.00–0.00	0	0	0
Little shearwater	7 800	4 090–13 200	4	1–10	0	0.00–0.00	0	0	0
NZ white-faced storm petrel	105 000	38 800–226 000	45	12–111	0	0.00–0.00	0	0	0
Western rockhopper penguin	7 510	5 580–9 990	3	1–8	0	0.00–0.00	0	0	0
Southern black-backed gull	371 000	148 000–751 000	94	25–231	0	0.00–0.00	0	0	0
Antarctic prion	40 100	9 230–110 000	5	2–10	0	0.00–0.00	0	0	0
Fairy prion	159 000	62 800–330 000	22	7–56	0	0.00–0.00	0	0	0
Erect-crested penguin	12 600	10 200–15 600	2	0–5	0	0.00–0.00	0	0	0
Broad-billed prion	106 000	48 700–201 000	11	4–26	0	0.00–0.00	0	0	0
NZ storm petrel	16	1–64	0	0–0	0	0.00–0.12	0	0	0.03
Chatham Island taiko	1	0–2	0	0–0	0	0.00–0.00	0	0	0.02
Chatham Island shag	51	38–68	0	0–4	0	0.00–0.08	0	0	0.02
Pitt island shag	100	51–178	1	0–6	0	0.00–0.06	0	0	0.01
South Georgian diving petrel	5	2–8	0	0–0	0	0.00–0.00	0	0	0
Bounty Island shag	17	11–26	0	0–0	0	0.00–0.02	0	0	0
Wedge-tailed shearwater	4 120	2 720–5 760	0	0–0	0	0.00–0.00	0	0	0
White-naped petrel	2 990	1 060–7 410	0	0–0	0	0.00–0.00	0	0	0
White-bellied storm petrel	66	29–131	0	0–0	0	0.00–0.00	0	0	0
Masked booby	46	26–76	0	0–0	0	0.00–0.01	0	0	0
Auckland Island shag	305	132–581	0	0–1	0	0.00–0.00	0	0	0
Campbell Island shag	298	153–534	0	0–0	0	0.00–0.00	0	0	0
Subantarctic skua	31	19–45	0	0–0	0	0.00–0.01	0	0	0
Caspian tern	176	92–299	0	0–1	0	0.00–0.00	0	0	0
White tern	18	13–26	0	0–0	0	0.00–0.00	0	0	0

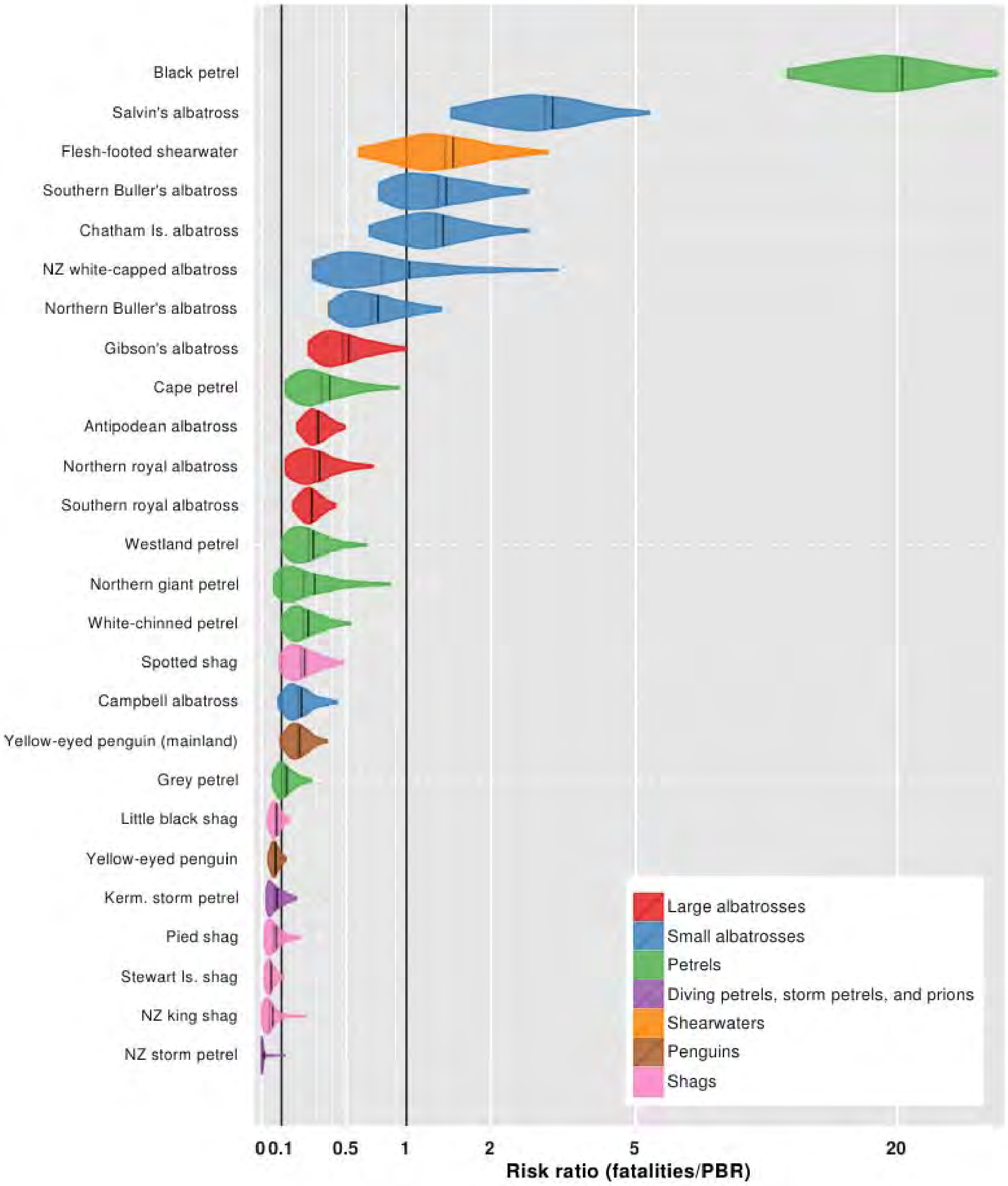


Figure 6.18: (reproduced from Richard & Abraham 2013b) Risk ratio (annual potential fatalities divided by Potential Biological Removal, PBR_1) with the recovery factor f set to 1 for the 26 most at-risk species. The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential 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 mean risk ratio (solid black line), and median (grey line). Seabird species are listed in decreasing order of their median risk ratio. Species with a 95% upper limit of less than 0.1 are not shown. The risk ratio for yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were from that population of 600–800 breeding pairs.

Table 6.26: Estimated of annual potential seabird fatalities by fishing method and fishery grouping (from Richard & Abraham 2013b, tables A-4 to A-8).

Fishing method	Fishery	Total annual potential seabird fatalities	95% c.i.
Trawl	Small inshore	2 650	1 850 – 3 650
	Large processor	1 190	929 – 1 510
	Large meal	831	641 – 1 050
	Large fresher	22	5 – 66
	SBW	66	36 – 113
	Scampi	1 490	1 090 – 2 070
	Mackerel	43	24 - 69
	Squid	2 350	1 720 – 3 180
	Deepwater	154	108 – 209
	Flatfish	1 070	713 – 1 580
Bottom longline	Bluenose	866	587 – 1 230
	Small	1 570	1 240 – 1 950
	Snapper	924	660 – 1 240
	Large	205	159 – 261
Surface longline	Large	130	107 – 153
	Small	1 200	1 040 – 1 440
Setnet		317	228 – 460
Total		**15 100**	**13 600 – 16 600**

As some of the demographic parameters were updated between this study and the previous risk assessment (Richard et al 2011), comparisons were made possible by back-calculating the values of PBR_1 from Richard et al (2011). The resulting PBR_1 values were typically lower in Richard & Abraham (2013b) than the previous study, owing to the inclusion of the calibration factor ρ and the changes in some of the demographic parameters (Table 6.27).

Table 6.28 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 693 (95% c.i. 522–884), exceeding PBR_1 (Richard & Abraham 2013b).

Table 6.27: (from Richard & Abraham 2013b) Comparison of the risk ratios between Richard et al (2011) and this study for the same studied species. Risk ratios of Richard et al (2011) were back-calculated with the recovery factor set to 1. The mean values are presented as median values were not available from Richard et al (2011). A "+" or "-" sign in the "Change" column indicates whether the new risk ratio is higher (respectively lower). A direction of change is only indicated if both mean values are outside the other assessment's confidence intervals. The species names were coloured according to their respective risk categories in the present study: 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.

	Richard et al 2011		This study		Change
Taxon / population	Mean	95% c.i.	Mean	95% c.i.	
Gibson's albatross	0.37	0.19–0.69	0.52	0.25–1.00	
Antipodean albatross	0.33	0.20–0.51	0.31	0.18–0.49	
Southern royal albatross	0.22	0.06–0.47	0.27	0.16–0.43	
Northern royal albatross	0.44	0.15–1.08	0.32	0.12–0.70	
Campbell black-browed albatross	0.55	0.23–0.96	0.21	0.08–0.44	-
NZ white-capped albatross	0.33	0.20–0.53	1.03	0.28–3.13	
Salvin's albatross	0.75	0.32–1.42	3.03	1.47–5.41	+
Chatham Island albatross	0.81	0.34–2.28	1.39	0.68–2.59	
Grey-headed albatross	1.05	0.40–2.15	0.02	0.00–0.07	-
Southern Buller's albatross	0.51	0.23–1.00	1.42	0.75–2.58	+
Northern Buller's albatross	0.32	0.08–0.70	0.74	0.38–1.36	+
Light-mantled sooty albatross	0.87	0.43–1.61	0.03	0.01–0.09	-
Northern giant petrel	1.5	0.41–3.93	0.29	0.06–0.85	-
Grey petrel	0.16	0.07–0.29	0.13	0.06–0.27	
Black petrel	3.34	1.78–5.57	20.5	11.40–32.80	+
Westland petrel	0.99	0.38–2.35	0.28	0.10–0.66	-
White-chinned petrel	0.24	0.06–0.43	0.25	0.10–0.53	
Flesh-footed shearwater	1.25	0.54–2.27	1.5	0.59–2.94	
Wedge-tailed shearwater	0	0.00–0.00	0	0.00–0.00	
Buller's shearwater	0.01	0.00–0.02	0	0.00–0.00	
Sooty shearwater	0.01	0.00–0.02	0.01	0.00–0.02	
Hutton's shearwater	0.02	0.01–0.04	0	0.00–0.01	-
Little shearwater	0	0.00–0.01	0	0.00–0.00	
Cape petrel	0.38	0.14–0.81	0.39	0.12–0.93	
Fairy prion	0	0.00–0.00	0	0.00–0.00	
Antarctic prion	0	0.00–0.00	0	0.00–0.00	
Broad-billed prion	0	0.00–0.00	0	0.00–0.00	
Pycroft's petrel	0.01	0.00–0.03	0.01	0.00–0.03	
Cook's petrel	0.01	0.00–0.02	0.01	0.00–0.02	
Chatham petrel	0.01	0.00–0.02	0.02	0.00–0.10	
Mottled petrel	0	0.00–0.01	0	0.00–0.01	
White-naped petrel	0	0.00–0.00	0	0.00–0.00	
Kermadec petrel	0	0.00–0.01	0	0.00–0.00	
Grey-faced petrel	0.01	0.00–0.01	0.01	0.00–0.02	
Chatham Island taiko	0	0.00–0.01	0.01	0.00–0.00	
White-headed petrel	0.01	0.00–0.01	0	0.00–0.00	
Soft-plumagedpetrel	0.02	0.00–0.06	0.01	0.00–0.05	
Common diving petrel	0	0.00–0.00	0	0.00–0.00	
South Georgian diving petrel	0	0.00–0.01	0	0.00–0.00	
NZ white-faced storm petrel	0	0.00–0.00	0	0.00–0.00	
White-bellied storm petrel	0	0.00–0.00	0	0.00–0.00	
Black-bellied storm petrel	0	0.00–0.01	0	0.00–0.01	
Kermadec storm petrel	0	0.00–0.00	0.08	0.02–0.18	+
NZ storm petrel	0	0.00–0.00	0.01	0.00–0.12	
Yellow-eyed penguin	0.02	0.00–0.08	0.07	0.03–0.12	
Western rockhopper penguin	0	0.00–0.01	0	0.00–0.00	
Fiordland crested penguin	0.13	0.04–0.29	0.01	0.00–0.04	-
Snares crested penguin	0.01	0.00–0.02	0	0.00–0.01	
Erect-crested penguin	0	0.00–0.00	0	0.00–0.00	
Australasian gannet	0.05	0.01–0.11	0.02	0.00–0.07	
Masked booby	0	0.00–0.00	0	0.00–0.01	
NZ king shag	0.62	0.13–1.43	0.06	0.00–0.24	-
Stewart Island shag	0.48	0.30–0.69	0.05	0.01–0.11	-
Chatham Island shag	0.02	0.00–0.05	0.01	0.00–0.08	
Bounty Island shag	0.01	0.00–0.02	0	0.00–0.02	
Auckland Island shag	0.01	0.00–0.01	0	0.00–0.00	
Campbell Island shag	0	0.00–0.00	0	0.00–0.00	
Spotted shag	0.25	0.08–0.41	0.23	0.09–0.48	
Pitt Island shag	0.03	0.01–0.08	0.01	0.00–0.06	
Subantarctic	0	0.00–0.00	0	0.00–0.01	
Southern black-backed gull	0	0.00–0.00	0	0.00–0.00	
Caspian tern	0	0.00–0.00	0	0.00–0.00	
White tern	0	0.00–0.00	0	0.00–0.00	

Table 6.28: 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.

	No cryptic mortality		With cryptic mortality	
Species	Mean	95% c.i.	Mean	95% c.i.
Gibson's albatross	55	41–73	121	86–164
Antipodean albatross	42	31–55	89	63–121
Southern royal albatross	50	36–67	116	82–160
Northern royal albatross	45	30–65	108	72–160
Campbell black-browed albatross	77	43–135	192	111–324
NZ white-capped albatross	394	338–454	2 830	2 080–3 790
Salvin's albatross	476	396–577	2 690	2 100-3 420
Chatham Island albatross	82	54–124	205	136–316
Grey-headed albatross	2	0–7	6	1–20
Southern Buller's albatross	136	119–159	663	520–839
Northern Buller's albatross	157	114–215	418	312–560
Light-mantled sooty albatross	3	0–10	7	2–20
Northern giant petrel	6	2–13	47	18–103
Grey petrel	112	79–161	247	169–364
Black petrel	693	522–884	1 440	1 070–1 900
Westland petrel	28	14–51	63	28–129
White-chinned petrel	567	485–686	1 670	1 210–2 330
Flesh-footed shearwater	333	234–434	780	523–1 090
Wedge-tailed shearwater	0	0–0	0	0–0
Buller's shearwater	5	1–16	10	2–32
Sooty shearwater	539	477–613	1 760	1 260–2 480
Hutton's shearwater	10	3–27	19	5–54
Little shearwater	9	3–19	15	4–36
Cape petrel	2	0–5	4	1–10
Gibson's albatross	125	88–172	254	175–361
Fairy prion	11	3–28	22	7–56
Antarctic prion	2	1–4	5	2–10
Broad-billed prion	5	1–13	11	4–26
Pycroft's petrel	0	0–1	1	0–2
Cook's petrel	8	3–17	17	6–35
Chatham petrel	0	0–0	0	0–1
Mottled petrel	23	8–47	45	17–98
White-naped petrel	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–1
Grey-faced petrel	53	26–98	108	51–207
Chatham Island taiko	0	0–0	0	0–0
White-headed petrel	11	5–20	23	11–41
Soft-plumaged petrel	1	0–1	1	0–3
Common diving petrel	14	6–26	36	15–77
South Georgian diving petrel	0	0–0	0	0–0
NZ white-faced storm petrel	26	5–62	45	12–111
White-bellied storm petrel	0	0–0	0	0–0
Black-bellied storm petrel	4	1–12	8	2–17
Kermadec storm petrel	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0
Yellow-eyed penguin	34	18–52	35	19–56
Northern little penguin	7	1–16	9	2–23
White-flippered penguin	1	0–4	2	0–4
Southern little penguin	3	0–7	3	1–9
Chatham Island little penguin	1	0–7	3	0–14
Western rockhopper penguin	2	1–5	3	1–8
Fiordland crested penguin	4	1–10	6	1–17
Snares crested penguin	6	2–13	8	2–19
Erect-crested penguin	1	0–2	2	0–5
Australasian gannet	56	5–181	62	7–222
Masked booby	0	0–0	0	0–0
Pied shag	9	3–20	10	3–24
Little black shag	6	4–9	8	5–14
NZ king shag	1	0–2	1	0–4
Stewart Island shag	12	3–28	13	3–29
Chatham Island shag	0	0–2	0	0–4
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	558	361–766	745	485–1 100
Pitt Island shag	0	0–3	1	0–6
Subantarctic skua	0	0–0	0	0–0
Southern black-backed gull	46	12–105	94	25–231
Caspian tern	0	0–0	0	0–1
White tern	0	0–0	0	0–0

The method described by Richard et al (2011) and Richard & Abraham (2013b) 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;
- 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 Richard & Abraham’s (2013b) revision, 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 2013 revision);
- 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 to uncertainty in potential fatalities would result (most such fisheries are poorly observed).

It should be noted that Richard & Abraham's (2013a) seabird risk assessment includes potential fatalities 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 (2013a) 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.

6.4.4.4. Fully quantitative modelling

Fully quantitative population modelling has been conducted only for southern Buller's albatross, black (Parkinson's) petrel, white capped albatross (mollymawk), and Gibson's (wandering) albatross. Data of similar quality and quantity are available for Antipodean (wandering) albatross, and this work should be commissioned soon, 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.

6.4.4.4.1. 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 6.19) 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 5 years of survival and other demographic data have since been recorded (Sagar et al 2010) and all monitored sites at the Snares Islands show substantial declines in the number of breeding pairs since 2006. The modelling has not yet been repeated.

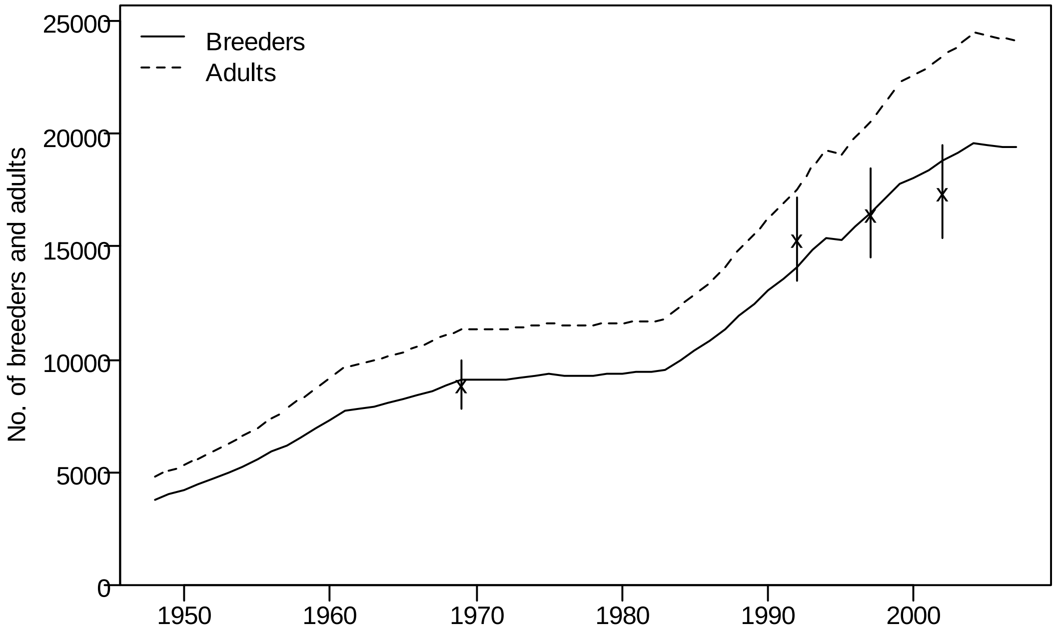


Figure 6.19: (from Francis et al 2008): Estimates from model SBA21 of numbers of breeders (solid line) and adults (broken line) in each year. Also shown are the census observations (after (Sagar & Stahl 2005) of numbers of breeders (crosses), with assumed 95% confidence intervals (vertical lines).

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.

6.4.4.4.2. Quantitative models for black petrel

Francis & Bell (2010) analysed data from the main population of black (Parkinson's) 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 6.20). 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.

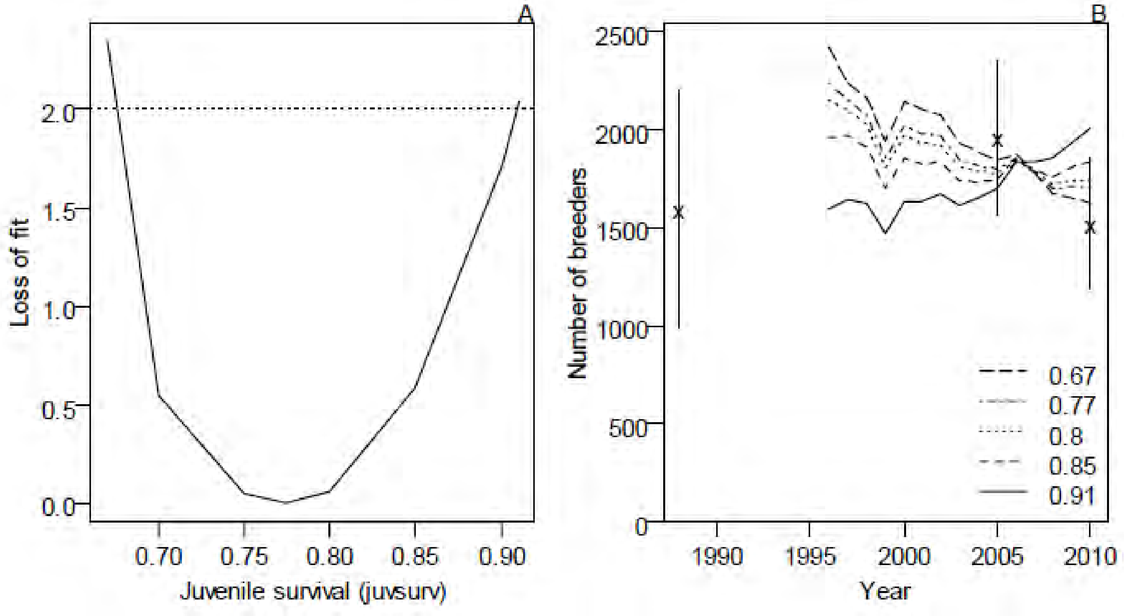


Figure 6.20: (from Bell et al 2012) Likelihood profile for annual probability of juvenile survival showing: A, the loss of fit (the horizontal dotted line shows a 95% confidence interval for this parameter); and B, population trajectories corresponding to different values of juvenile survival, together 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.

6.4.4.4.3. 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, counts of white-capped albatross have increased (Baker et al 2013, Figure 6.21) and the time series now suggests substantial between-year variation in breeding rather than a declining population.

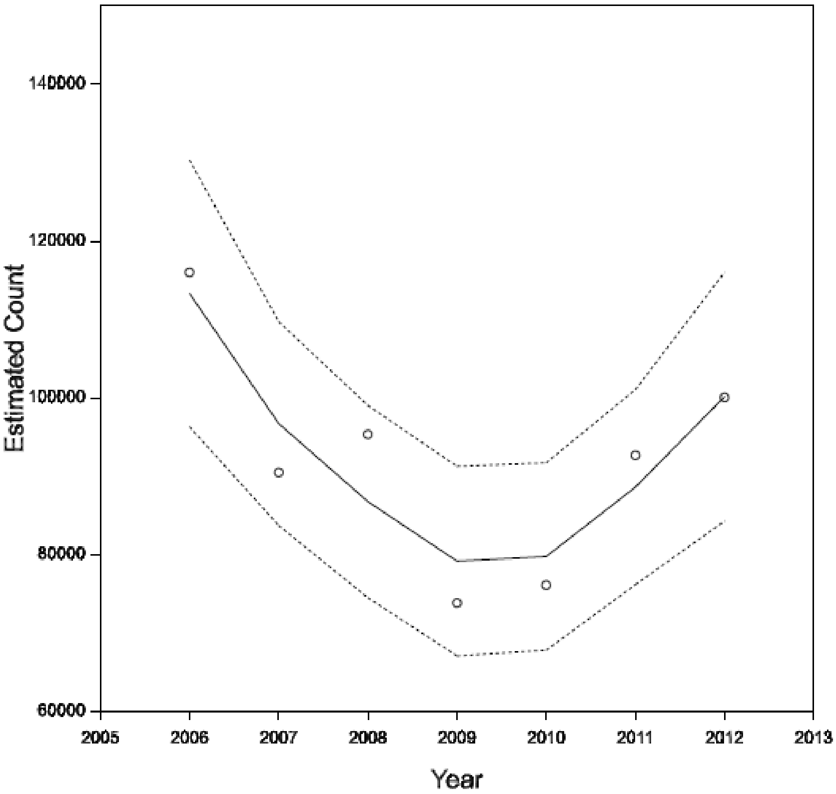


Figure 6.21 (reproduced from Baker et al 2013): Total counts of white-capped albatross at the Auckland Islands (as adjusted for the presence of non-breeding birds) and smoothed trend line with 85% confidence intervals.

6.4.4.4.4. 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 6.22). Forward projections showed that the most important of these to the future status of this population is adult survival (Figure 6.23).

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.

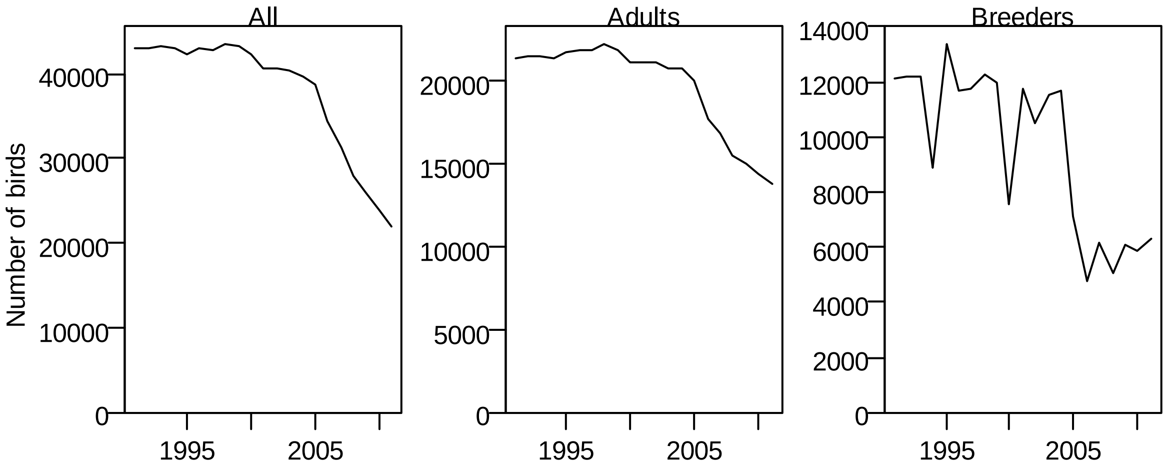


Figure 6.22: Estimated population trajectories for the whole Auckland Islands population of Gibson's wandering albatross. These were calculated by scaling up Francis et al's (2013) GIB5 trajectories to match the Walker & Elliott (1999) estimate for the whole population.

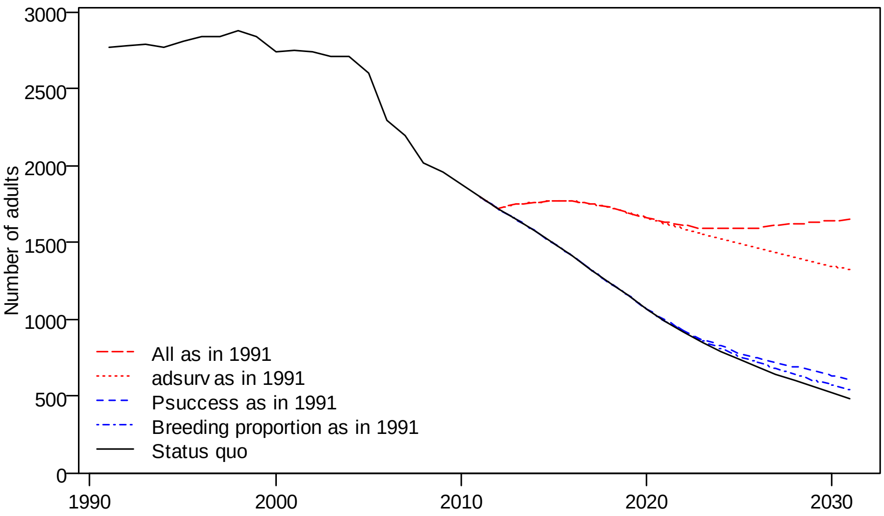


Figure 6.23: Estimated population trajectory for adults from Francis et al's (2013) model GIB5 with 20-year projections under five alternative scenarios about three demographic parameters: adult survival (adsurv); breeding success (Psuccess); and proportion of adults breeding. These scenarios differ 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.

6.4.4.4.5. 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 6.28). 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.

6.4.4.4.6. 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 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.

6.4.4.5. Seabird species identified as being at risk in the 2013 semi-quantitative risk assessment

6.4.4.5.1. Black petrel

The species found to be the most at risk was black petrel (Figures 6.17 and Table 6.25). This species was also identified as being the most at risk in the previous Level 2 seabird risk assessment (Richard et al 2011). Based on an estimated total number of annual potential fatalities of 1440 (95% c.i.: 1070 – 1900) and a PBR_1 of 74 (47–117), the median risk ratio for black petrel was estimated to be 19.9 (11.4–32.8). This estimate was considerably higher than the previous mean risk ratio of 3.34 (1.78–5.57) (Richard et al 2011, back-calculated to f = 1). The increase in the risk ratio was partly due to a decrease in PBR1, from a mean of 331 (216–512) to a mean of 74 (47–117). There were two reasons for this decrease, including a lower population estimate and the inclusion of a calibration factor in the updated calculation of the PBR for black petrel. The population estimate used by Richard & Abraham (2013b) was 1059 breeding pairs, based on a recent survey (Bell et al 2012), compared with the estimate of 1 750 breeding pairs used in the previous assessment (Richard et al 2011). Furthermore, it was found by Richard & Abraham (2013b) that the estimated PBR needed to be corrected by multiplying by a calibration factor of 0.33.

Another reason for the increase in the risk ratio for this species was an increase in the number of annual potential fatalities, from a mean of 1060 (95% c.i.: 725–1520) to a mean of 1440 (1080–1900). This increase was due to a higher observed capture rate in the two most recent fishing years, 2009–10 and 2010–11. Observed captures in 2009–10 included a single bottom-longline trip that caught 27 black petrel. As a sensitivity analysis, Richard & Abraham (2013b) estimated the number of annual potential fatalities without including the data from this trip. Although the exclusion of this trip reduced the risk ratio by almost 50%, the median risk ratio remained high at 10.39 (5.71–18.13).

Excluding cryptic mortalities, the estimated mean number of observable black petrel captures was 693 (95% c.i. 522–884), still exceeding PBR_1 (Table 6.28, Richard & Abraham 2013b). As an assessment of this value, simple ratio methods were used to estimate the observable captures of this species in bottom longline fisheries. Over the 5-year study period, observer coverage in snapper and bluenose bottom longline target fisheries was 1.7% and 0.9%, respectively, and there were a total of 23 and 19 observed black petrel captures. Based on these observer data, ratio estimated annual observable captures were 271 in snapper bottom longline fisheries, and 422 in bluenose bottom longline fisheries per year. Thus, the high estimated potential fatalities of black petrel are not an artefact of the statistical model.

The risk assessment by Richard & Abraham (2013b) included only commercial trawl, longline, and set-net fisheries in New Zealand waters. During the breeding season, black petrel forage in north-eastern New Zealand waters, where they may interact with recreational fisheries. Based on limited interview data, there were estimated to be potentially around 10 000 captures of seabirds by recreational fishers annually in this region (Abraham et al 2010a), and some of these captures may result in black petrel fatalities. Moreover, black petrel migrate to the eastern Pacific Ocean during the non-breeding season, where they likely interact with overseas and high seas fisheries (Richard & Abraham 2013b).

The population trend of this species is unclear. Data from random transect surveys of the Great Barrier Island colony, conducted in 2004–05 and 2009–10, suggested an apparent population decline of 22% over 5 years (Bell et al 2012). Census grid data, however, did not confirm this decline. Summarising all population data, Bell et al (2012) concluded that it is likely that the mean rate of change of the black petrel population has not exceeded 2% per year, that the direction of change is uncertain, may differ across years, but that the population is most likely to be in decline. Since the modelling was completed, Bell et al (2013) reported that 26 random transects were surveyed in 2012/13 and these showed an increase of 110% in the number of annual breeding pairs since 2009/10, and an increase of 65% since 2004/05, with much of the difference due to changes in breeding rate and success.

6.4.4.5.2. Salvin's albatross

The species at second-most risk was Salvin's albatross. Salvin's albatross are endemic to New Zealand, where they breed on Bounty Islands and the western chain of Snares Islands, with a total population of approximately 32 000 annual breeding pairs concentrated on Bounty Islands (ACAP 2010). This species was caught in a range of fisheries in New Zealand waters, mainly by small inshore trawlers, large processor trawlers (with or without meal plants), trawlers targeting scampi, and small bottom longliners (Richard & Abraham 2013b). There were 150 observed captures over the 5-year reporting period, and there were estimated to be 2690 (95% c.i. 2100 – 3420) annual potential fatalities. With a PBR_1 estimated to be 975 (521–1740), the median risk ratio with f = 1 was 2.88 (1.47–5.41). Although the number of annual potential fatalities was lower than in the previous assessment (Richard et al 2011), the estimated risk ratio was higher (see Table 6.27 and Figure 6.18) as a result of the inclusion of the calibration factor in the updated calculation of the PBR.

Of the 150 observed Salvin's albatross captures between 2006–07 and 2010–11, 147 occurred during the breeding season, with only three observed captures outside the breeding season (Richard & Abraham 2013b). In contrast, a comparatively large number of annual potential fatalities was estimated for the non-breeding period, with a mean of 627 (95% c.i.: 453 – 855) compared with a mean of 2060 (1510–2750) during the breeding season. The reason for this difference was the low observed overlap with small-vessel inshore trawling (0.5%) outside the breeding season, compared with observed overlap of 2.5% during the breeding season. Nevertheless, the estimated number of potential annual fatalities during the breeding season alone exceeded PBR_1 for this species.

Amey & Sagar (2013) analysed ground counts at the Bounty Islands from 1997, 2004 and 2011, and found 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 by 30% between 1997 and 2011. Counts of nests on Depot Island decreased by 10% between 2004 and 2011.The overall population trend of Salvin's albatross is unclear because different methodologies have been used to survey populations over time. Recent surveys of the smaller Snares Islands population showed an apparent decline of about 8% between 2008 and 2010 (Sagar et al 2011). On the Bounty Islands, population estimates for Salvin's albatross have not been comparable, the most recent complete census by Baker et al (2010b) estimated the total count of nesting Salvin's albatrosses in October 2010 to be 41 101 (95%c.i.: 40 696–41 506), although this count is probably somewhat biased high because loafing birds would have been included and ground truthing was not possible. A further survey was undertaken in October 2013 including ground truthing, and is currently being analysed.

6.4.4.5.3. Flesh-footed shearwater

The species with the third highest risk ratio was flesh-footed shearwater. There were 124 observed captures in the fishing years between 2006–07 and 2010–11, with most fatalities occurring in bottom-longline fisheries targeting snapper, and trawl fisheries targeting scampi. All captures were during the breeding season, as this species migrates out of New Zealand waters to the North Pacific during winter (Richard & Abraham 2013b). The total number of annual fatalities was estimated to be 780 (95% c.i. 523 – 1090), which was lower than the 1380 (1080–1770) annual potential fatalities estimated by Richard et al (2011) (Table 6.27). The annual potential fatalities exceeded the PBR_1 of 590 (288–1200) and the median risk ratio was 1.41 (0.59–2.94) (Table 6.25), an increase from the 1.25 (0.54–0.54) estimated by Richard et al (2011). This was caused by the inclusion of the calibration factor (ρ = 0:41) in the updated PBR calculation (Richard & Abraham 2013b).

Flesh-footed shearwater forage in the north-eastern New Zealand region and fatalities occur in recreational fisheries (Abraham et al 2010a). Recent anecdotal evidence also implicated recreational fisheries in the capture of this species, with carcasses washed ashore in apparently good condition, but with recreational fishing hooks inside or suffering from trauma. The extent of the recreational fisheries bycatch remains unknown (Richard & Abraham 2013b).

About 10 000–12 000 pairs of flesh-footed shearwater breed annually on nine New Zealand islands (Baker et al 2010a, Waugh & Taylor 2012), considerably fewer than Taylor (2000) suggested (25 000–50 000 breeding pairs). A large flesh-footed shearwater population also breeds on Lord Howe Island, eastern Australia (Priddel et al 2006). It is possible that some of the birds caught in New Zealand originate from Lord Howe Island, which would lead to an overestimation of the risk (and, conversely, captures of New Zealand breeding birds outside New Zealand waters would lead to underestimation of total risk).

6.4.4.5.4. Southern Buller’s albatross

Southern Buller’s albatross are endemic to New Zealand and breed only on Snares and Solander Islands, with a population of almost 14 000 annual breeding pairs. This species has shown a long-term population increase, although population modelling suggests a declining survival rate (Francis & Sagar 2012). The median risk ratio with f = 1 was estimated as 1.32 (95% c.i. 0.75 – 2.58) from a total estimated number of annual fatalities of 663 (520–839) and a PBR_1 of 513 (270–831). Fatalities were estimated to occur mainly in large-vessel processor trawl fisheries (with and without meal plants) and in trawl fisheries targeting squid (Richard & Abraham 2013b).

6.4.4.5.5. Chatham Island albatross

Chatham Island albatross are endemic to New Zealand, and breed only on The Pyramid, Chatham Islands, with a population that appears stable with recent estimates varying between 5194 and 5407 breeding pairs. For Chatham Island albatross, the median risk ratio with f = 1 was estimated to be 1.3 (95% c.i. 0.68 – 2.59), from a total number of annual fatalities estimated to be 205 (136–316) and a PBR_1 of 159 (94–264). Fatalities were estimated to occur mainly in small bottom-longline fisheries. Although the risk ratio is high, there is no evidence of a population decline for this species. The risk ratio increased from a previous estimate of 0.81 (0.34–2.28) partly because of the introduction of the calibration factor (ρ = 0:43) and partly because Richard & Abraham (2013b) assumed a higher adult survival rate (96.7% compared with 86.8% in Richard et al 2011). The survival rate used by Richard et al (2011) was unusually low for an albatross species, and Richard & Abraham (2013a) used the survival rate for the closely related Salvin’s albatross to better approximate natural survival (without human-caused mortality). As a consequence of these two changes, PBR decreased from 1240 (918–1720) to 159 (94–264). However, the risk ratio increased by a smaller amount because estimated annual potential fatalities decreased from 980 (463–2680) to 205 (136–316). The high potential fatalities estimate of Richard et al (2011) was probably a result of a lack of constraint in the estimation of vulnerabilities and low observer coverage around the Chatham Islands.

6.4.4.5.6. New Zealand white-capped albatross

New Zealand white-capped albatross are endemic to New Zealand, and breed mainly in Antipodes Island and the Auckland Islands (77 000 annual breeding pairs in 2010, noting that there have been substantially higher counts since, Baker et al 2013). Their median risk ratio with f = 1 was estimated to be 0.78 (95% c.i. 0.28–3.13), from a total number of annual fatalities estimated to be 2830 (2080–3790) and a PBR_1 of 4040 (908–9840). Fatalities occurred mainly in small-vessel inshore trawl fisheries and in trawl fisheries targeting squid. The risk ratio increased from the previous assessment, from a mean of 0.33 (0.2–0.53), mainly because of a lower PBR caused by the calibration factor, ρ = 0:43, and an updated estimate of annual survival (Francis 2012). The uncertainty in this estimate of annual survival was large (90.7–99.5%), leading to large uncertainty in the risk ratio. White-capped albatross are frequently caught in New Zealand commercial fisheries (Abraham et al 2013) but are also caught in fisheries in South Africa and in the southern Indian Ocean, with an estimate of around 8000 individuals killed in the Southern Ocean each year (Baker et al 2007b). This estimate included cryptic mortality in only some of the fisheries assessed, but did not include assessment of recent management responses in South Africa and may be biased. Fatalities outside of the New Zealand region are not considered in this risk assessment. Since the introduction of mandatory warp mitigation in 2006, there has been a decrease in the number of white-capped albatross killed in the New Zealand squid fishery (Abraham et al 2013). The highest number of potential fatalities occurs in small-vessel trawl fisheries, however, and warp mitigation is not mandatory in these fisheries.

6.4.4.6. 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.

6.4.4.6.1. 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), noting that the results of that exploration are constrained by the structure of that analysis. Richard & Abraham (2013b) provided plots of such an exploration for 12 taxa (Figure 6.24). 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 and Chatham Island, antipodean, and southern royal albatrosses if better estimates of potential fatalities were available, and better estimates of population size would be useful for Salvin’s, antipodean, and the two royal albatrosses, and for Cape petrel. 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 both are 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.

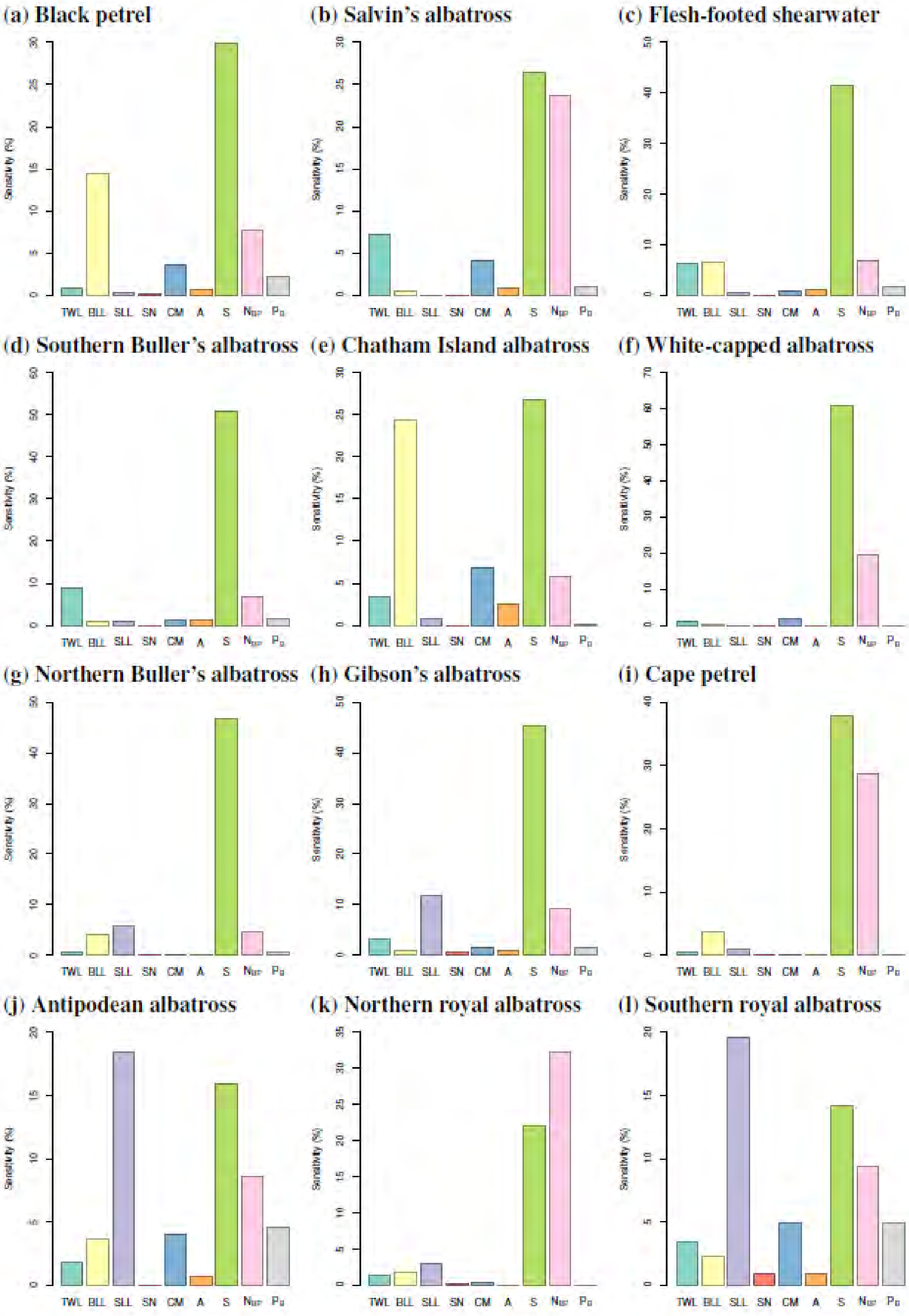


Figure 6.24: (from Richard & Abraham 2013b): Sensitivity of the uncertainty in the risk ratio for the 12 seabird species with the highest risk ratio. For each seabird type, the sensitivity to the uncertainty in the following parameters is considered: annual potential fatalities in trawl, bottom-longline, 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 (NBP); 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.

6.4.4.6.2. 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).

6.4.4.6.3. 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 6.25).

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.

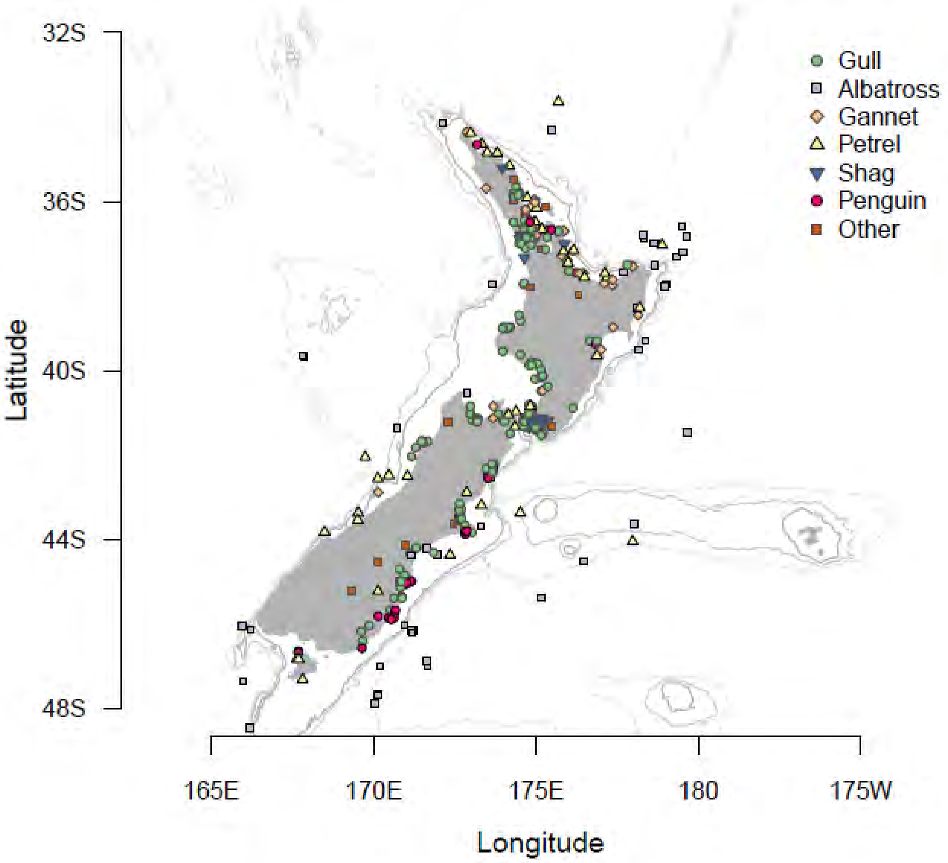


Figure 6.25 (from Abraham et al 2010a): Distribution of the reported capture locations for banded seabirds reported as being captured in fishing gear, 1952–2007. Note, band recovery locations are reported with low spatial precision and some of the inland locations may be correct.

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.

6.4.4.6.4. 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 6.29), 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. 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 6.29: (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

6.4.4.6.5. Other sources of anthropogenic mortality.

Taylor (2000) listed a wide range of threats to New Zealand seabirds including introduced mammals, avian predators (weka), disease, 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. 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.

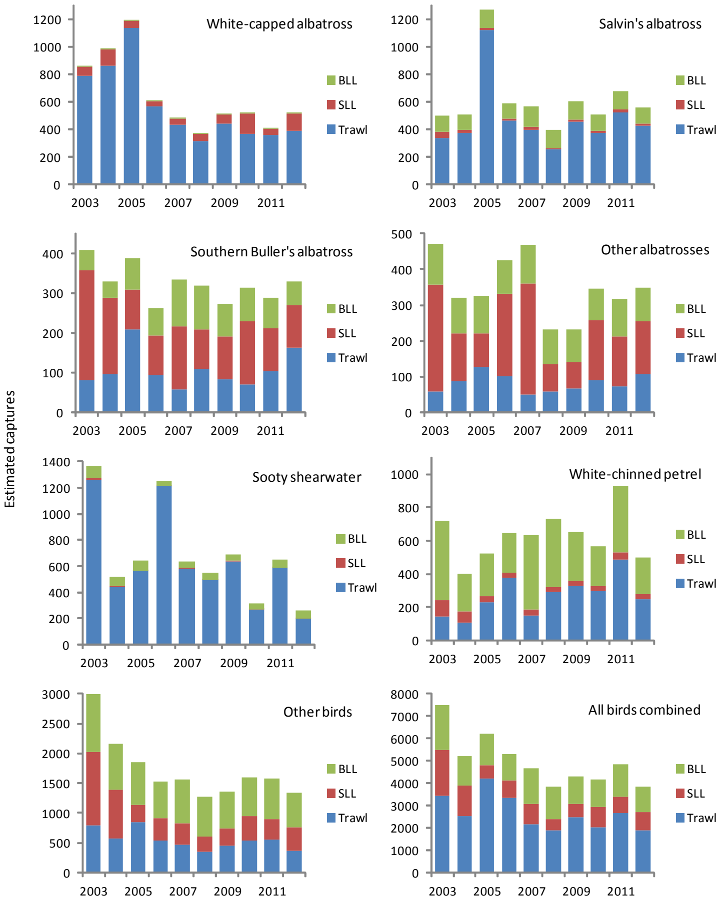
6.4.4.6.6. Future development of the risk assessment framework

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.

A workshop was held 19/20 November 2013 to review the level-2 risk assessment results for the 26 seabird taxa in all risk categories other than very low (i.e., those species for which the upper limit of the 95% confidence range for the risk ratio was less than 0.1.PBR_1). Consistent with the intent of the hierarchical framework for ecological risk assessment, many more probable positive biases than negative biases for risk ratios were identified. The results of the workshop will be published in early 2014 but were not available at the time of going to press. The workshop also recommended several changes to the input data for the level-2 risk assessment when it is next updated. This is likely to occur in mid-2014.

6.5. *Indicators and trends*

<table>
<tr><td><i>Population size</i></td><td>Multiple species and populations: see Taylor (2000)</td></tr>
<tr><td><i>Population trend</i></td><td>Multiple species and populations: see Taylor (2000)</td></tr>
<tr><td><i>Threat status</i></td><td>Multiple species and populations: see Robertson et al (2013)</td></tr>
<tr><td><i>Number of interactions</i></td><td>In the 2011–12 October fishing year, there were an estimated 3856 seabird captures (excluding cryptic mortalities) across all trawl and longline fisheries (Data version v20130304). About 49% of the estimated captures across these fisheries (other fisheries such as set net are excluded) were in trawl fisheries, 21% in surface longline fisheries, and 30% in bottom longline fisheries:
<table>
<tr><th>Bird group</th><th>Trawl</th><th>Surface longline</th><th>Bottom longline</th><th>All these methods</th></tr>
<tr><td>White-capped albatross</td><td>391</td><td>124</td><td>5</td><td>520</td></tr>
<tr><td>Salvin’s albatross</td><td>427</td><td>15</td><td>116</td><td>558</td></tr>
<tr><td>Southern Buller’s albatross</td><td>162</td><td>109</td><td>58</td><td>329</td></tr>
<tr><td>Other albatrosses</td><td>108</td><td>147</td><td>93</td><td>348</td></tr>
<tr><td>White-chinned petrel</td><td>246</td><td>30</td><td>222</td><td>498</td></tr>
<tr><td>Sooty shearwater</td><td>197</td><td>1</td><td>64</td><td>262</td></tr>
<tr><td>Other birds</td><td>373</td><td>381</td><td>589</td><td>1343</td></tr>
<tr><td>All birds combined</td><td>1 904</td><td>808</td><td>1 144</td><td>3 856</td></tr>
</table></td></tr>
<tr><td><i>Trend in interactions</i></td><td>Captures of all birds combined show a decreasing trend between 2002–03 and 2011/12 (Data version v20130304) but there are substantial differences in trends between species and fisheries. Captures of white-capped albatross have decreased, especially in offshore trawl fisheries, whereas captures of white-chinned petrel have increased:

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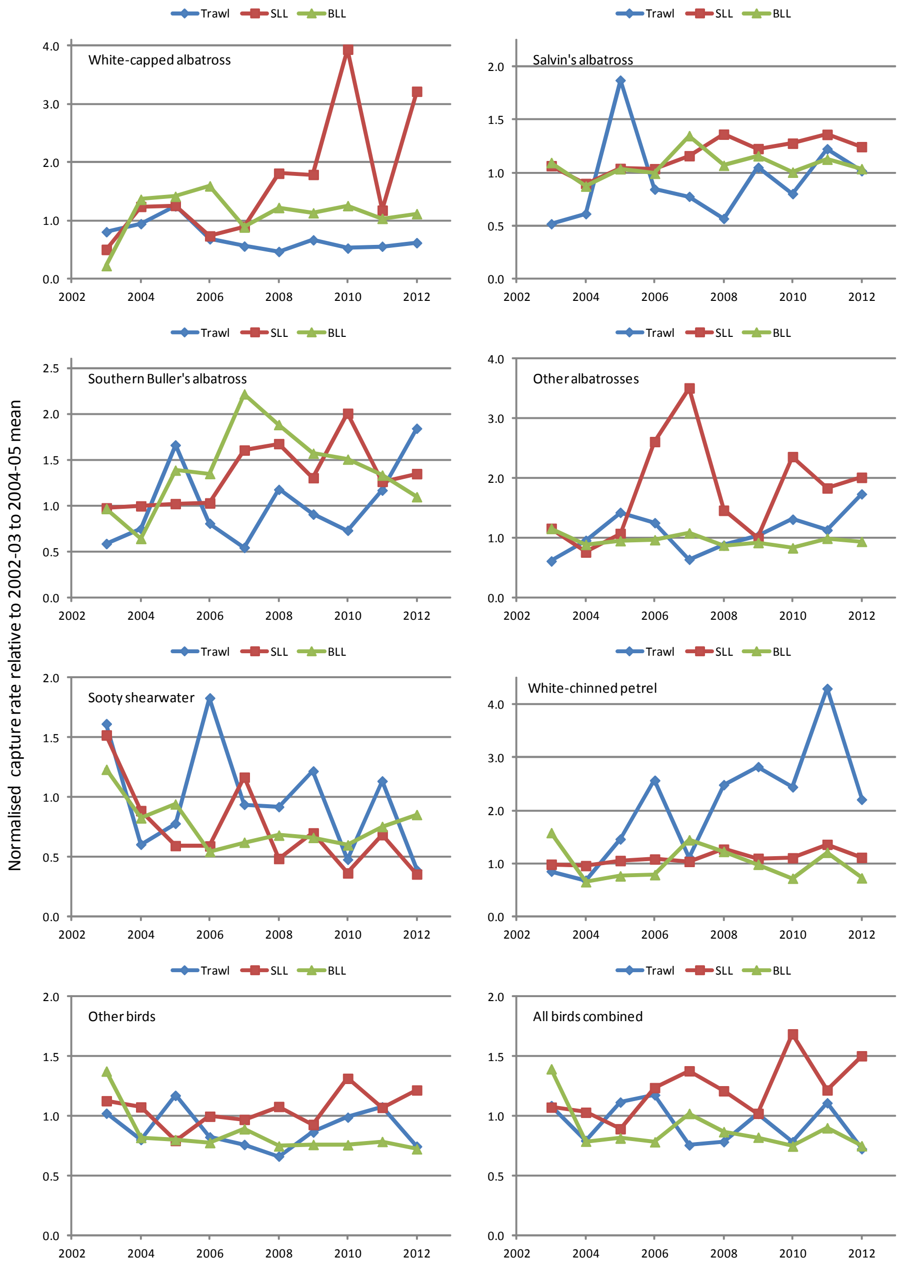
</table>

Trend in interactions contd.	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 trawl fisheries for squid and scampi 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. 

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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. Note this may also include some protected species. Research in this field is 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. The fisheries summarised are as follows: **Trawl fisheries:** Arrow squid; Hoki/hake/ling; Jack mackerel; Southern blue whiting; Orange roughy; Oreo; Scampi **Longline fisheries:** Ling (bottom); Tuna (surface) **Other fisheries** Albacore tuna troll; Skipjack tuna purse seine
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. • Potential for considerable reduction of discards by discretionary fishing practices such as the use of mid-water nets, where practicable, and meal plants. • 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 increasing 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 lengths 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) HMS201201 (bycatch in tuna longline fisheries)
Other Govt 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 2013.

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 is 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 is 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) is addressed in the HMS fish plan. Tuna fisheries incidental bycatch has been 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 are also available.

Inshore fisheries

The three National Fisheries Plans for Inshore species (finfish, shellfish and freshwater fisheries) also include objectives which address non-protected species bycatch, but research on these objectives has yet to be conducted. However, summaries of the main bycatch species are occasionally included in reports from fisheries characterisation projects, for example school shark, red gurnard, and elephantfish (Starr et al2010a, b, c, Starr & Kendrick 2012).

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 innumerable 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 typically much lower but, because they are so widespread, their contribution to global discards is considerable. 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 has reduced considerably since the Alverson et al1994 estimate, but differences in the methodology and definition of bycatch used (Kelleher 2005, Davies et al2009) make it difficult to quantify the decline. The main reasons for the decline in bycatch are thought to have been 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 al2011). 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 al2011). 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 al2011, Borges et al2005).

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 al2011), and as third party fishery certification schemes examine more closely the effects of fishing on the ecosystem. These data can also be used to assess impacts on non-target species (e.g., Pope et al2000, Casini et al2003).

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 6.1).

Table 7.1: Summary of research into bycatch and discards in New Zealand fisheries.

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)
Hake trawl	Ballara et al(2010) Anderson (2013b)
Ling trawl	Ballara et al(2010) Anderson (2013b)
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)
Scampi trawl	Clark et al(2000) Anderson (2004a) Anderson (2011) Anderson (2013b)

Longline fisheries	Report
Ling (bottom)	Anderson et al(2000) Anderson (2008) Anderson (2013b)
Tuna (surface)	Francis et al(1999a, 1999b)

	Ayers et al(2004) Francis et al(2004) Griggs et al(2007) Griggs et al(2008) Griggs & Baird (2013)

Other fisheries	Report
Albacore tuna troll	Griggs et al(in press)
Skipjack tuna purse seine	Griggs (unpublished data)

Trawl and bottom longline fisheries

The estimation process for the trawl and bottom longline fisheries uses rates of bycatch and discards in various categories (in most cases “all QMS species combined”, “all non-QMS species combined”, “all invertebrate species combined”) and 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 codes, (e.g., the increase in bycatch of floppy tubular sponges in the hoki/hake/ling trawl fishery reflects the improved identification of these sponges in more recent years), and improvements in species identification over time, (e.g., generic codes being replaced by species specific codes such as giant spider crab (GSC) for 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 bycatch of smooth red swimming crabs (*Nectocarcinus bennetti*) appears to be at the expense of bycatch of the similar-looking paddle crabs (*Ovalipes catharus*) with the seemingly generic species code (PAD).

The approach used in these analyses relies heavily on an appropriate level and spread of observer effort being achieved, and this is examined in detail in each report. Although details of bycatch and discards are also recorded directly by vessel skippers for all fishing events through catch effort forms, these data are generally inadequate for precise measurement of annual totals as the forms list only the top five catch species, discards are not well recorded, and they generally lack the accuracy and precision of observer data. Despite these inadequacies annual bycatch totals are usually derived from catch effort data, but only as secondary estimates.

Surface longline fisheries

The estimation process used for surface longline fisheries is similar to that used for trawl and bottom longline fisheries, with each species assessed separately. In this case CPUE is 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 is expressed using a ratio of means estimator (see Bradford 2002, Ayers et al2004). The total number of each species caught in each stratum is estimated by scaling up the CPUE to the total number of hooks set. These numbers are then summed across strata to give total annual catch estimates. An analytical estimator is 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 are 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 has been low (e.g., fewer than 2% of tows observed in 2009–10, Ramm 2012) and coverage is mainly focused on monitoring the Hector's and Maui's dolphin Threat Management Plan. There are also practical and logistical issues of 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 SNA1 MPI has committed to 100% observer or camera coverage for all trawl vessels by October 1, 2015[42], therefore information should improve quickest in this fishery.

In addition 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 has ranged from 6% to 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*). 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 addresses 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 is assumed to be randomly selected from a population of trips) and treating 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

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[42] http://www.fish.govt.nz/en-nz/Consultations/SNA1+management+decision.htm

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 have been 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%); 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 dogfish (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.

More than 75% of the sharks and dogfish, 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.

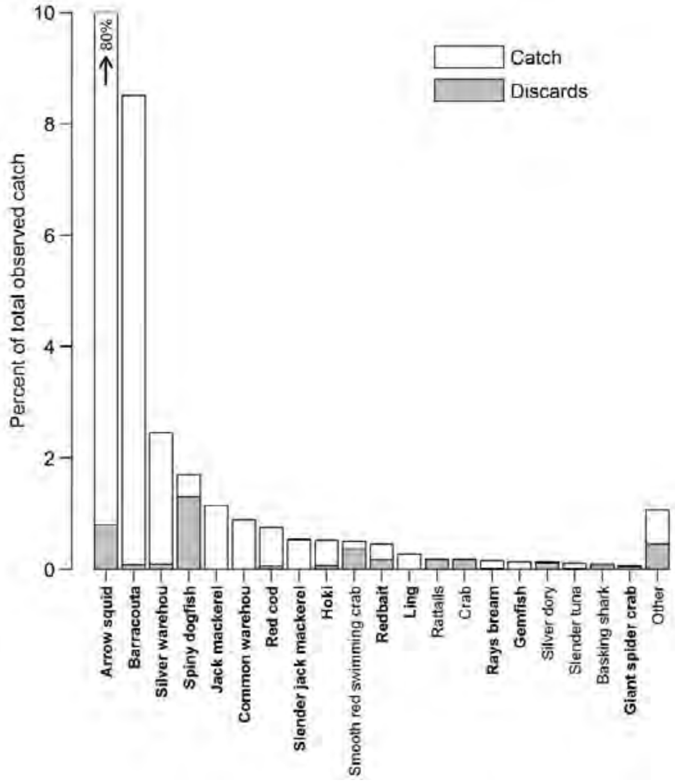

Figure 7.1: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the arrow squid fishery, and the percentage discarded. The "Other" category is the sum of all bycatch species representing less than 0.05% of the total catch. QMS species are shown in bold.

Total annual bycatch in the arrow squid fishery ranged from about 4500 t to 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.

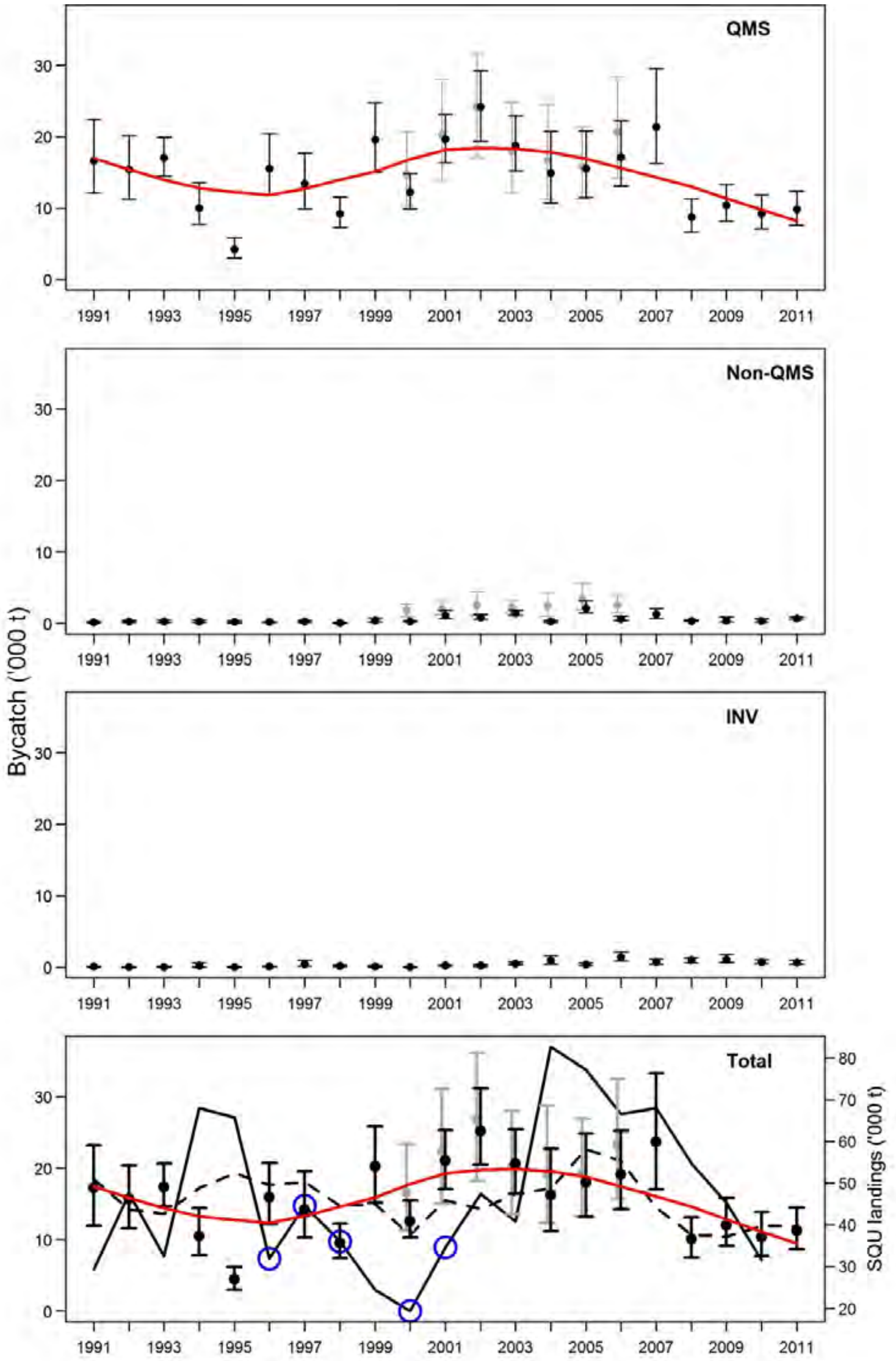

Figure 7.2: Annual estimates of bycatch in the arrow squid trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2010–11. Also shown (in grey) are estimates of bycatch in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). 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).

Trends in 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).

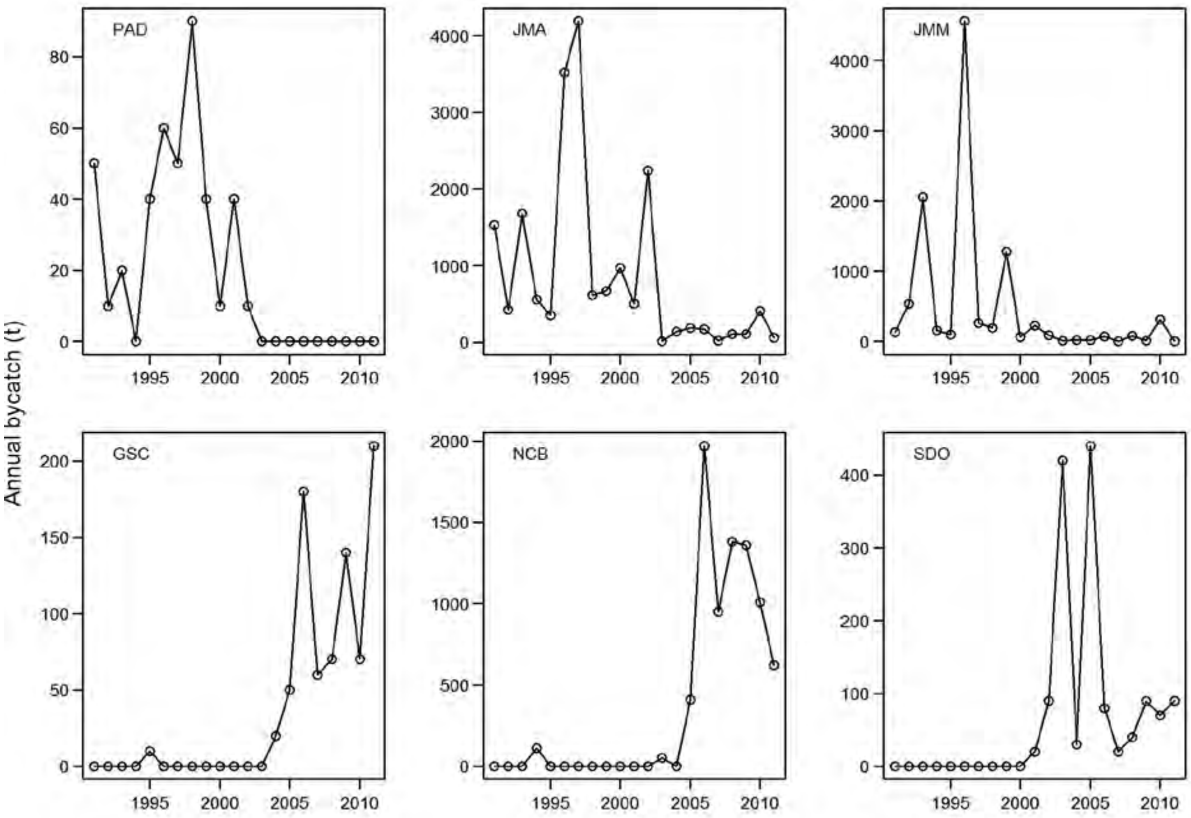

Figure 7.3: Annual bycatch estimates in the arrow squid trawl fishery for the species which had the greatest catch decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes (from Anderson 2013b).

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%).

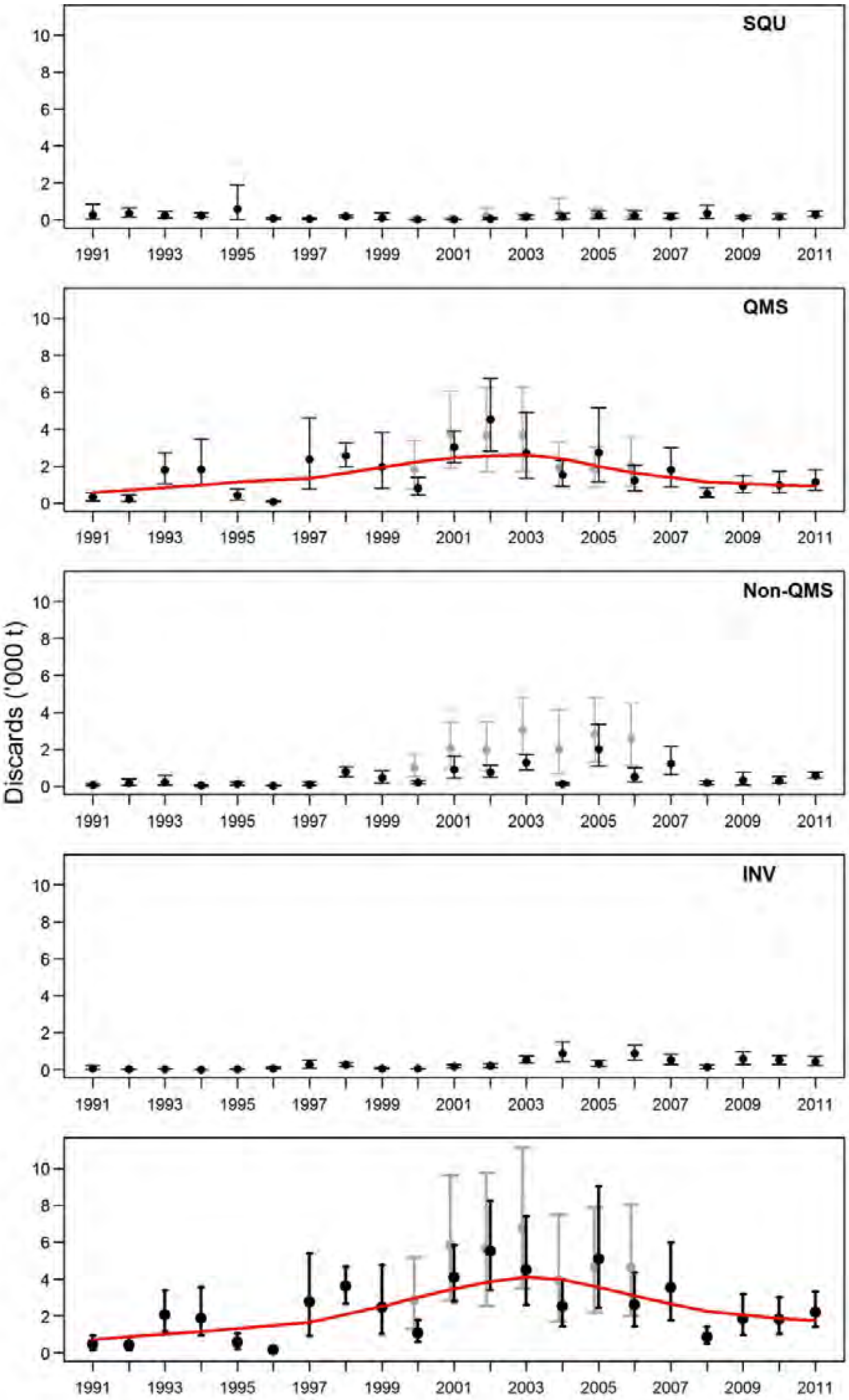

Figure 7.4: Annual estimates of discards in the arrow squid trawl fishery, for arrow squid (SQU), QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2010–11. Also shown (in grey) are estimates of discards in each category (excluding INV) calculated for 1999–2000 to 2005–06 (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 considers bycatch and discards for the fishery as defined by the three target species combined—but hoki is dominant in this fishery, accounting for over 90% of the catch.

Observer coverage in the hoki, hake, and ling trawl fishery between 2000–01 and 2006–07 ranged from 11% to 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 has been 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 have been achieved in the Cook Strait and Puysegur fisheries, and coverage was lower still around the North Island although this area accounts 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 have been 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, have 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.

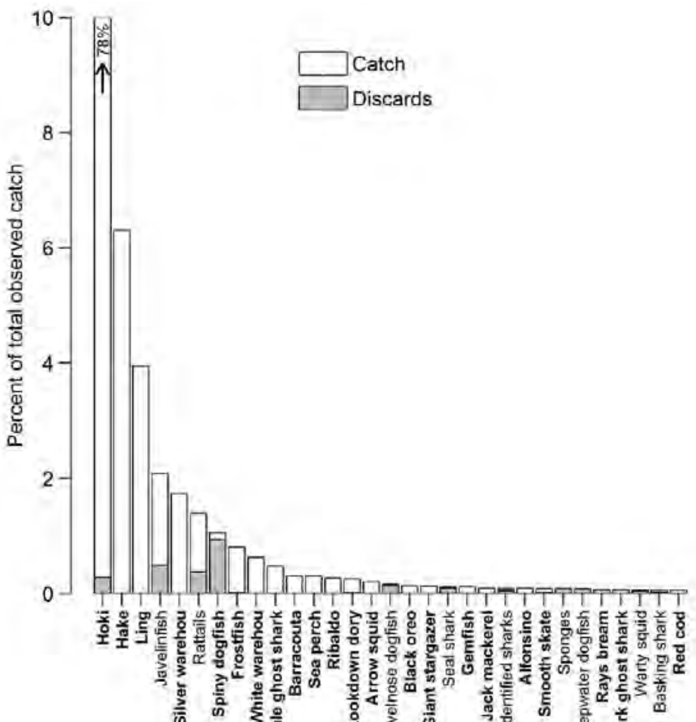

Figure 7.5: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the hoki/hake/ling fishery, and the percentage discarded. QMS species are shown in bold.

Total bycatch in the hoki, hake, and ling fishery between 2000–01 and 2006–07 ranged from about 36 000 to 58 000 t per year (compared to the combined total landed catch of hoki, hake, and ling of 130 000 to 238 000 t). Estimates of total bycatch for 1990–91 to 1998–99 from earlier projects (for the hoki target fishery alone), ranged from about 15 000 t to 60 000 t (Figure 7.6). Overall, total bycatch increased during the 1990s to a peak in the early 2000s, and has since 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.

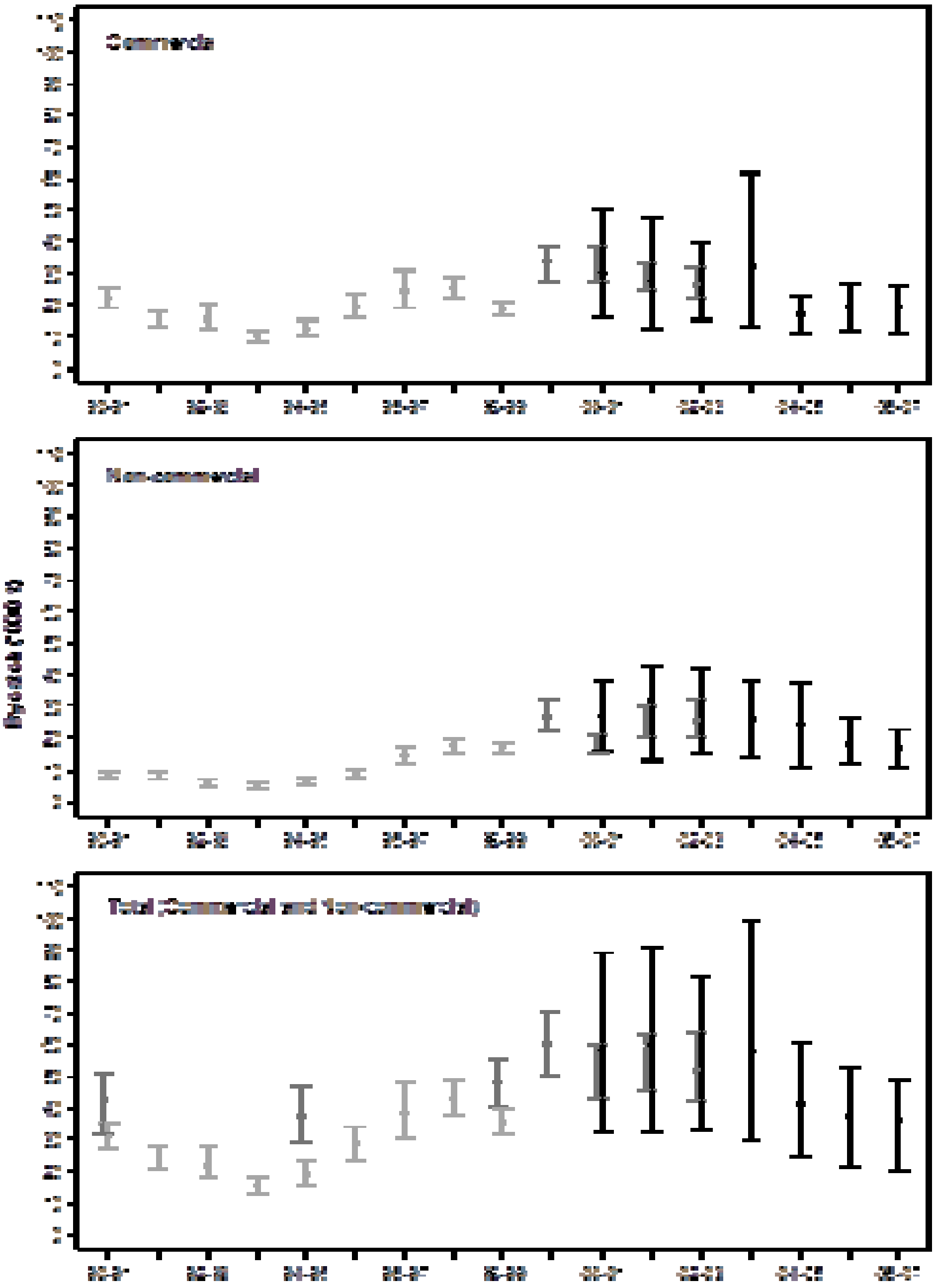

Figure 7.6: Annual estimates of fish bycatch in the target hoki, hake and ling trawl fishery, calculated for commercial species, non-commercial species, and overall for 2000–01 to 2006–07 (black). Also shown (in light grey) are the equivalent bycatch estimates calculated for 1990–91 to 1998–99 by Anderson 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.

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 have shown a decrease in catch over time and 102 an increase in catch.
- The species that showed the greatest decline were skates (SKA), 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) (Figure 7.7)

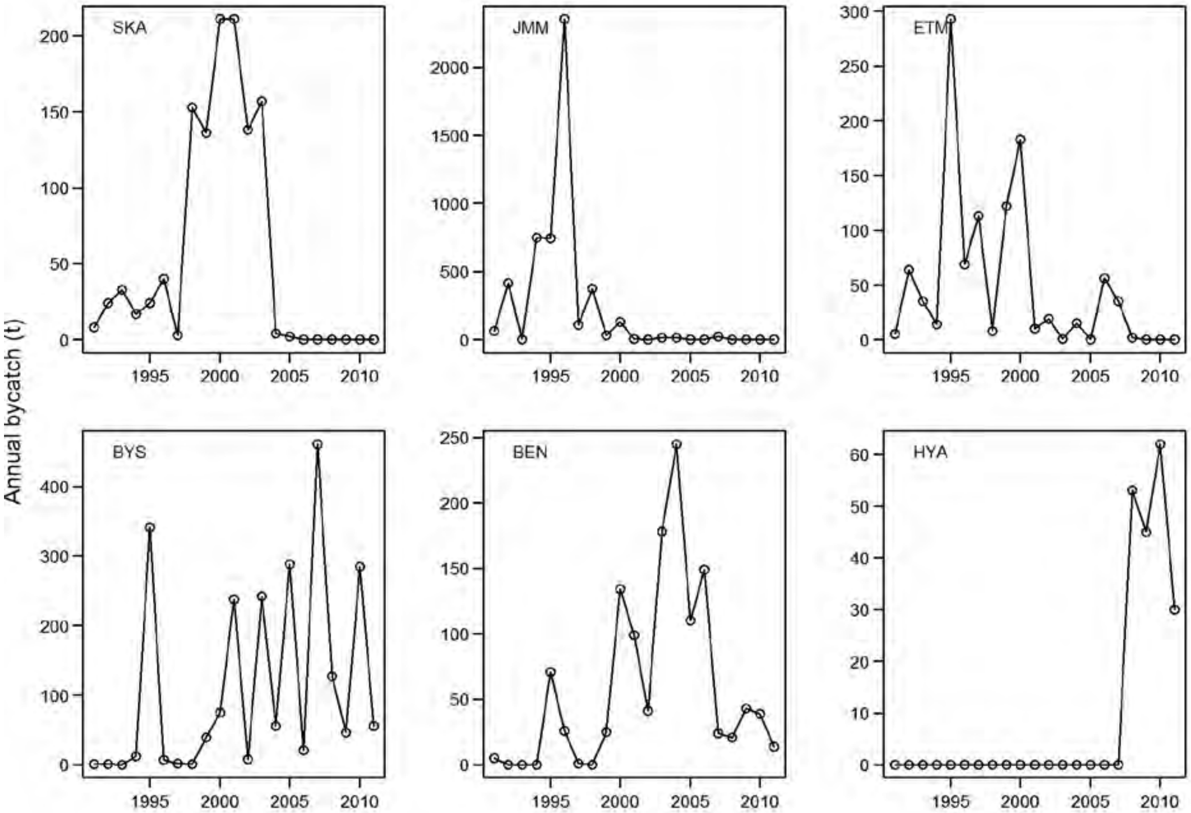

Figure 7.7: Annual bycatch estimates in the hoki, hake, and ling trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discard estimates for 2000–01 to 2006–07 ranged from about 5500 to 29 000 t per year with the main species being discarded including spiny dogfish, rattails, javelinfish, hoki, and shovelnose dogfish. Total annual discards for 1990–91 to 1998–99 were between 6600 t and 17 900 t, and overall there has been 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 was 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, has become more prevalent in recent years.

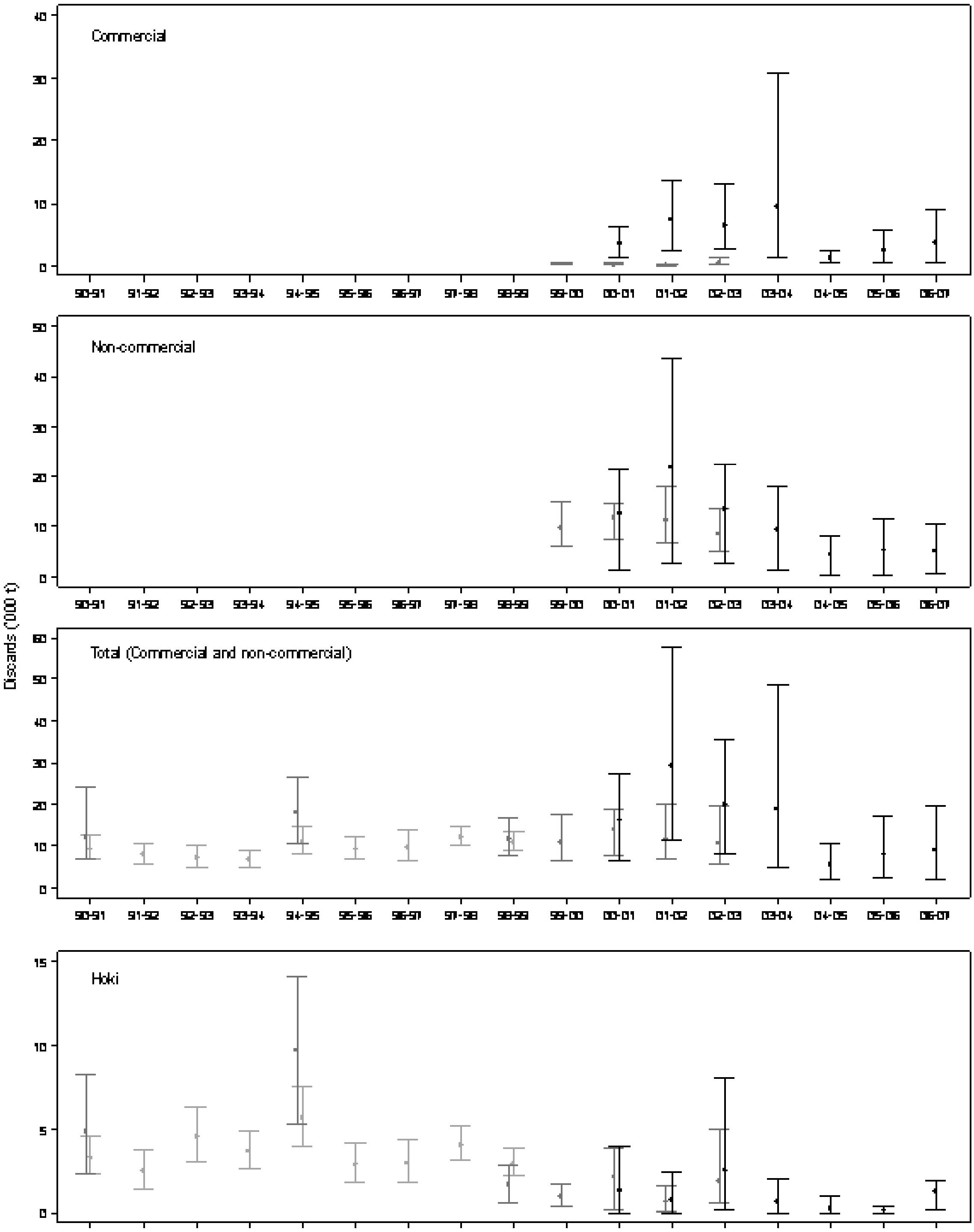

Figure 7.8: Annual estimates of fish discards in the target hoki, hake, and ling trawl fishery, calculated for commercial species, non-commercial species, hoki, and overall for the period 2000–01 to 2006–07 (black). Also shown (in light grey) are the equivalent discard estimates calculated for the period 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, with this fishery due for reassessment in 2014-15. The annual level of observer coverage in this fishery has varied between 8% and 27% of the target fishery catch but was usually between 15% and 20%. For the most recent period examined in detail, 2001–02 to 2004–05, the majority of the observer effort has 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 significant periods in each year when commercial fishing effort was not observed, coverage encompassed all seasons for the four years combined. More recently observer coverage has been 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 have taken over 90% of the catch in this fishery since 2002–03 (Ministry for Primary Industries 2013b).

Jack mackerel species accounted for 70% of the total estimated catch from all trawls targeting jack mackerel between 2001–02 and 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 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.

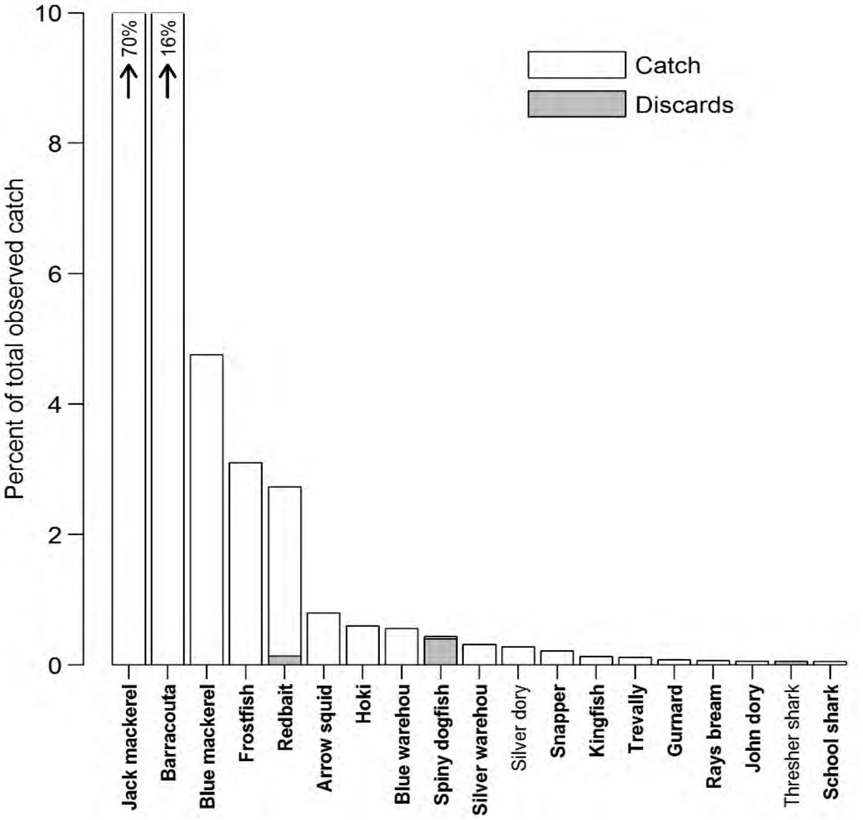

Figure 7.9: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the jack mackerel fishery, and the percentage discarded. QMS species are shown in bold.

Total bycatch in the jack mackerel trawl fishery between 2001–02 and 2004–05 ranged from about 7700 t to 11 900 t. Estimates of total bycatch for 1990–91 to 2003–04 from earlier projects ranged from about 5400 t to 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 comprised commercial (mainly QMS) species.

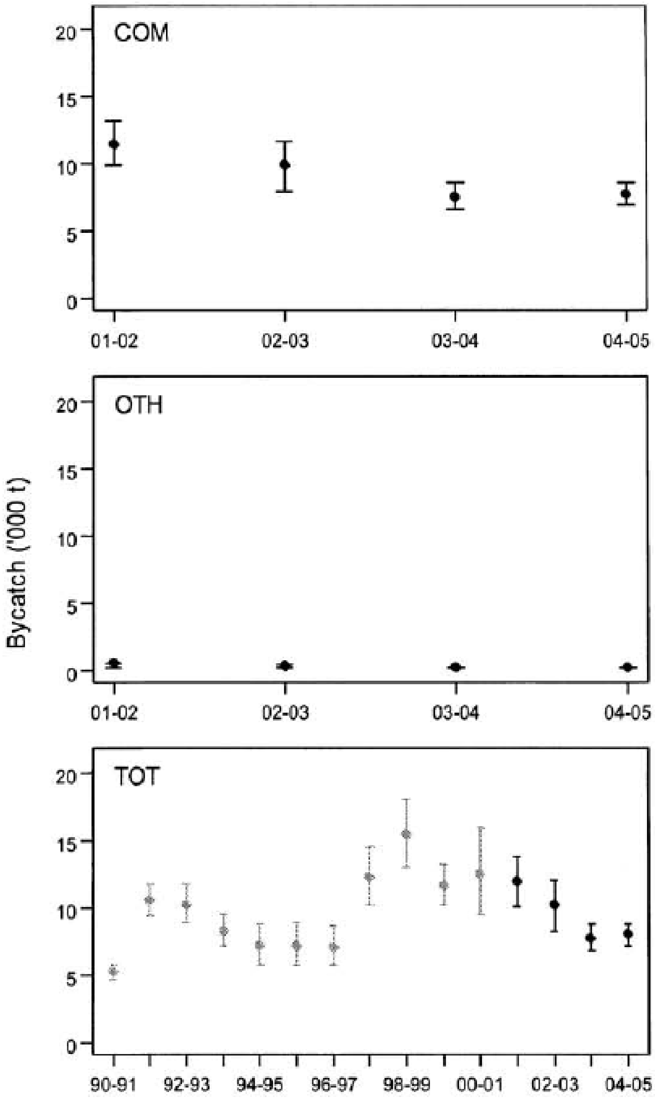

Figure 7.10: Annual estimates of fish bycatch in the target jack mackerel trawl fishery for the 2001–02 to 2004–05 fishing years (in black), calculated for commercial species (COM), non-commercial species (OTH), and overall (TOT). Also shown (in grey) are estimates of overall bycatch calculated for 1990–91 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 have shown a decrease in catch over time and 18 an increase in catch.
- The species that showed the greatest decline were dark ghost shark (GSH), 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).

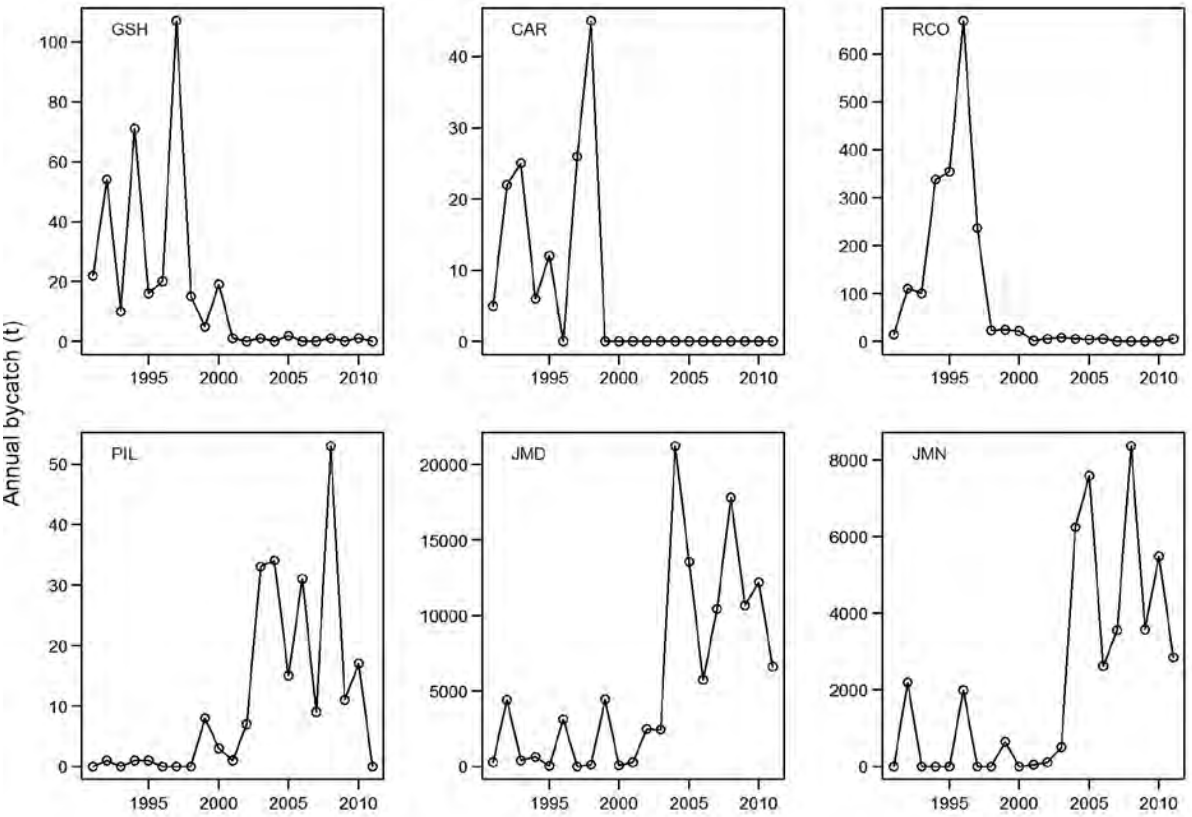

Figure 7.11: Annual bycatch estimates in the jack mackerel trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may 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 comprised a roughly equal amount of commercial and non-commercial species in the recent study, although commercial species discards were substantially greater in 2001–02.

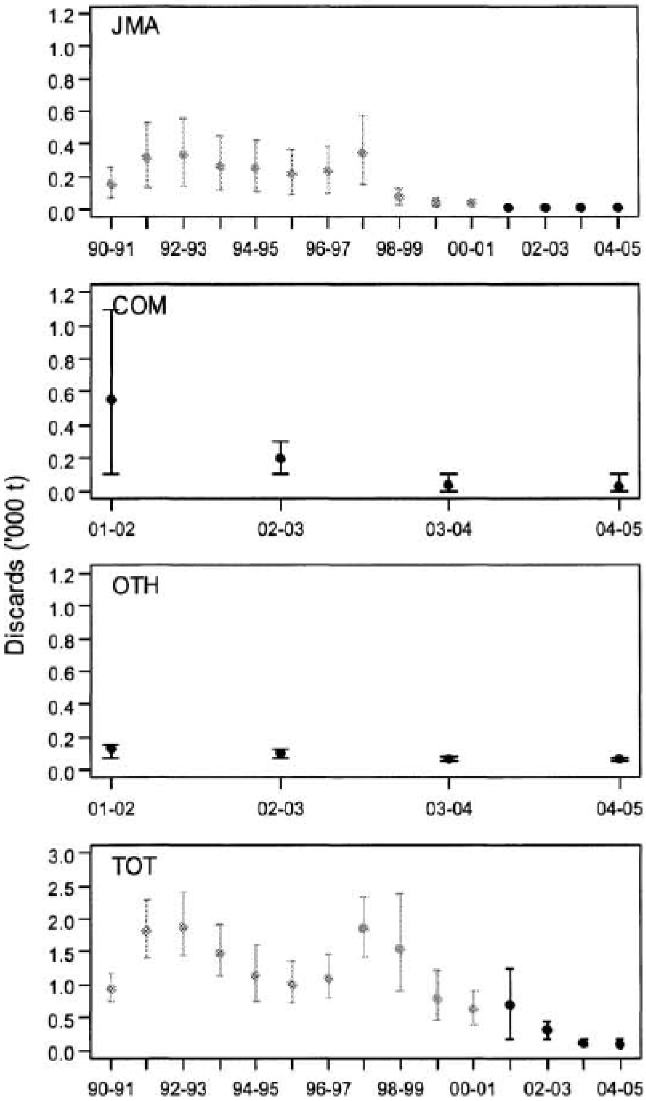

Figure 7.12: Annual estimates of fish discards in the target jack mackerel trawl fishery for the 2001–02 to 2004–05 fishing years (in black), calculated for jack mackerel (JMA), commercial species (COM), non-commercial species (OTH), and overall (TOT). Also shown (in grey) are estimates of jack mackerel 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 the most recent study, covering the period 2002–03 to 2006–07, the ratio estimator used to calculate bycatch and discard rates in this fishery was based on trawl duration. 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 between about 22% and 53% of the target fishery catch between 2002–03 and 2006–07 and similar levels were reported from earlier reports, for 1990–91 to 2001–02. The spread of observer data, across a range of variables, has shown no significant 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 accounted for more than 99% of the total estimated catch from all observed trawls targeting southern blue whiting between 2002–03 and 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 being 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.

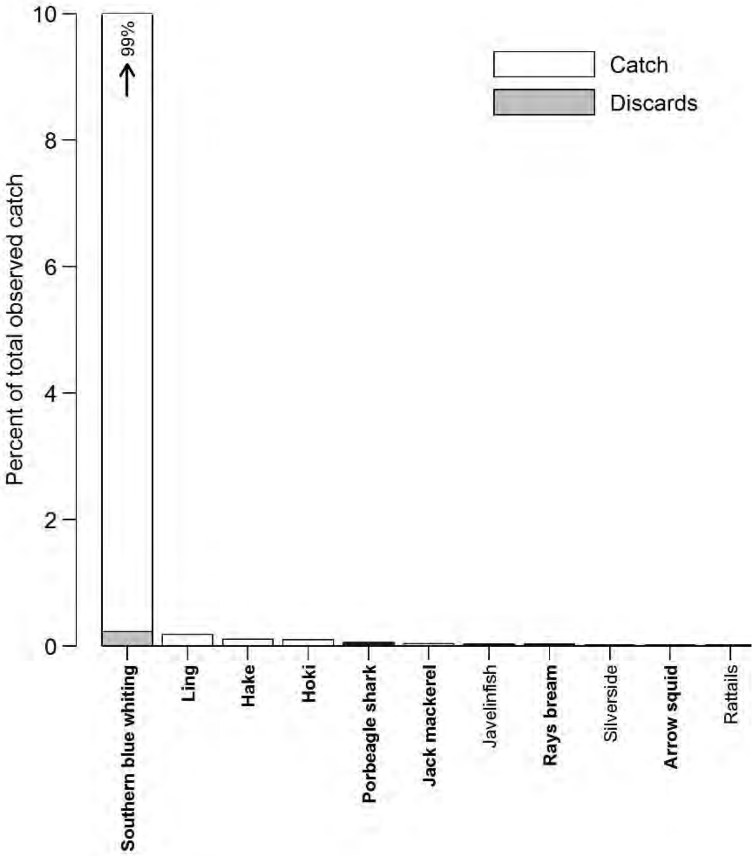

Figure 7.13: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the southern blue whiting fishery, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch estimates for 2002–03 and 2006–07 ranged from about 40 t to 390 t, compared with approximate target species catches in the same period of about 22 000 to 42 000 t. This bycatch was fairly evenly 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 between about 60 t and 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.

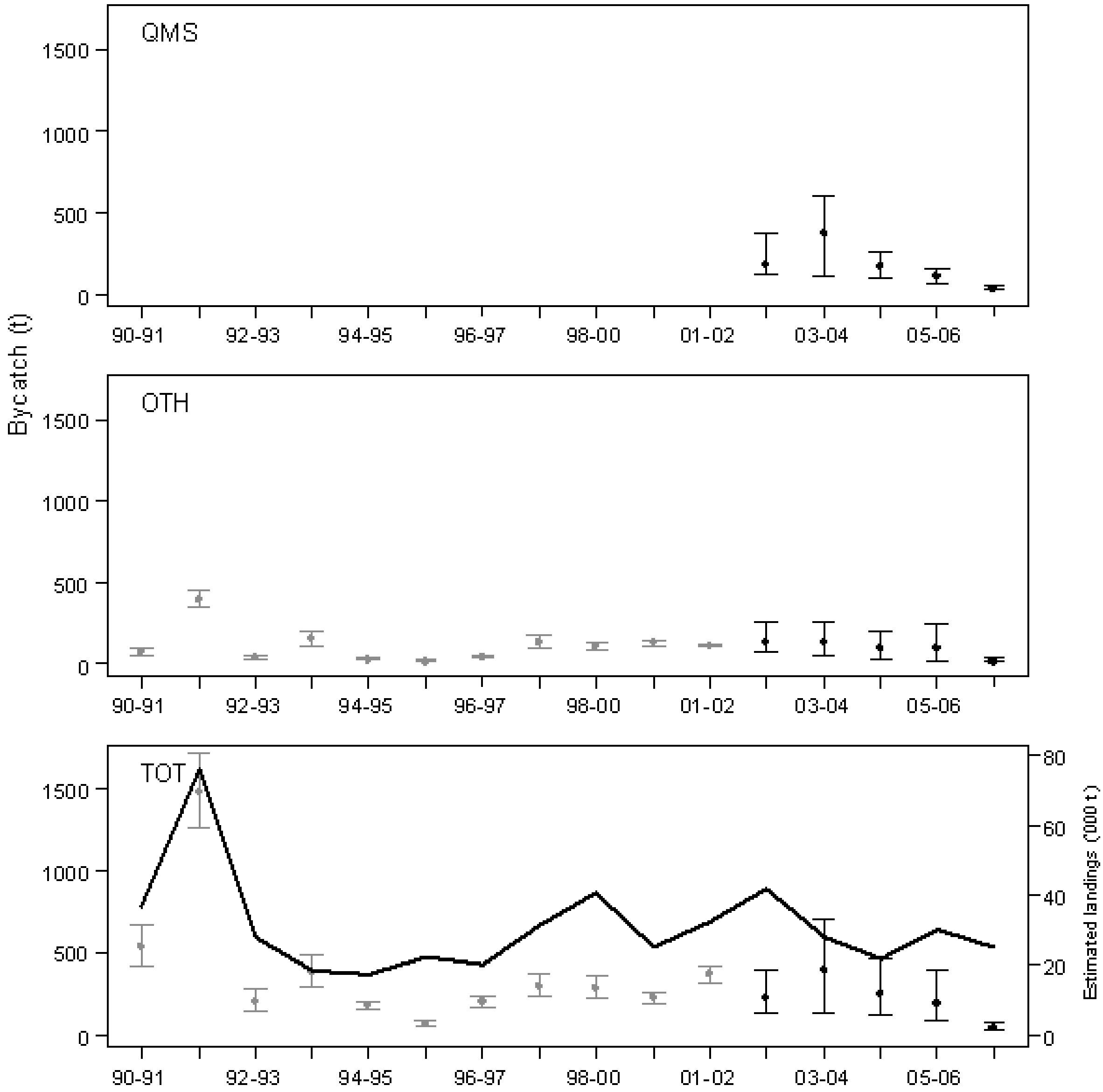

Figure 7.14: Annual estimates of fish bycatch in the southern blue whiting trawl fishery, calculated for QMS species, non-commercial species (OTH), and overall (TOT) for 2002–03 to 2006–07 (in black). Also shown (in grey) are estimates of bycatch in each category (excluding QMS) for 1990–91 to 2001–02 (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).

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 have shown a decrease in catch over time and 4 an increase in catch.
- The species that showed 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) (Figure 7.15).
- The species that showed the greatest increase were pale ghost shark (*Hydrolagus bemisi*, GSP), ray's bream (*Brama brama*, RBM) and opah (*Lampris immaculatus*, PAH) (Figure 7.15).

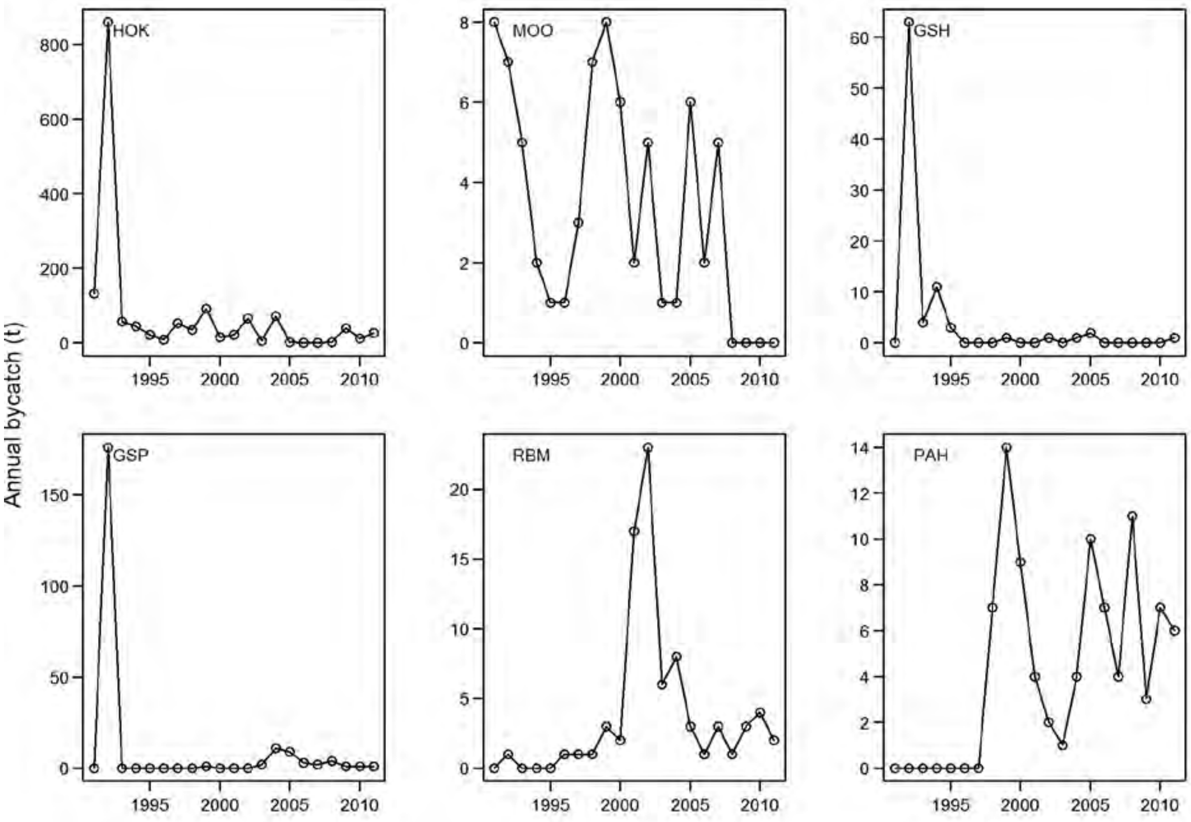

Figure 7.15: Annual bycatch estimates in the southern blue whiting trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discard estimates between 2002–03 and 2006–07 ranged from about 90 t to 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 between about 140 t and 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 have remained at low levels, below 250 t per year, at least up until 2006–07.

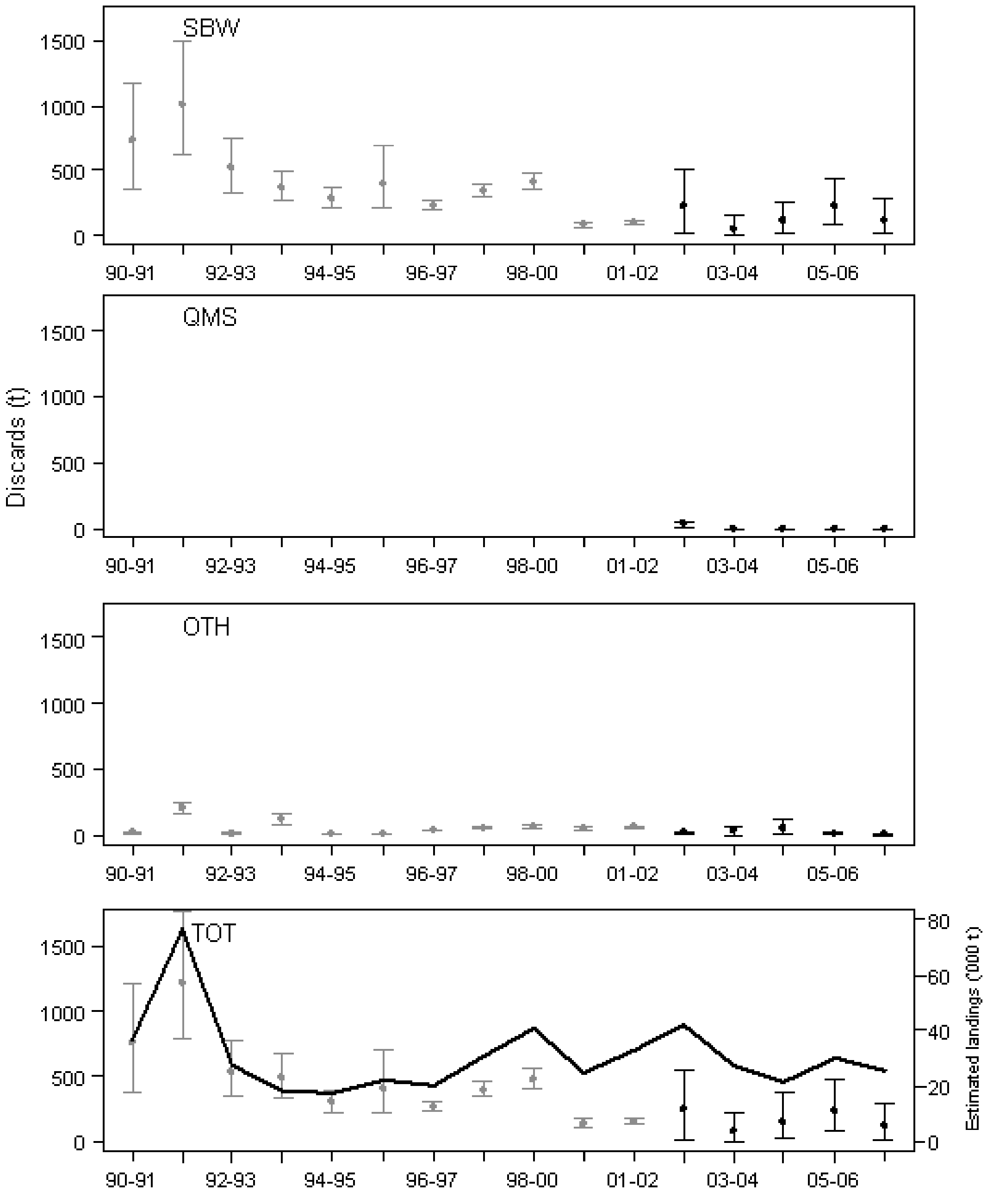

Figure 7.16: Annual estimates of fish discards in the southern blue whiting trawl fishery, calculated for the target species (SBW), QMS species, non-commercial species (OTH), and overall (TOT) for 2002–03 to 2006–07 (in black). Also shown (in grey) are estimates of discards in each category (excluding 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).

7.3.6. Orange roughy trawl fishery

In the most recent study, covering the period 1990–91 to 2008–09, the ratio estimator used to calculate bycatch and discard rates in the orange roughy fishery was based on the number of trawls. 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 has been relatively 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.

For the recent orange roughy fishery (since 2005–06), orange roughy accounted for 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 of which is likely to have been Baxter's dogfish (*E. 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 being 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).

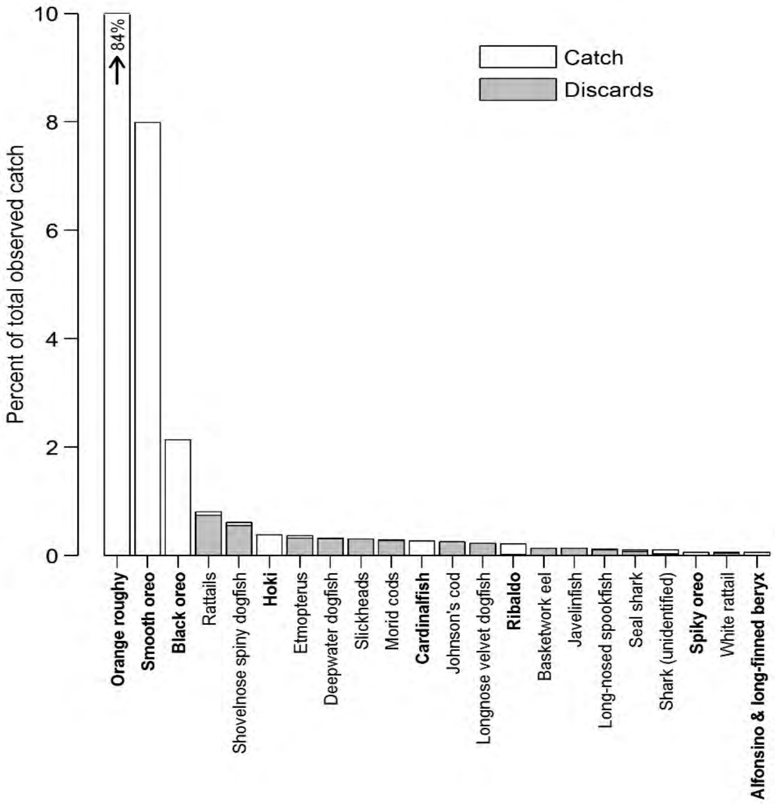

Figure 7.17: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the orange roughy fishery, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch in the orange roughy fishery since 1990–91 ranged from about 2300 t to 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 (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.

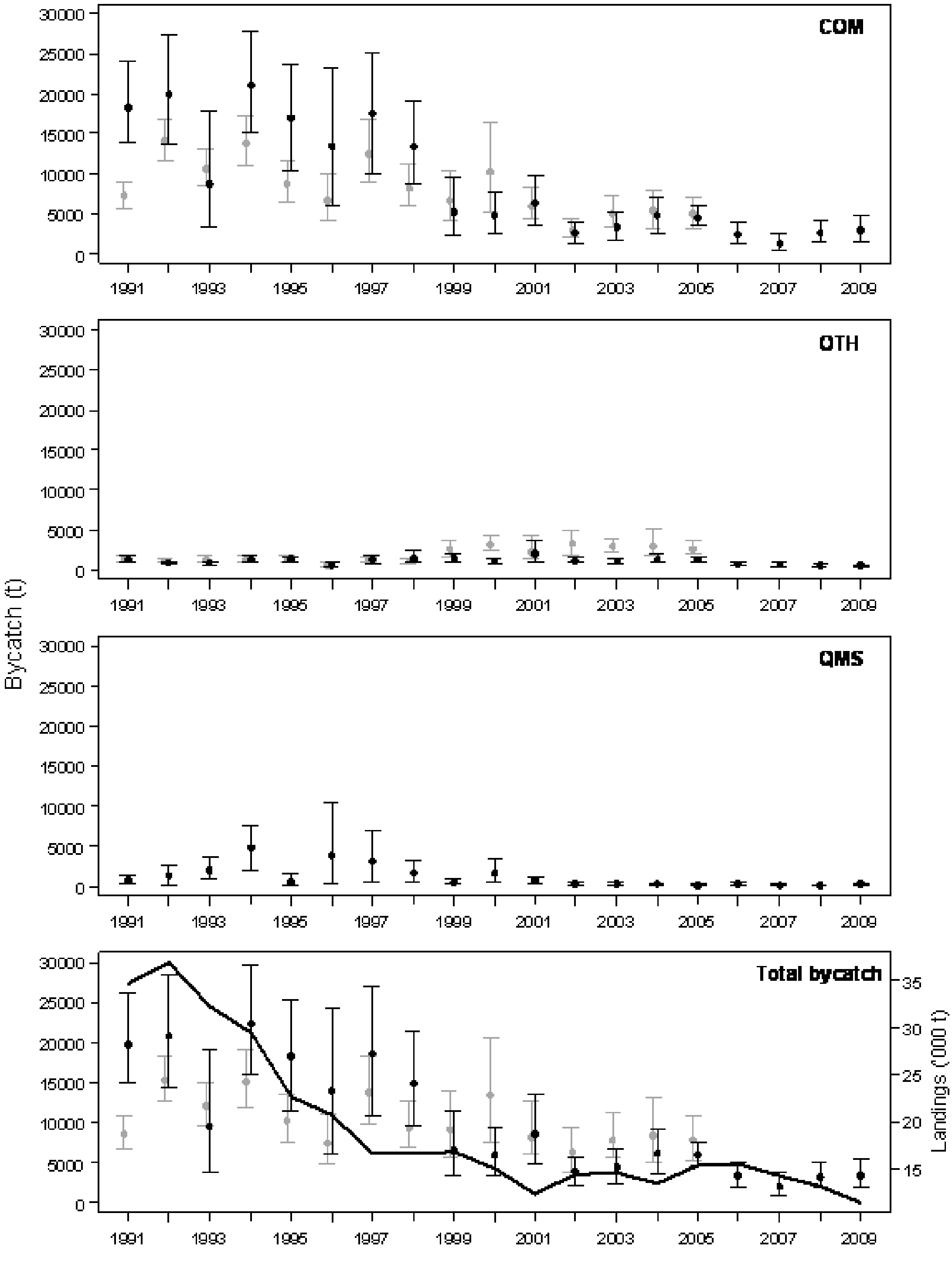

Figure 7.18: Annual estimates of fish bycatch in the orange roughy trawl fishery, calculated for commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are earlier estimates of bycatch in each category (excluding QMS) calculated for 1990–91 to 2004–05 (Anderson et al2001, 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 have shown a decrease in catch over time and 51 an increase in catch.
- The species showing the greatest decline were alfonsino (BYX) (a species not found south of the Chatham Rise), spiny dogfish (SPD), and oreos (Oreosomatidae, OEO) (Figure 7.19).
- The species showing the greatest increase were bushy hard coral (*Goniocorella dumosa*, GDU), longnose velvet dogfish (*Centroscymnus crepidater*, CYP), and morid cods (Moridae, MOD) (Figure 7.19).

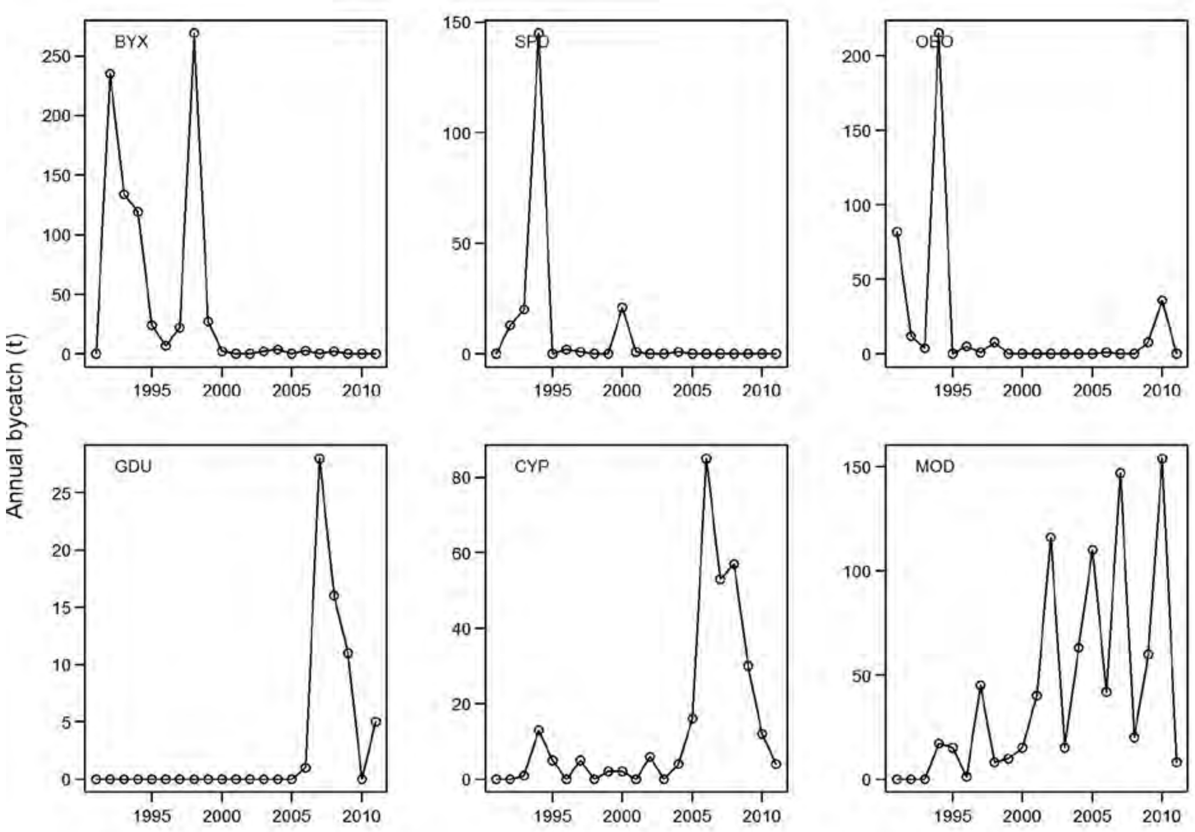

Figure 7.19: Annual bycatch estimates in the orange roughy trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (see text above). See text above for species codes.

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.

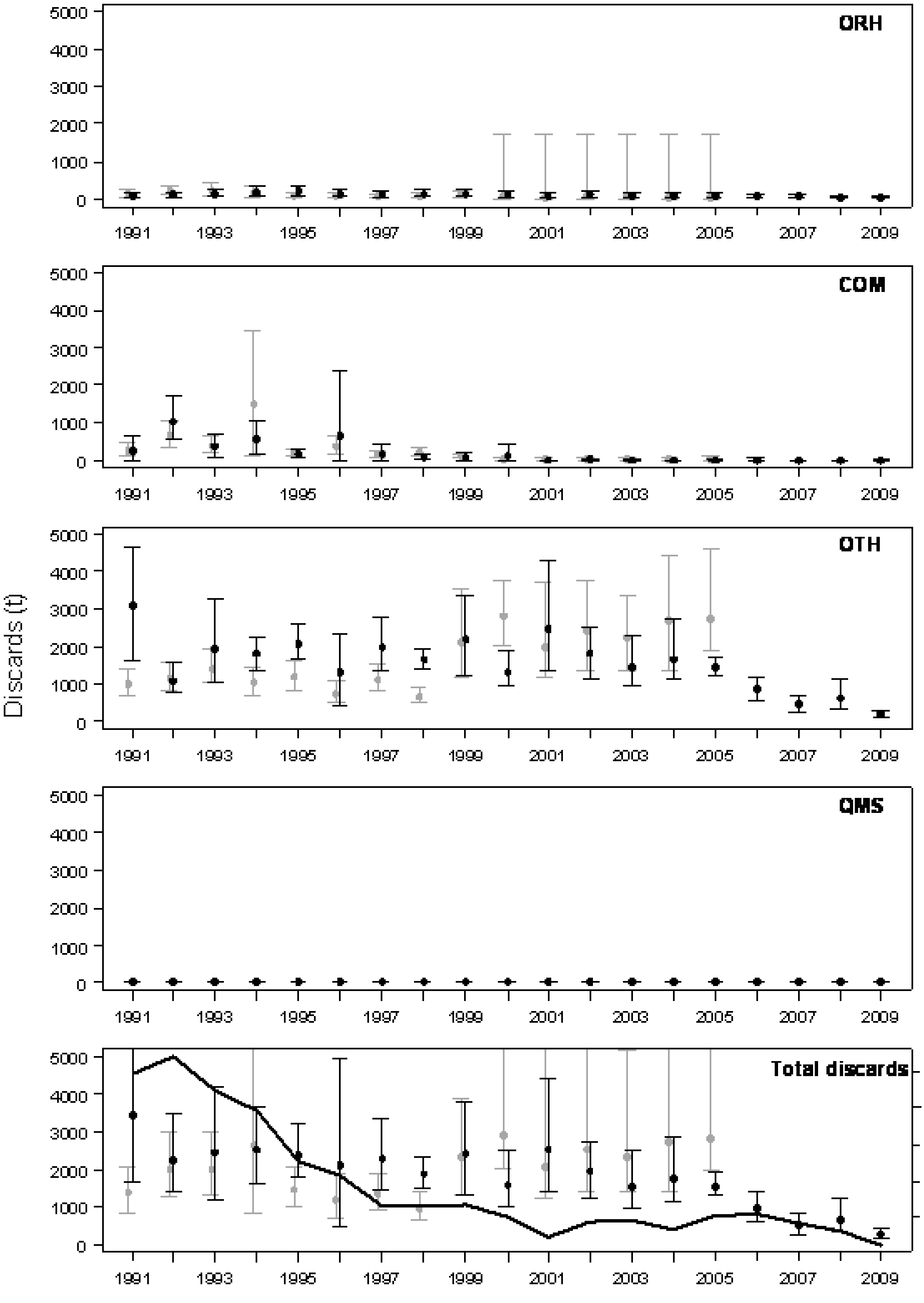

Figure 7.20: Annual estimates of fish discards in the orange roughy trawl fishery, calculated for the target species (ORH), commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2004–05 (Anderson et al2001, 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

In the most recent study, covering the period 1990–91 to 2008–09, the ratio estimator used to calculate bycatch and discard rates in the oreo fishery was based on the number of trawls. 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 is 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 is 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 somewhat underrepresented and large vessels overrepresented. The fleet has shrunk in recent years and the remaining vessels are 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.

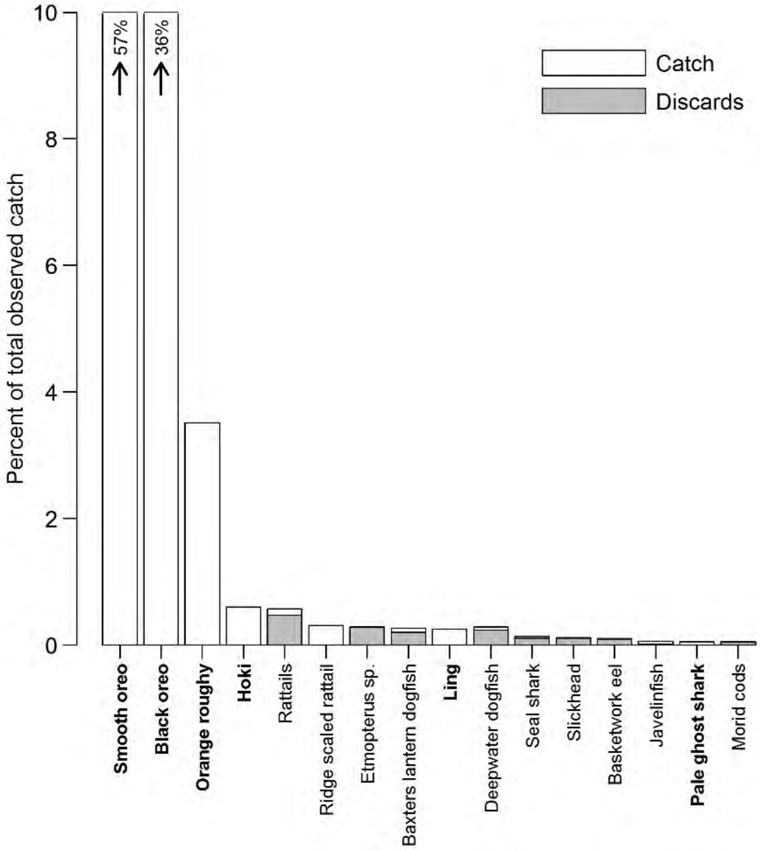

Figure 7.21: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the oreo fishery, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch in the oreo fishery since 1990–91 has ranged from about 270 t to 2200 t and, apart from some higher levels in the late 1990s, not shown any obvious trends (Figure 7.22). Bycatch has been split almost evenly between commercial and non-commercial species overall, although after 2002 about 60% of the bycatch comprised commercial species.

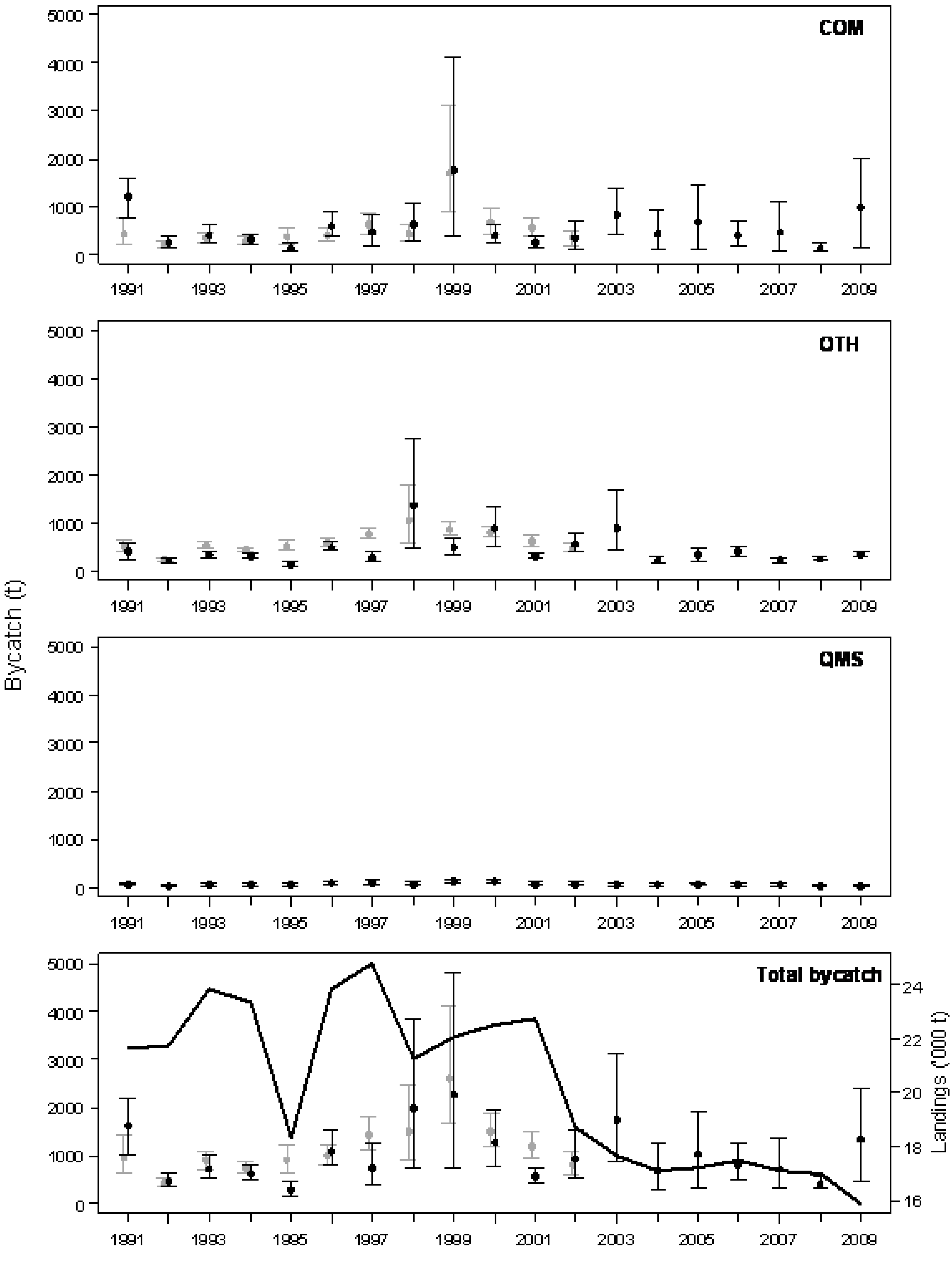

Figure 7.22: Annual estimates of fish bycatch in the oreo trawl fishery, calculated for commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of bycatch in each category (excluding QMS) calculated 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 have shown a decrease in catch over time and 27 an increase in catch.
- The species showing the greatest decline were dark ghost shark (GSH), unspecified shark (SHA), and ling (LIN) (Figure 7.23).
- The species showing 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).

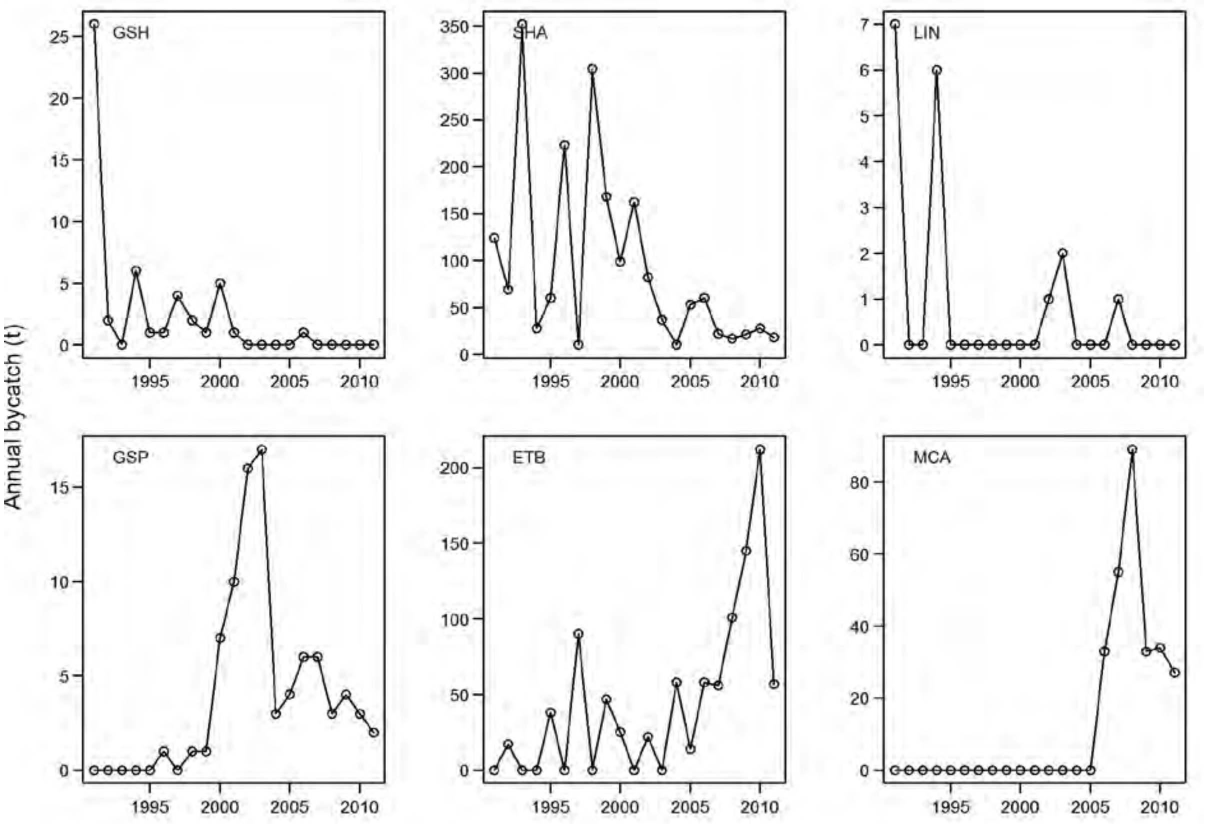

Figure 7.23: Annual bycatch estimates in the oreo trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1). See text above for species codes.

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.

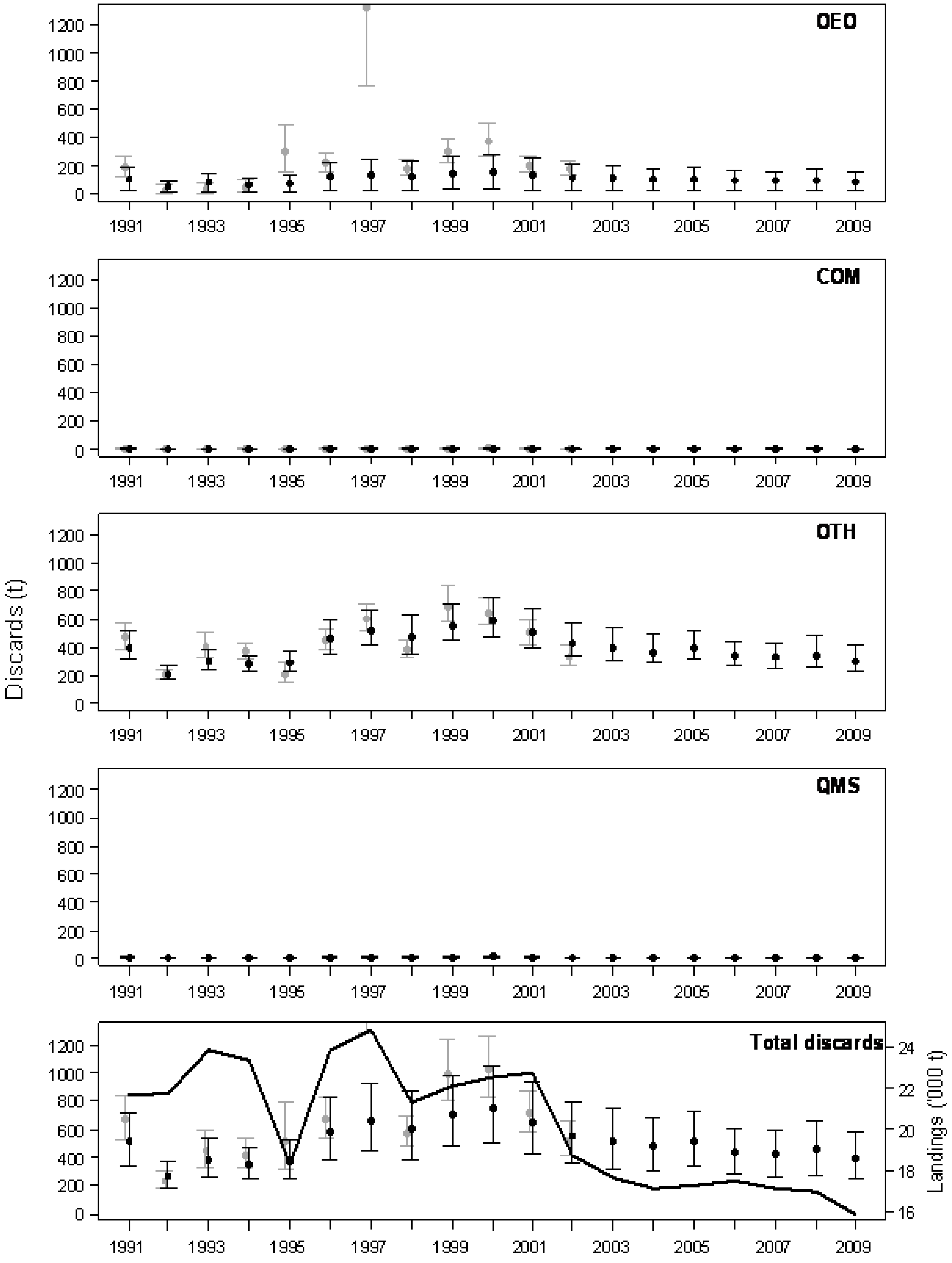

Figure 7.24: Annual estimates of fish discards in the oreo trawl fishery, calculated for the target species (OEO), commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of discards in each category (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

In the most recent study, covering the period 1990–91 to 2009–10, the ratio estimator used to calculate bycatch and discard rates in the scampi fishery was based on the number of trawls. 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%).

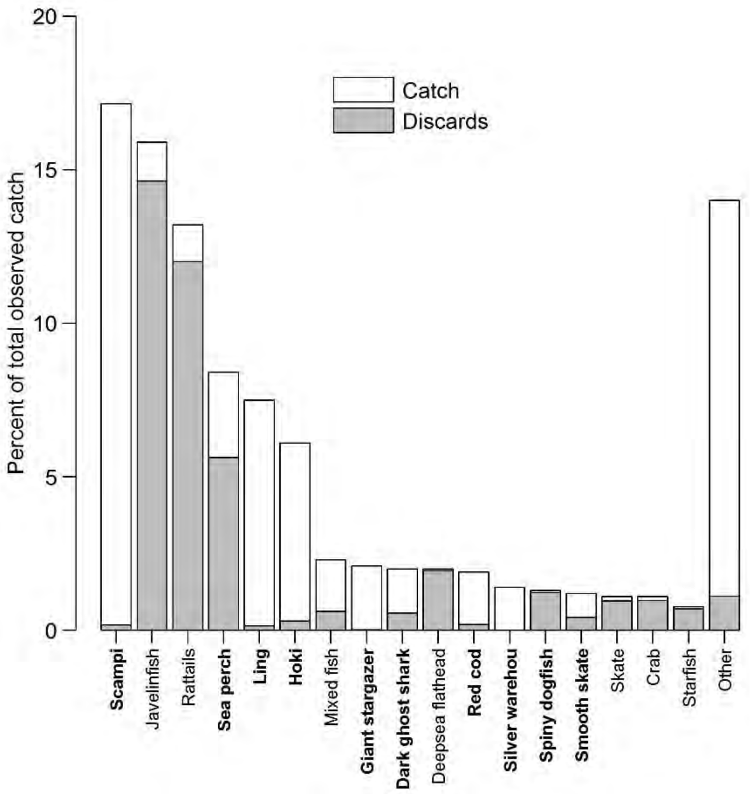

Figure 7.25: Percentage of the total catch contributed by the main bycatch species (those representing 1% or more of the total catch) in the observed portion of the scampi fishery, and the percentage discarded. The "Other" category is the sum of all other bycatch species (fish and invertebrates) representing 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.

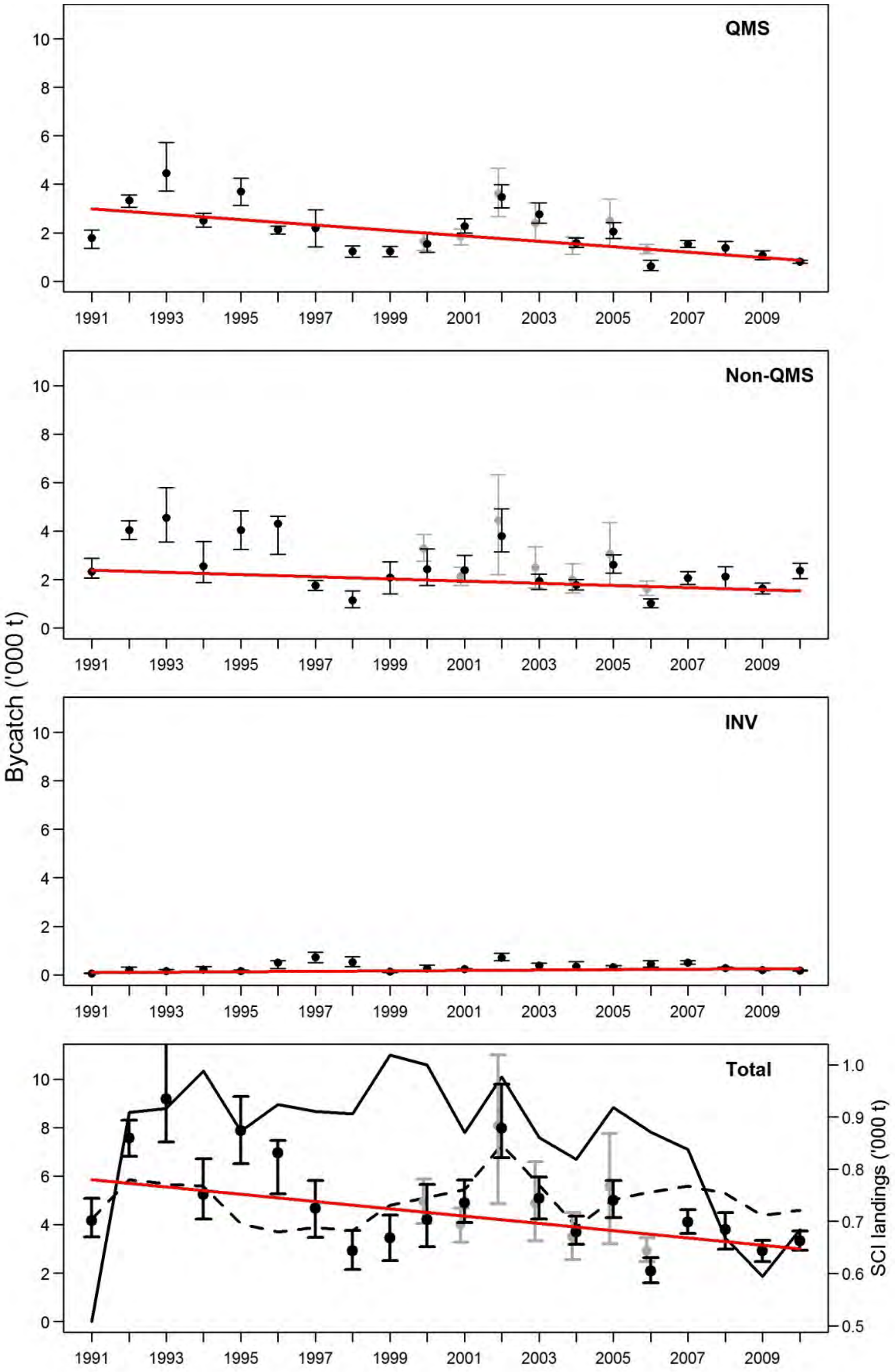

Figure 7.26: Annual estimates of bycatch in the scampi trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2009–10. Also shown (in grey) are estimates of bycatch in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). 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 have shown a decrease in catch over time and 59 an increase in catch.
- The species showing the greatest decline were skates (Rajidae and Arhynchobatidae, SKA), bluenose (*Hyperoglyphe antarctica*, BNS) (a species not present at the Auckland Islands) and alfonsino (*Beryx* spp., BYX) (a species not found south of the Chatham Rise) (Figure 7.27).
- The species showing the greatest increase were common roughy (*Paratrachichthys trailli*, RHY), jackknife prawn (*Haliporoides sibogae*, HIS), and spiny masking crab (*Teratomaia richardsoni*, SMK) (Figure 7.27).

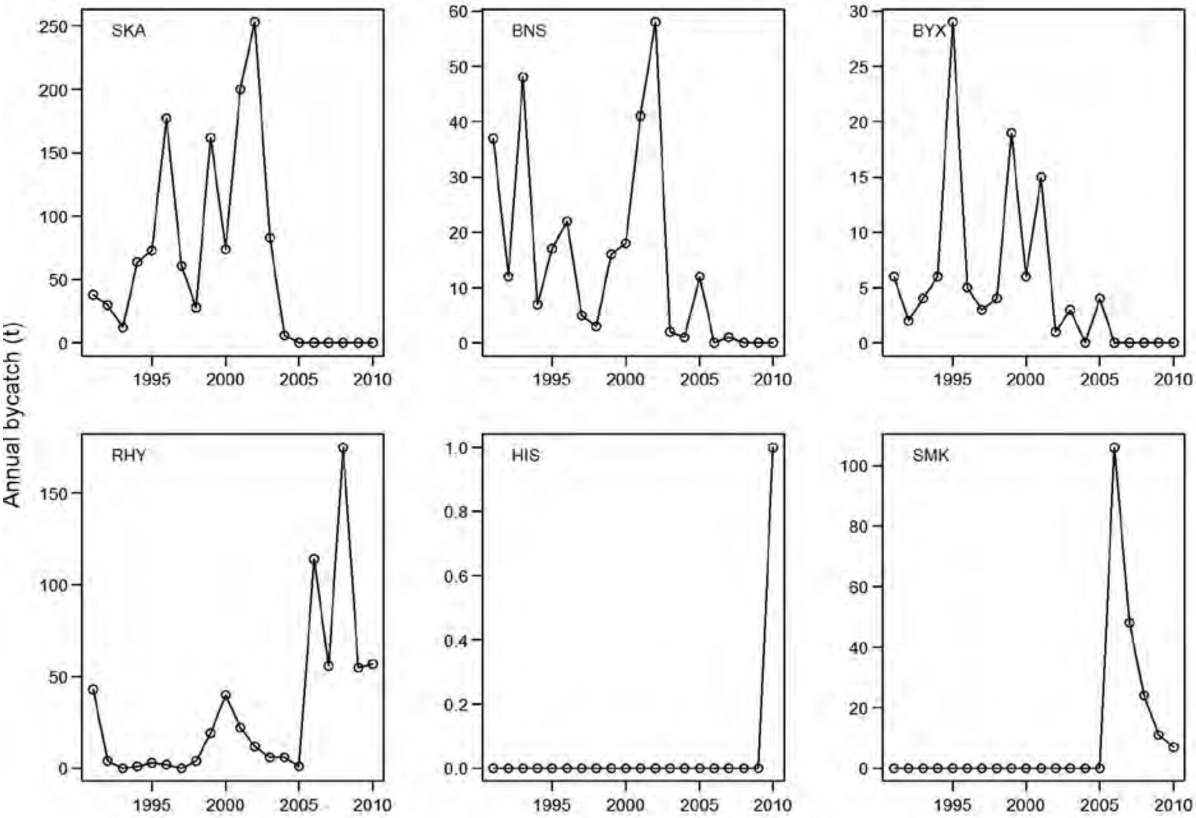

Figure 7.27: Annual bycatch estimates in the scampi trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1), and may be area-specific (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 showing 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.

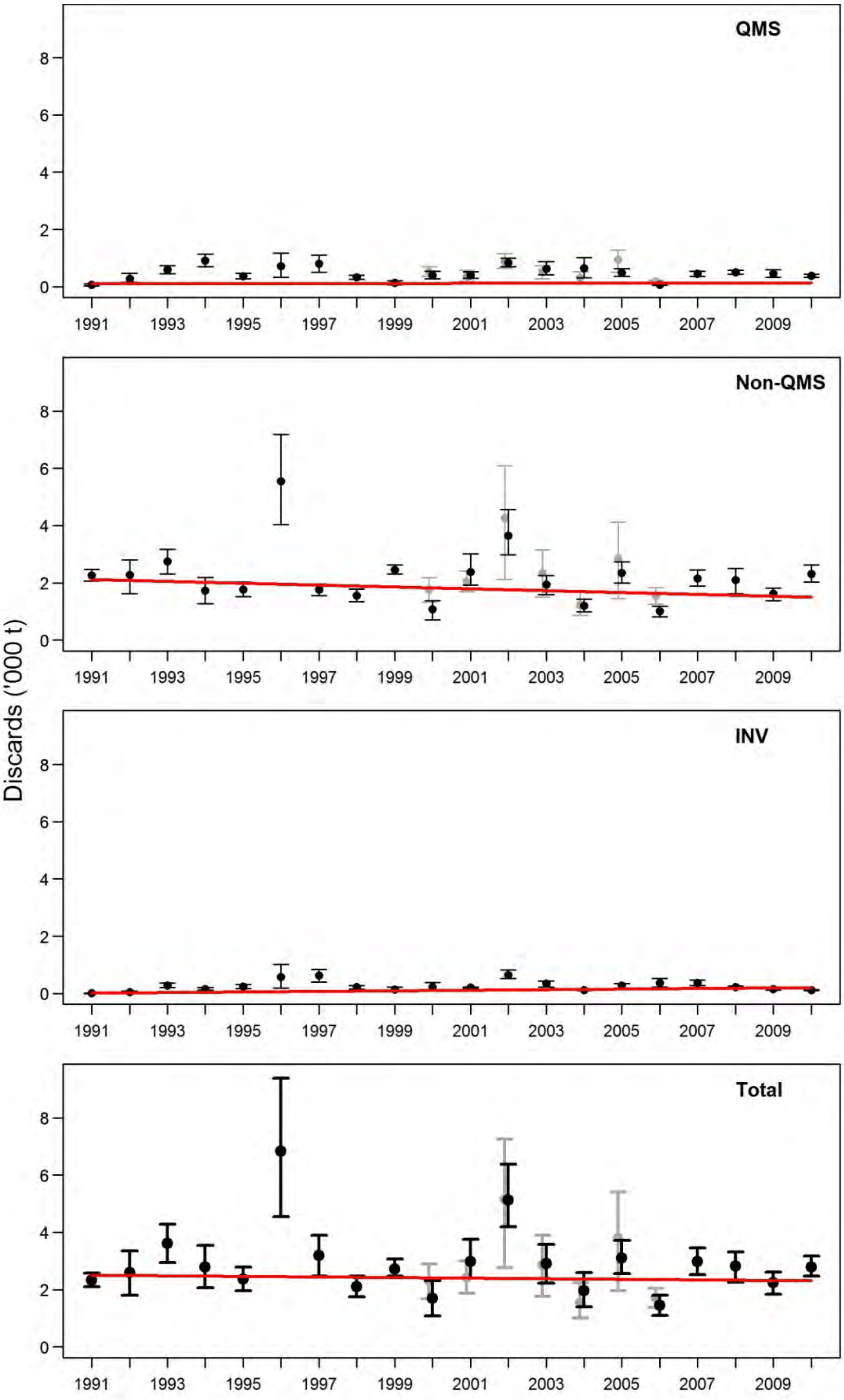

Figure 7.28: Annual estimates of discards in the scampi trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2009–10. Also shown (in grey) are estimates of discards in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). 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, and the second (and latest) analysis covered the following years up to 2005–06. To enable a comparison of estimates between studies, which used slightly different methodologies, the 1994–95 fishing year was re-assessed in the recent analysis. In addition to estimating the bycatch of all quota species combined, and all non-quota species combined, in the recent 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 ranged from 324 to 1605 compared with the total target fishery effort of about 2500 to 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 accounted for 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) accounted for 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 surprising 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.

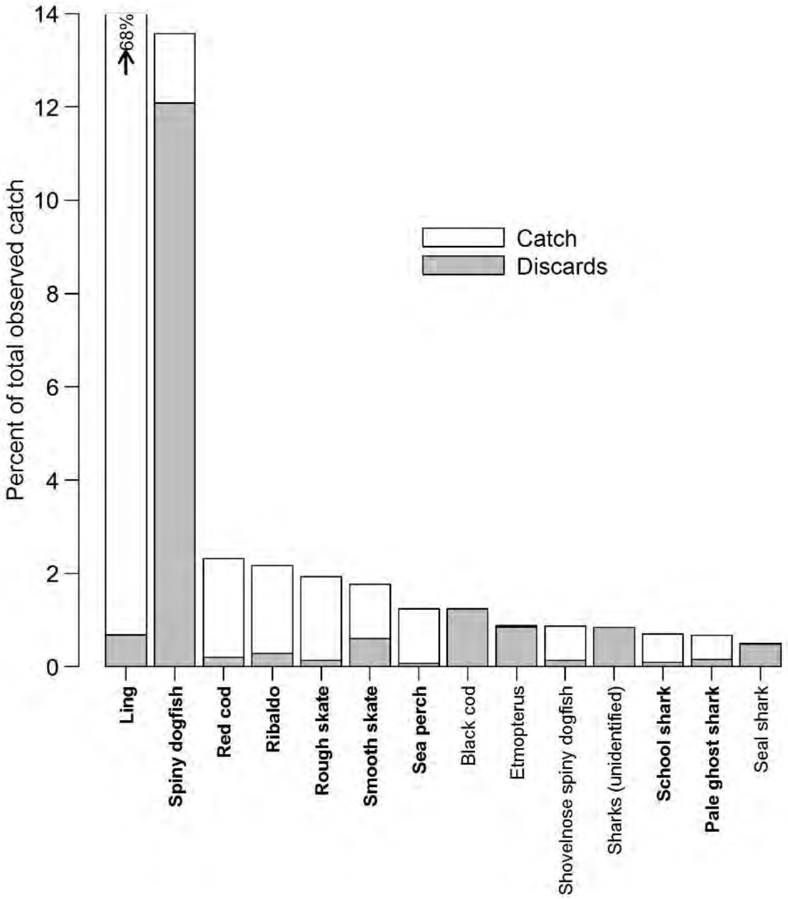

Figure 7.29: Percentage of the total catch contributed by the main bycatch species (those representing 0.5% or more of the total catch) in the observed portion of the ling longline fishery, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch estimates for 1998–99 to 2005–06 ranged from about 2200 t to 3700 t, compared with approximate target species catches in the same period of between about 3500 and 8700 t. A large part of this bycatch (40–50%) comprised a single species, spiny dogfish, and 80% of the bycatch were quota species (Figures 7.30 and 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 ranged from about 880 t to 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.

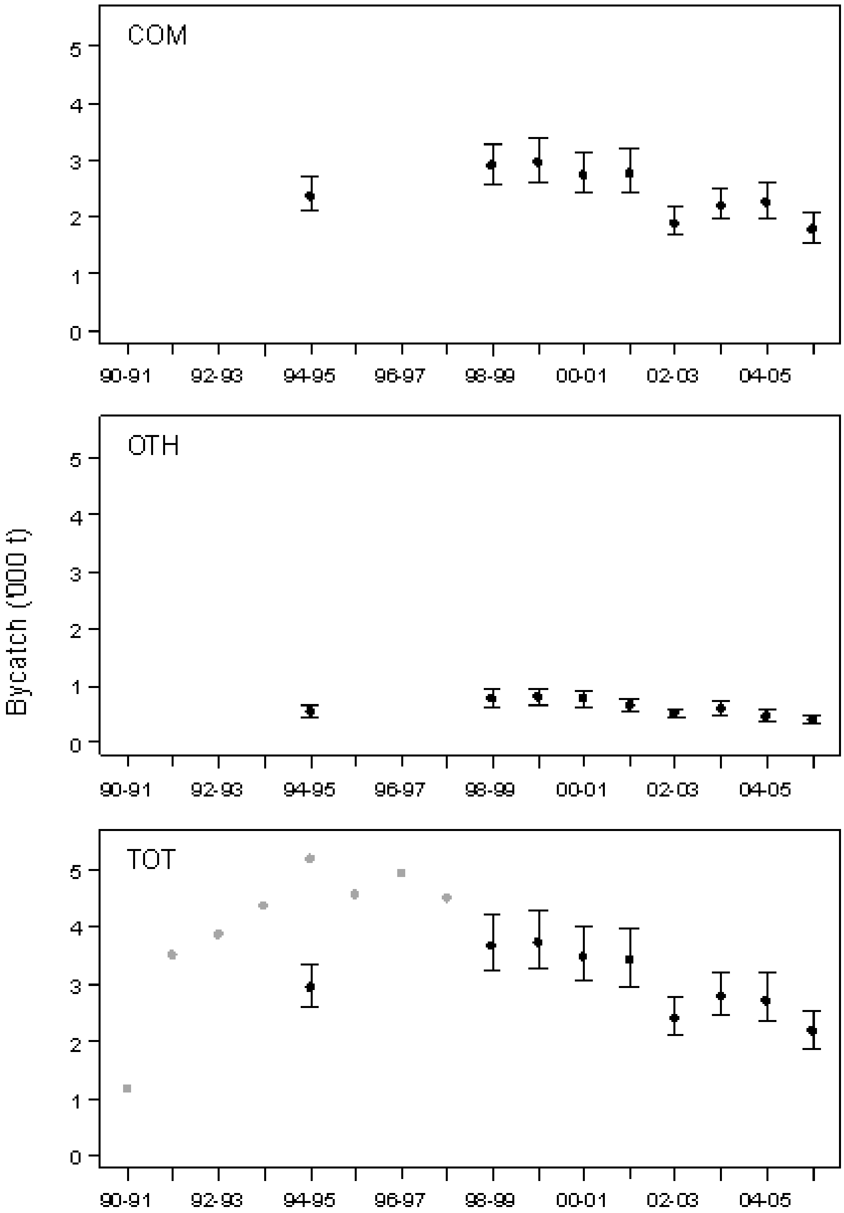

Figure 7.30: Annual estimates of fish bycatch in the target ling longline fishery, calculated for commercial (QMS) species (COM), non-commercial (non-QMS) species (OTH), and overall (TOT) for the years 1994–95 and 1998–99 to 2005–06 (in black). Also shown (in grey) are estimates of total bycatch calculated for the period 1990–91 to 1997–98 by Anderson et al(2000). Error bars show the 95% confidence intervals.

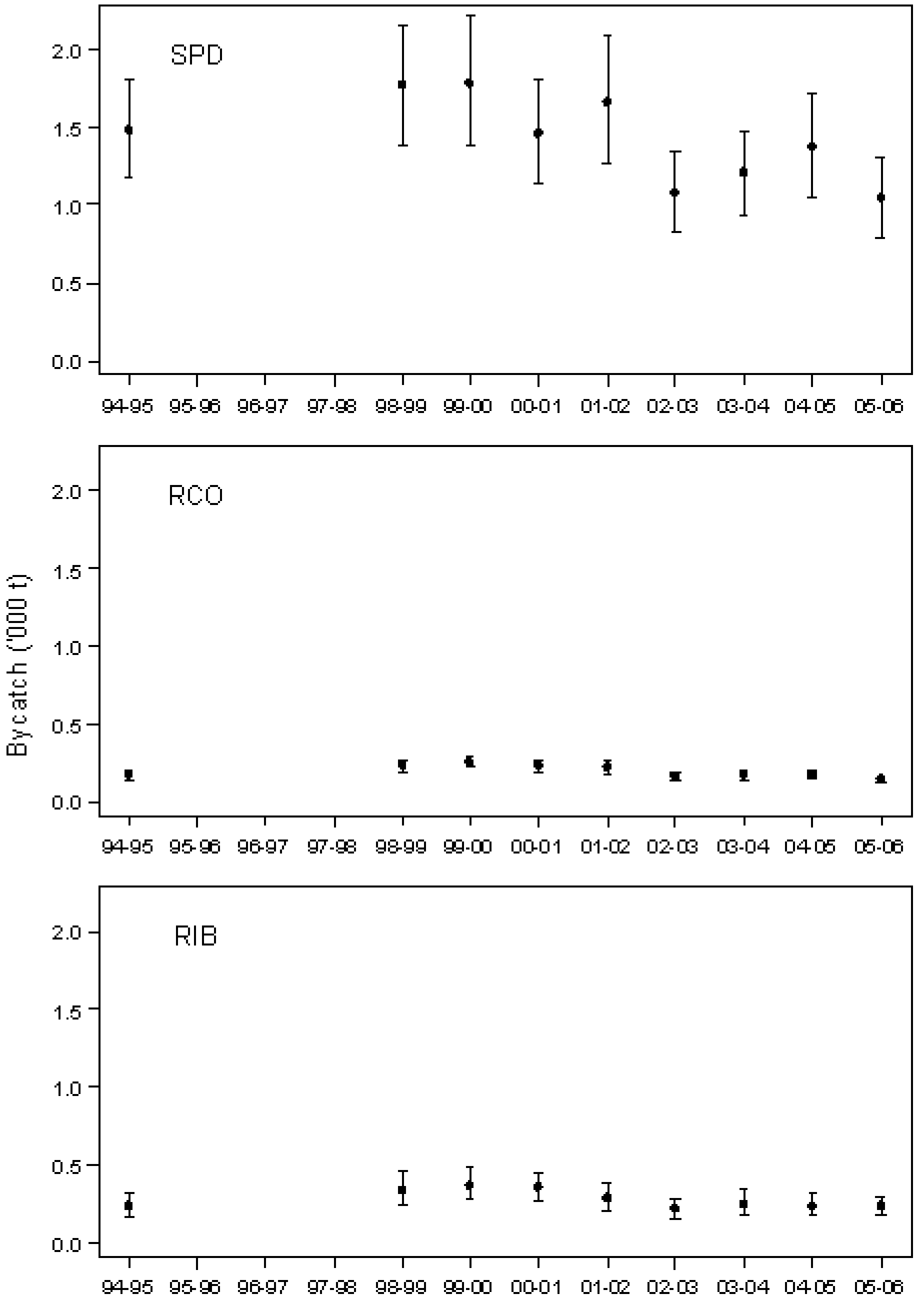

Figure 7.31: Annual estimates of the bycatch of spiny dogfish (SPD), red cod (RCO), and ribaldo (RIB) in the target ling longline fishery for the years 1994–95 and 1998–99 to 2005–06. Error bars show the 95% confidence intervals.

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), Antarctic rock cods (Nototheniidae, NOT), and conger eels (*Conger* spp., CON) (Figure 7.32).
- The species showing the greatest increase were leafscale gulper shark (*Centrophorus squamosus*, CSQ), rough skate (*Zearaja nasuta*, RSK), and hairy conger (*Bassanago hirsutus*, HCO) (Figure 7.32).

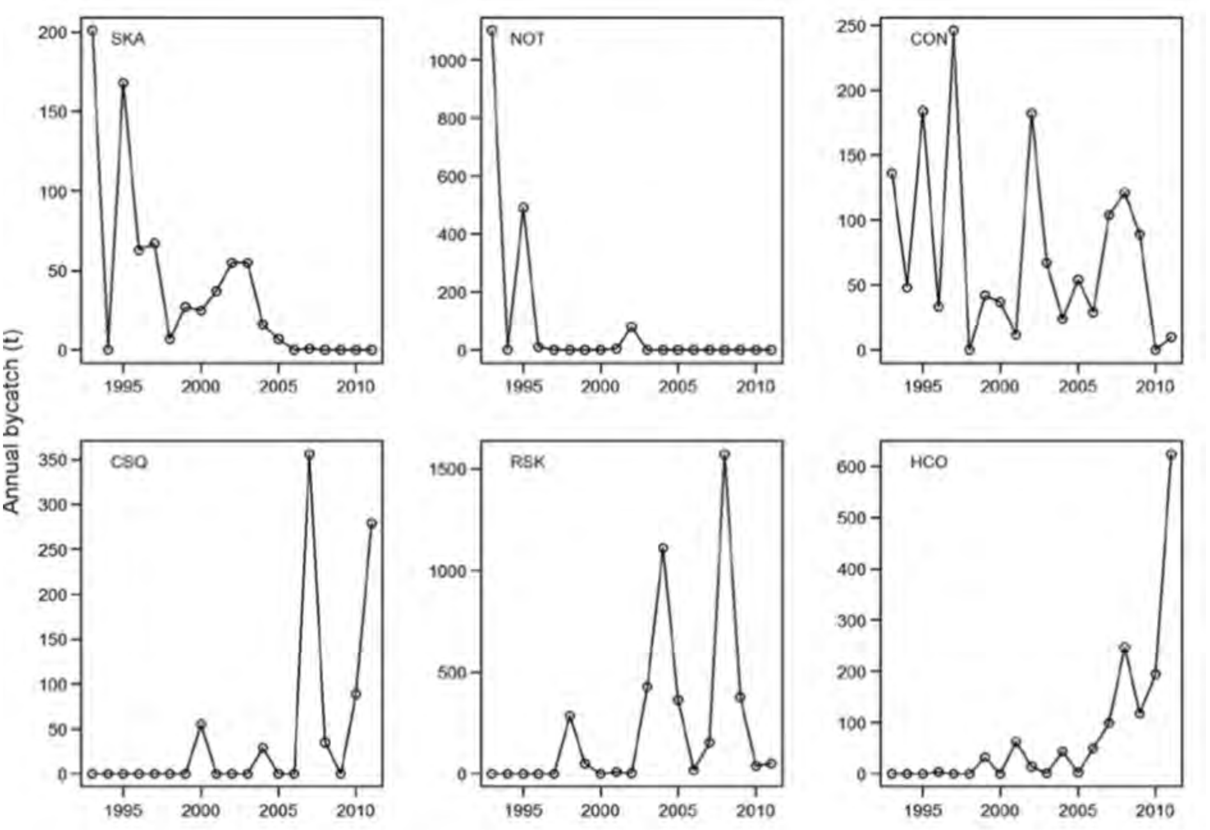

Figure 7.32: Annual bycatch estimates in the ling longline fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2010–11. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 7.3.1). See text above for species codes.

Total annual discard estimates for 1998–99 to 2005–06 ranged from about 1400 t to 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 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 between about 350 t and 1600 t. Total discard estimates for 1994–95 were similar for the two studies.

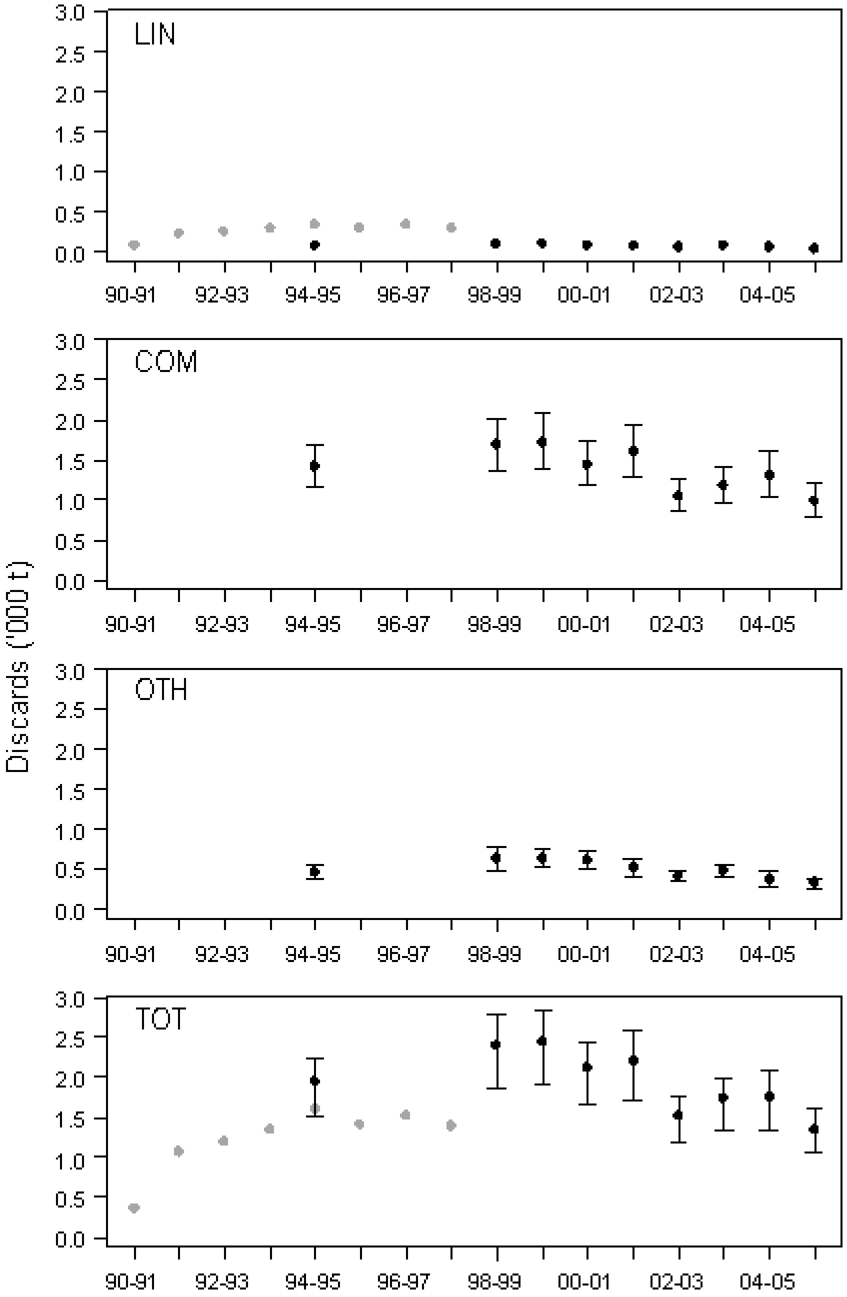

Figure 7.33: Annual estimates of fish discards in the target ling longline fishery, calculated for ling (LIN), commercial (QMS) species (COM), non-commercial (non-QMS) species (OTH), and overall (TOT) for the years 1994–95 and 1998–99 to 2005–06 (in black). Also shown (in grey) are estimates of the ling and total discards calculated for 1990–91 to 1997–98 by Anderson et al(2000). Error bars show the 95% confidence intervals.

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 has been the dominant fleet in the fishery since 1993–94 (Figure 7.34).

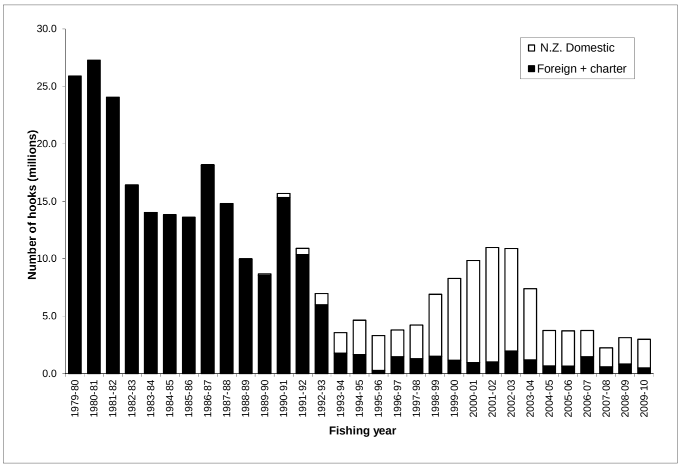

Figure 7.34: Effort (hooks set) in the tuna longline fishery. Black bars are Foreign and Charter vessels, white bars are NZ domestic vessels.

The Japanese charter fleet mainly target southern bluefin tuna off the west coast South island (WCSI), and domestic vessels target mainly southern bluefin tuna and bigeye tuna and the fishery is concentrated on the east coast of the North Island (ECNI) with some fishing for southern Bluefin tuna on the WCSI.

The most recent analysis of fish bycatch in tuna longline fisheries covered the 2006−07 to 2009−10 fishing years (Griggs & Baird 2013)

Observer effort has mainly focused on the Japanese charter vessels (all vessels covered and usually about 80% of hooks observed), with lower coverage of the domestic fishery (approximately 7–8% during 2006−07 to 2009−10). Most of the fishing effort is carried out by the domestic fleet so this fleet is under-observed.

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 are blue sharks, mako sharks, porbeagle sharks, school shark, moonfish, Ray's bream, and swordfish. Swordfish is also sometimes targeted.

Table 7.2: Species composition of observed tuna longline catches. Number of fish observed are shown for 2006-–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 troll fishery

This fishery is comprised entirely of 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 has ranged from 0.5–1.5% of days fished over the 2009−10 to 2010−12 fishing years.

Albacore has made up 93.5% of the observed catch over the past six years, followed by Ray’s bream (3.1%) and Skipjack tuna (2.1%) and small numbers (less than 1%) of a few other species (Table 7.3).

Table 7.3: Species composition of observed albacore troll catches for 2006–07 to 2011–12.

		Number of fish caught						
Species	Scientific name	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	Total of 6 years
Albacore tuna	*Thunnus alalunga*	1 684	1 776	1 755	5 403	4 905	2 772	18 295
Rays bream	*Brama brama*		18	12	537	35	7	609
Skipjack tuna	*Katsuwonus pelamis*	1	2	26	20	359	2	410
Barracouta	*Thyrsites atun*			1		24	13	38
Kahawai	*Arripis trutta*			6		3	14	23
Kingfish	*Seriola lalandi*			2	4	4		10
Dolphinfish	*Coryphaena hippurus*				1			1
Mako shark	*Isurus oxyrinchus*						1	1
Unidentified		2			174			176

7.3.12. Skipjack purse seine fishery

Skipjack tuna makes up 98.9% of the catch observed on purse seine vessels in New Zealand waters.

Catch composition from eight observed purse seine trips operating within New Zealand fisheries waters in 2010 and 2011 can be seen in Table 7.4.

Table 7.4: Species composition of observed skipjack purse seine catches in 2010 and 2011.

Common name	Scientific name	2010–2011 Observed catch weight (kg)	% Catch
Skipjack tuna	*Katsuwonus pelamis*	3 600 988	98.92
Jack mackerel	*Trachurus* spp.	22 090	0.61
Jellyfish	Scyphozoa	6 740	0.19
Blue mackerel	*Scomber australasicus*	4 040	0.11
Manta ray	*Mobula japanica*	2 122	0.06
Sunfish	*Mola mola*	1 456	0.04
Striped marlin	*Tetrapturus audax*	820	0.02
Mako shark	*Isurus oxyrinchus*	517	0.01
Albacore tuna	*Thunnus alalunga*	422	0.01
Porcupine fish	*Tragulichthys jaculiferus*	343	0.01
Flying fish	Exocoetidae	174	<0.01
Frigate tuna	*Auxis thazard*	100	<0.01
Hammerhead shark	*Sphyrna zygaena*	80	<0.01
Frostfish	*Lepidopus caudatus*	79	<0.01
Thresher shark	*Alopias vulpinus*	75	<0.01
Salps	Thaliacea	57	<0.01
Barracouta	*Thyrsites atun*	42	<0.01
Moonfish	*Lampris guttatus*	40	<0.01
Discfish	*Diretmus argenteus*	25	<0.01
Electric ray	*Torpedo fairchildi*	21	<0.01
Slender tuna	*Allothunnus fallai*	20	<0.01
Blue shark	*Prionace glauca*	10	<0.01
Garfish	*Hyporhamphus ihi*	5	<0.01
Pilot fish	*Naucrates ductor*	5	<0.01
Porbeagle shark	*Lamna nasus*	5	<0.01
Smooth skate	*Dipturus innominatus*	5	<0.01
Pilchard	Sardinops neopilchardus	3	<0.01
Starfish	Asteroidea & ophiuroidea	3	<0.01
Dealfish	*Trachipterus trachypterus*	2	<0.01
Arrow Squid	*Nototodarus sloanii & n gouldi*	2	<0.01
Dolphinfish	*Coryphaena hippurus*	1	<0.01
Gurnard	*Chelidonichthys kumu*	1	<0.01
John dory	*Zeus faber*	1	<0.01
Decapod	Crustacea	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 estimates of this measure are provided in Table 7.5 for those fisheries where the necessary data were available.

Table 7.5: Fishery efficiency. Kilograms of discards per kilogram of target species catch. The numbers are the most recent 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

Comparison of estimates of total discards over time from all the Deepwater trawl fisheries (Figure 7.35) shows the large size of discards from the hoki/hake/ling fisheries (2011–12 hoki total TACC of 130 000 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 (2011–12 scampi total TACC of 1191 t) and the squid fishery (2011–12 squid total trawl TACC of 107 120 t).

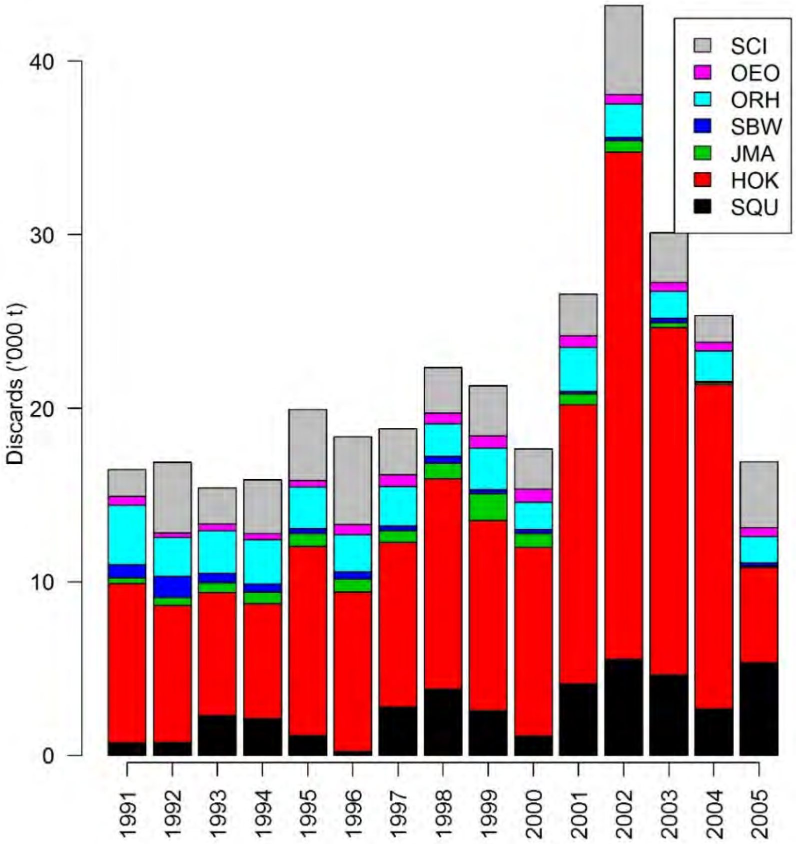

Figure 7.35: Comparison of total estimated discards for all the deepwater trawl fisheries 1990–91 to 2004–05. Data after 2004–05 are incomplete. SCI, scampi; OEO, oreos; ORH, orange roughy; SBW, southern blue whiting; JMA, jack mackerels; HOK, hoki/hake/line; SQU, arrow squids.

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 7.6: 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 increasing 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 increasing effort away from undersea features.
Scampi trawl	Linear regression modelling of observer catch data indicated significant trends of decreasing bycatch over time for QMS species and total species bycatch and a significant trend of increasing bycatch for invertebrates. A significant trend of increasing discards over time was shown for invertebrates, both rattail categories, and for rattails overall. Recent fleet-wide alterations to the nets providing 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 shows 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 declines 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 seem 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								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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[43]
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*
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*

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[43] Includes the MPI code SFI

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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*
BYX	0.00	0.02	-0.25	-0.05	-0.01	-0.31	0.00	-0.15	*Beryx splendens & B. decadactylus*[44]
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[45]
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

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[44] Includes the MPI code BYC
[45] Includes the MPI code EPT

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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.
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)

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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)
ECN		0.00	0.13	-0.01		0.01	0.00	-0.02	Echinoid[46]
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*

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[46] Includes the MPI code URO

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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)
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*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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[47]
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*

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[47] Includes the MPI code SCC

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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
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*[48]
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.

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[48] Includes the MPI code LLT

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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.
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*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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
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

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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*
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*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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*
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.

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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[49]
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.

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[49] Includes the MPI codes OSD and DWD

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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*
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*[50]

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[50] Includes the MPI codes PHM and ECT

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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*
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*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
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

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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, trends in key indicators of fishing effects. Note this also includes 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 is 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)[51]. 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 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[52]. 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 al2000, 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

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[51] ftp://ftp.fao.org/docrep/fao/006/x3170e/X3170E00.pdf

[52] 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.

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 al1998, Smith et al1998, Dulvy et al2003, Pikitch et al2008, 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 al2010a, 2010b, Forman & Dunn 2012, Dunn et al2013). The diets of blue, porbeagle and mako sharks have been analysed using samples collected by observers on tuna longline vessels (Horn et al2013). 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 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, though 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 al2013). However unreported catches are undoubtedly substantial so the true extent of chondrichthyan catches remains unclear (Bonfil 1994, Camhi et al1998, Clarke et al2006, Worm et al2013). 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 al1999a, Campana et al2009, Griggs & Baird 2013), but estimates of subsequent survival of live releases are rare (Moyes et al2006, Campana et al2009, Musyl et al2011, Hutinchision et al2013).

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 al2012, Worm et al2013).

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 alin 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	-	-	-

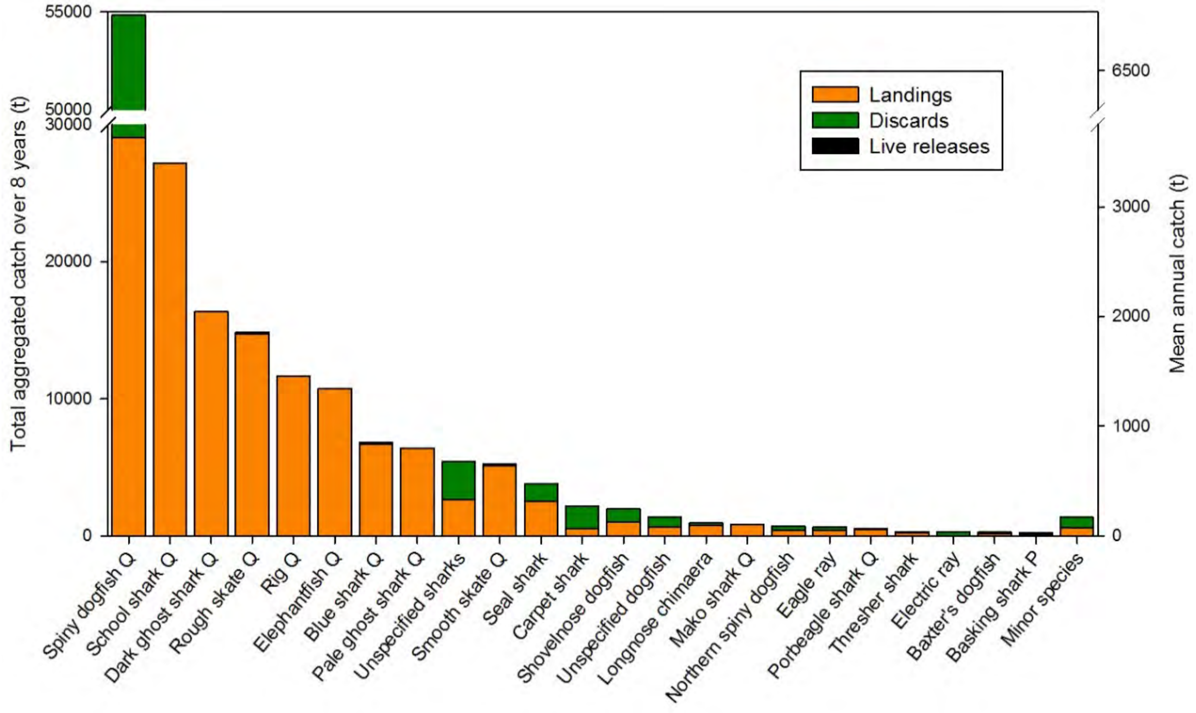

Figure 8.1: Reported total landings, discards and live releases for chondrichthyan species aggregated across 2004−05 to 2011−12. The average annual catches are shown on the right axis. ‘Q’ indicates QMS species, ‘P’ indicates protected species. Basking shark was protected in 2010. Source: Ministry for 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 & 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 (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 al2008), trawl in Hawke Bay, and by the NIWA research trawl vessel *Tangaroa* on the Norfolk Ridge (Garrick 1974, Stewart 1997, Fergusson et al2008), 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 al1982); 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 al1999b), 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 al1999b).

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.

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 are 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	+		

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 8.1). Data are available from the MPI Observer Programme (Figure 2), but coverage of the distribution of deepwater sharks has been unrepresentative.

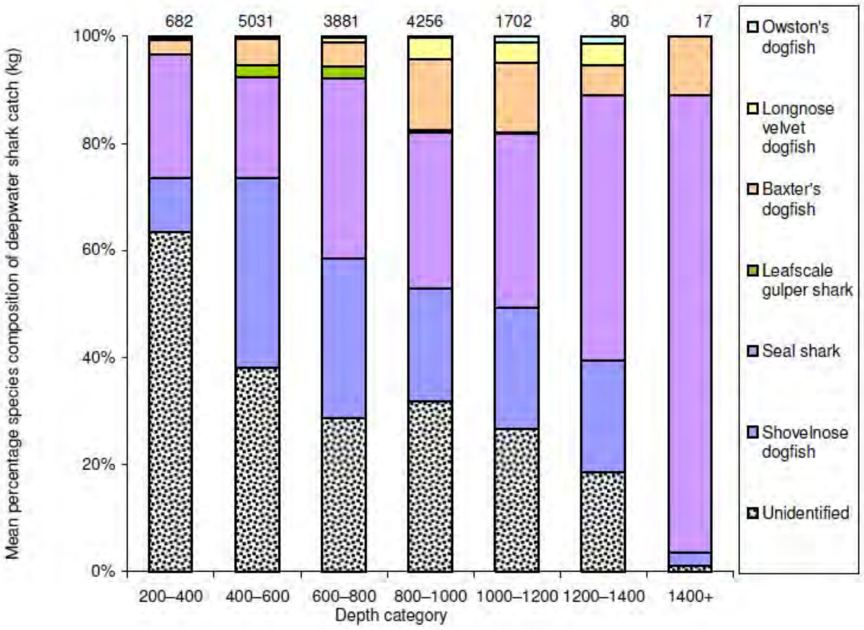

Figure 8.2: Mean catch composition of deepwater chondrichthyans reported from the Observer Programme database, all years 2001–02 to 2005–06, by major depth category (number of observations shown above bars). Source: Blackwell (2010).

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.

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.

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:

🟩 Trend up in recent years

⬜ Stable in recent years

🟥 Trend down in recent years

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 8.3 (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).

Other 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 8.5 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 Subantarctic, 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 7.1 – from the non-protected bycatch chapter).

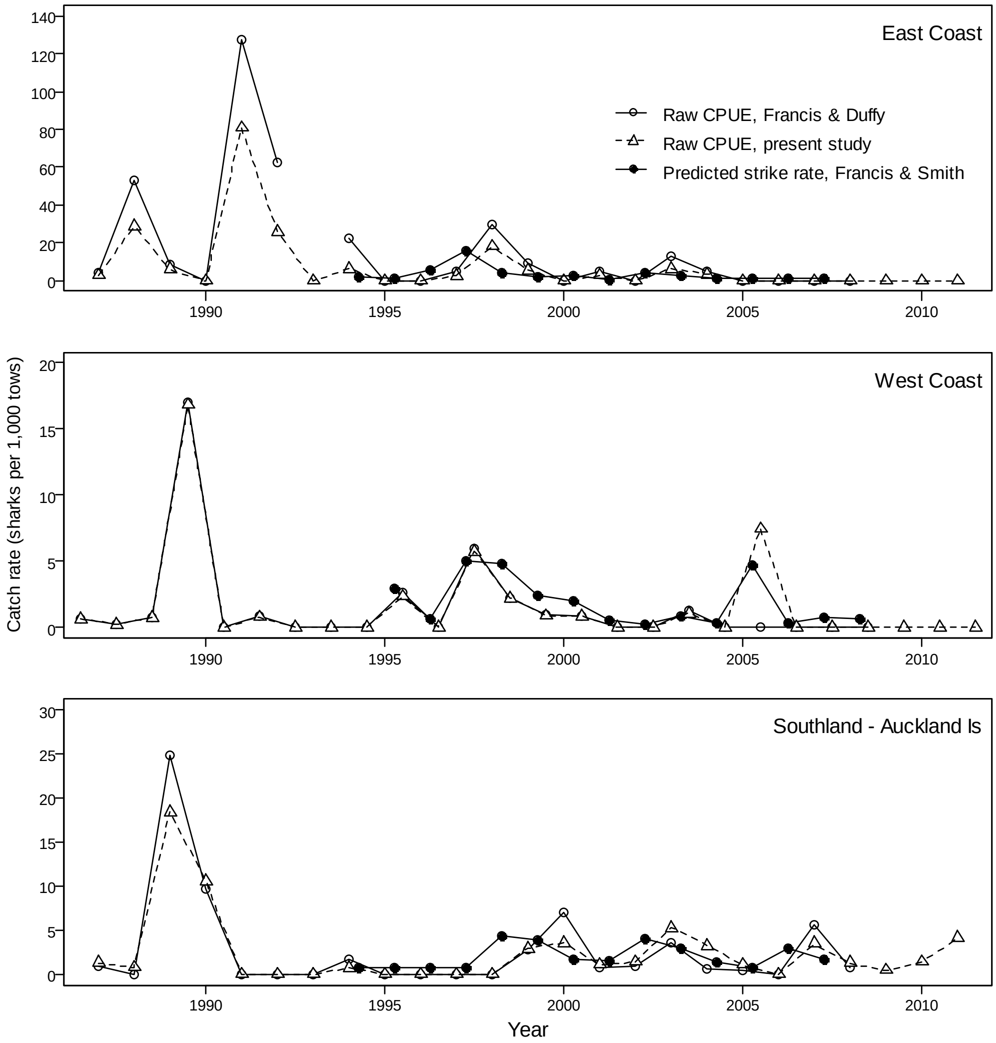

Figure 8.3: Basking shark catch rate indices for three fishery areas. For raw CPUE indices, years are calendar years for West Coast and July−June years (labelled as the greater of the two years) for East Coast and Southland-Auckland Is. For predicted strike rate, years are fishing years (labelled as 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

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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	Manage-ment 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 B_{MSY}, the average biomass associated with a maximum sustainable yield (MSY) strategy, or F_{MSY}, 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 B_{MSY} (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, F_{MSY}, or an appropriate proxy is exceeded on average, overfishing will be deemed to have been occurring, because stocks fished at rates exceeding F_{MSY} will ultimately be depleted below B_{MSY}.
- A stock that is determined to be below the soft limit [default: $^{1}/_{2}$ B_{MSY} 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: $^{1}/_{4}$ B_{MSY} 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=478).

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 first 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 in the EEZ 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. Because of the low spatial resolution of reporting up to 2006/07, the spatial distribution of trawling within the TS is less well understood. 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.
MFish 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*; DEE2010/05, *Development of a suite of environmental indicators for deepwater fisheries;* DEE2010/06, *Design a programme to monitor trends in deepwater benthic communities;* BEN2012-01, *Spatial overlap of mobile bottom fishing methods and coastal benthic habitats.*
NZ Government Research (current)	MSI (ex-FRST) programmes: C01X0907, *Coastal Conservation Management;* C01X0906, *Impacts of resource use on vulnerable deep-sea communities*; C01X0808, *Deepsea mining of the Kermadec Ridge*. Previous OBI programmes *Coasts & Oceans* C01X0501 and *Marine Biodiversity & Biosecurity* C01X0502 are now part of NIWA core funding.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture
Related chapter/ issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring, marine mining/sand extraction, land-based effects.

Note: No update has been made to this chapter since the AEBAR 2012.

9.1. *Context*

For the purpose of this document, mobile bottom fishing methods include all types of trawl gear that are used in contact with the seabed, Danish seines, and various designs of shellfish dredges. The information available on the distribution and effects of Danish seining is poor relative to that on trawls and dredges, so that method is not considered here 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 not always negligible) and these methods are not considered in this version.

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 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 trawl closures introduced in 2008 to protect Hector's and Maui's dolphins). 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 2009). 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 and Clark 2003, see Figure 9.1). These areas include 25 features, including 12 large seamounts >1000 m high, covering 2% (81, 000 km^2) 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 km^2, 10 additional active hydrothermal vents, and 35 topographic features) that complemented the existing seamount closures was implemented by regulation in 2007 (Helson et al 2009, Figure 9.3). BPAs cover about 1.1 million km^2 (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 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.

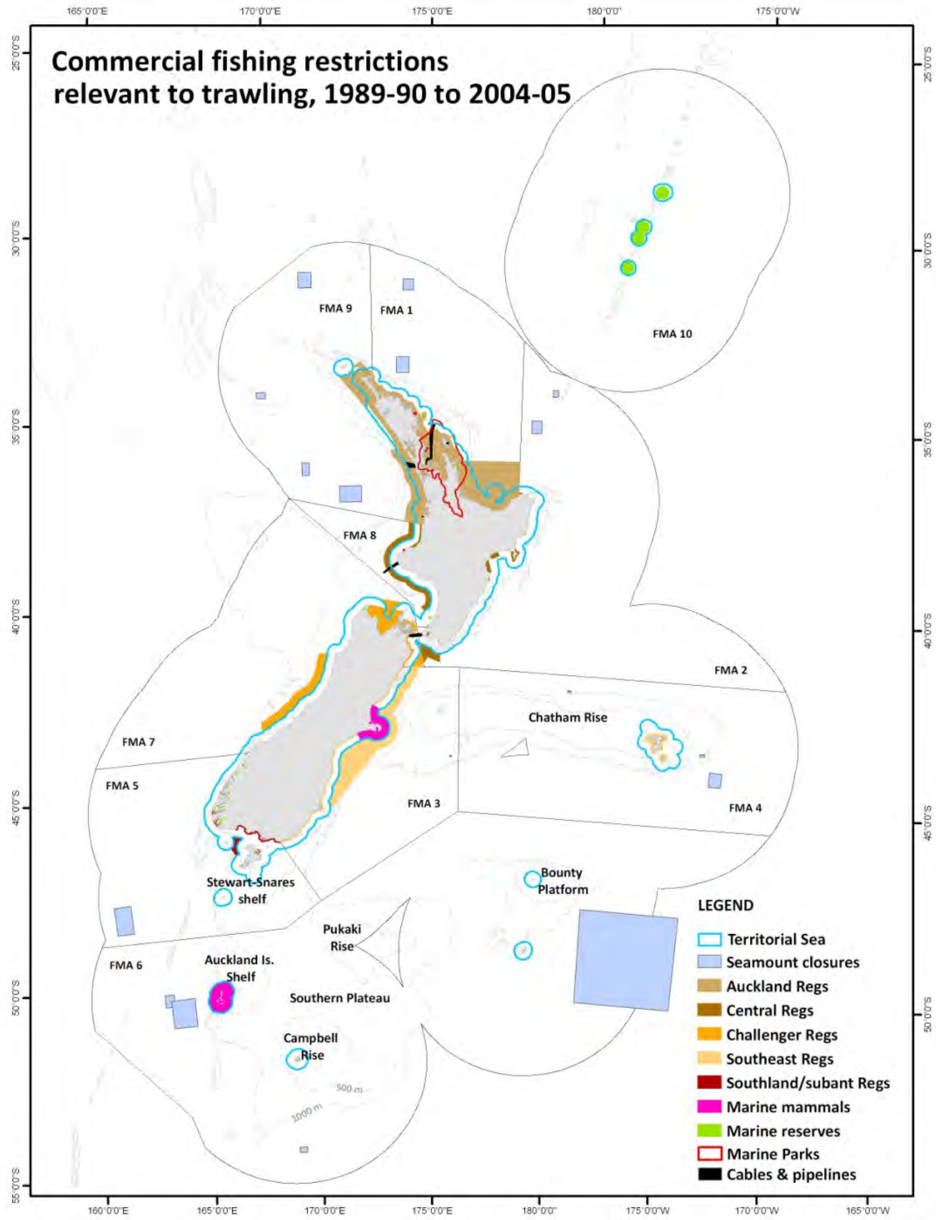


Figure 9.1: Map, from Baird and Wood 2010, of the major spatial restrictions to trawling present at some stage during 1989–90 to 2004–05 and the Ministry for Primary Industries Fishery Management Areas (FMAs) within the outer boundary of the New Zealand EEZ. Vessels longer than 28 m may not trawl within 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.

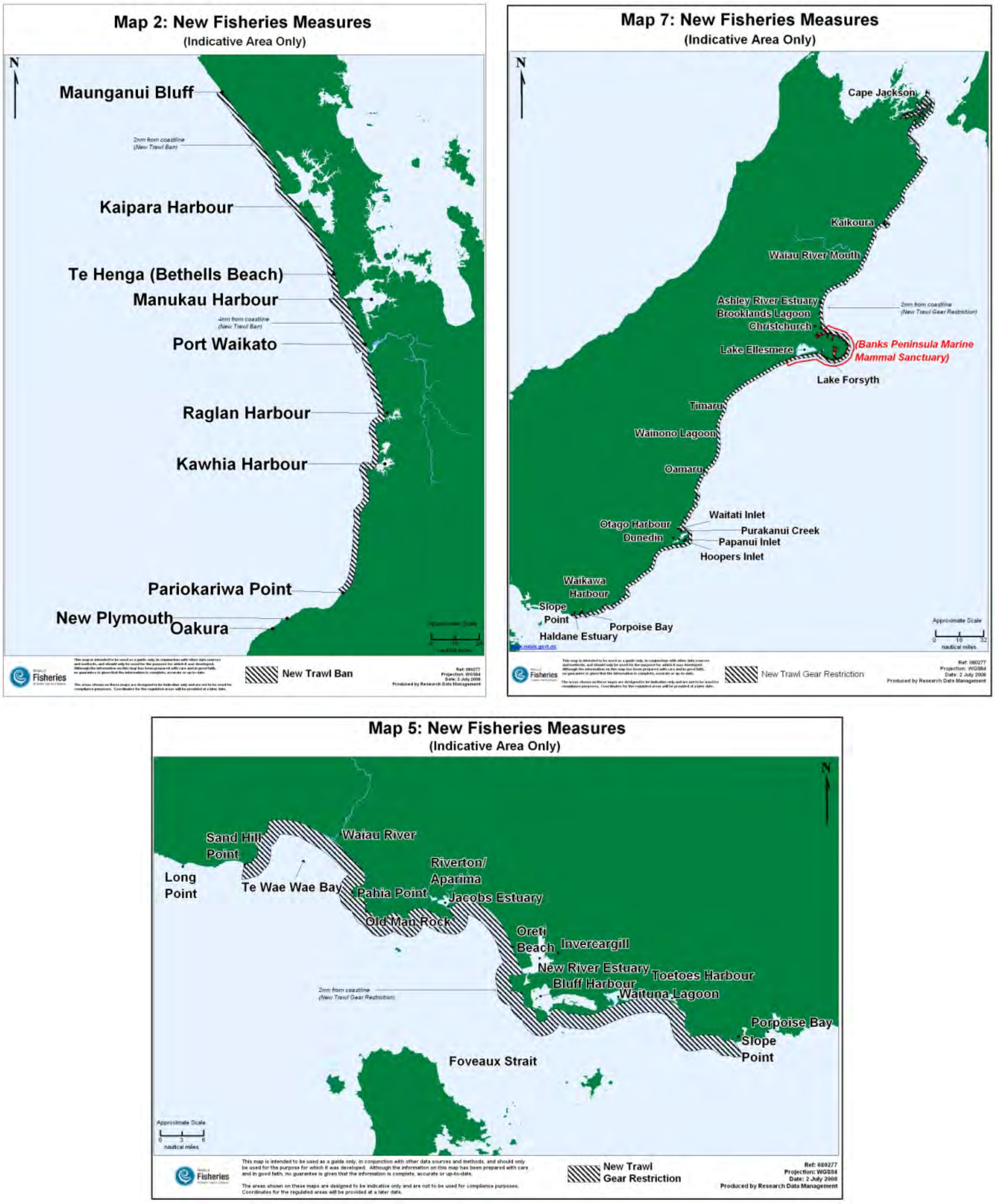


Figure 9.2: Maps from Ministry of Fisheries website showing the general locations of areas closed to trawling to protect Hector's and Maui's dolphins. Note scales differ. (http://www.fish.govt.nz/en-nz/Consultations/Archive/2008/Hectors+dolphins/Decisions.htm?wbc_purpose=Basic&WBCMODE=PresentationUnpublished%2525252525252cPresentationUnpublished)

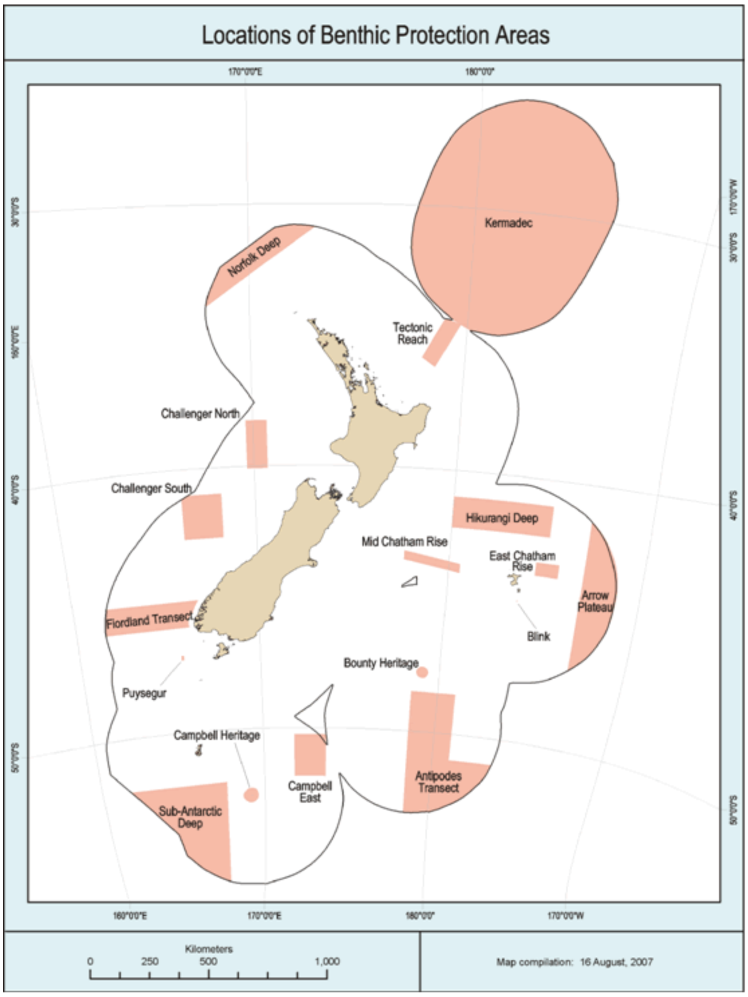


Figure 9.3: Map from Ministry of Fisheries website showing the general locations of Benthic Protection Areas (BPAs) (http://www.fish.govt.nz/en-nz/Environmental/Seabed+Protection+and+Research/Benthic+Protection+Areas.htm?wbc_purpose=basic&WBCMODE=presentationunpublished&MSHiC=65001&L=10&W=BPA%20&Pre=%3Cspan%20class%3d'SearchHighlight'%3E&Post=%3C/span%3E). See also Helson et al 2009.

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 and Kaiser 1998; Watling and Norse 1998; Lindeboom and deGroot 1998, Auster and Langton 1999; Hall 1999; ICES 2000a and b, Kaiser and de Groot 2000; NMFS 2002, NRC 2002, Dayton et al 2002; Thrush and Dayton 2002; Lokkeborg 2005, Barnes and Thomas 2005, Clark and Koslow 2007).

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 and the level of effect will depend on the type of trawl doors and ground gear used, and the physical and biological characteristics of seabed habitats in the fishing grounds. The effects are difficult to assess because of the complexity of benthic communities and their temporal and spatial variations, and interpretation can 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 depends on sediment type, currents, and wave action (if any). Bottom trawling can also alter natural sediment fluxes and reduce the depth of the oxic layer in sediments (Churchill 1989, Warnken et al 2003, Bradshaw et al 2012), and trawling can modify 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 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 such 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 such changes 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). Hard-bottom fauna is predicted to recover most slowly and Williams et al (2010) concluded that hard-bottom fauna on seamounts did not show signs of recovery within 5–10 years on Australasian seamounts. Recovery rate is typically correlated with the spatial extent of a disturbance event (e.g., Hall 1994, Kaiser et al 2003, see also Figure 9.4) 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).

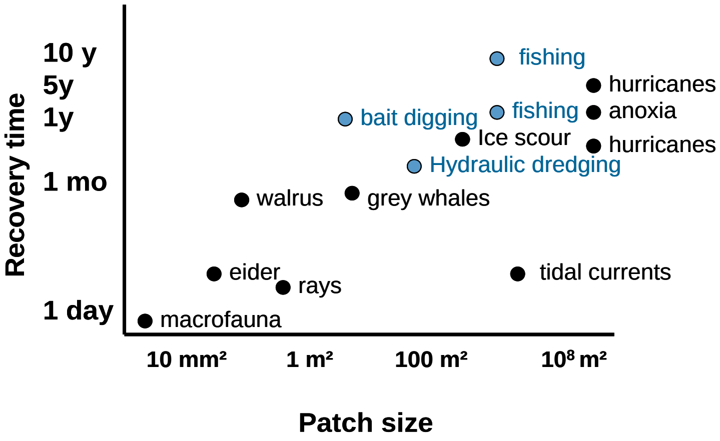


Figure 9.4: General relation between the spatial extent of disturbance events and the time taken to recover from such events in marine systems (after Kaiser et al 2003). Blue dots signal human impacts, including fishing in habitats of different abilities to recover, and black dots signal natural disturbance.

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., Jennings 2002, Hermsen et al 2003, Reiss et al2009) 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 and 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 and 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. Lundquist et al (2007, 2010) 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.

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 on

- 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, and 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 9.5, 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 in 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 all out-performed the original MEC for demersal fish, particularly at lower levels of classification detail and 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:
http://www.mfe.govt.nz/environmental-reporting/report-cards/seabed-trawling/2010/index.html).

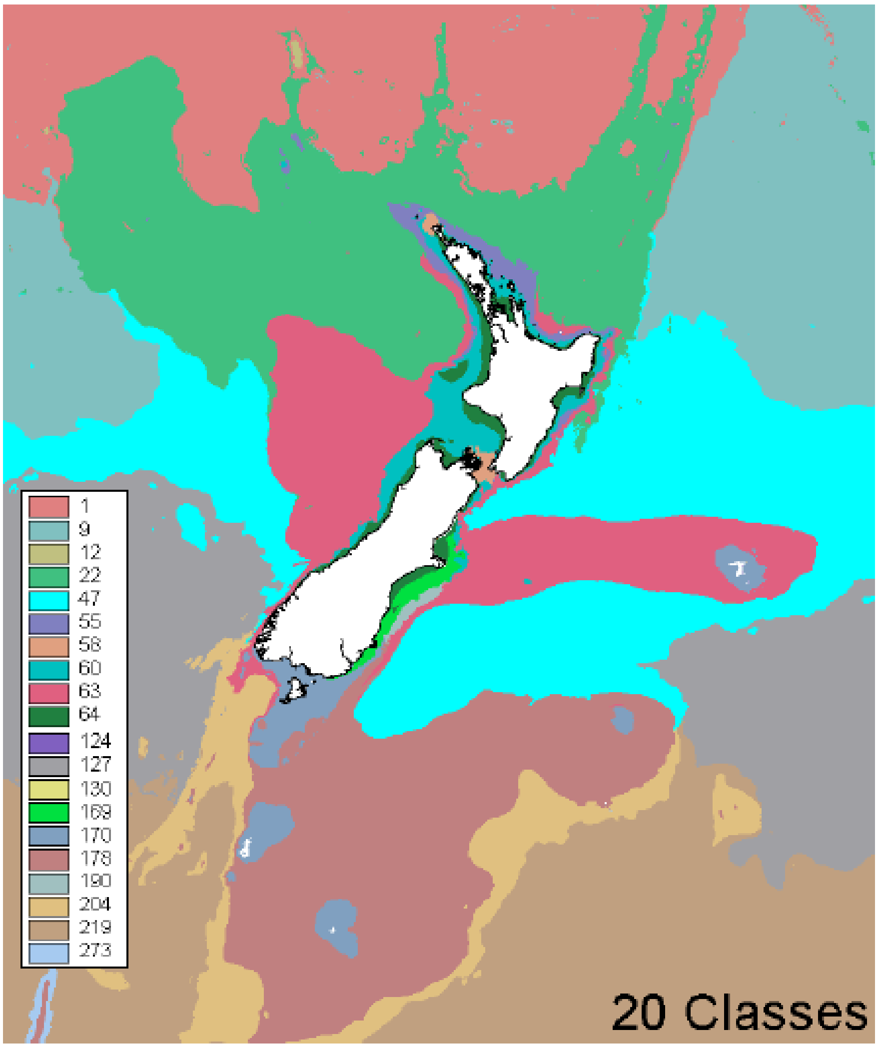


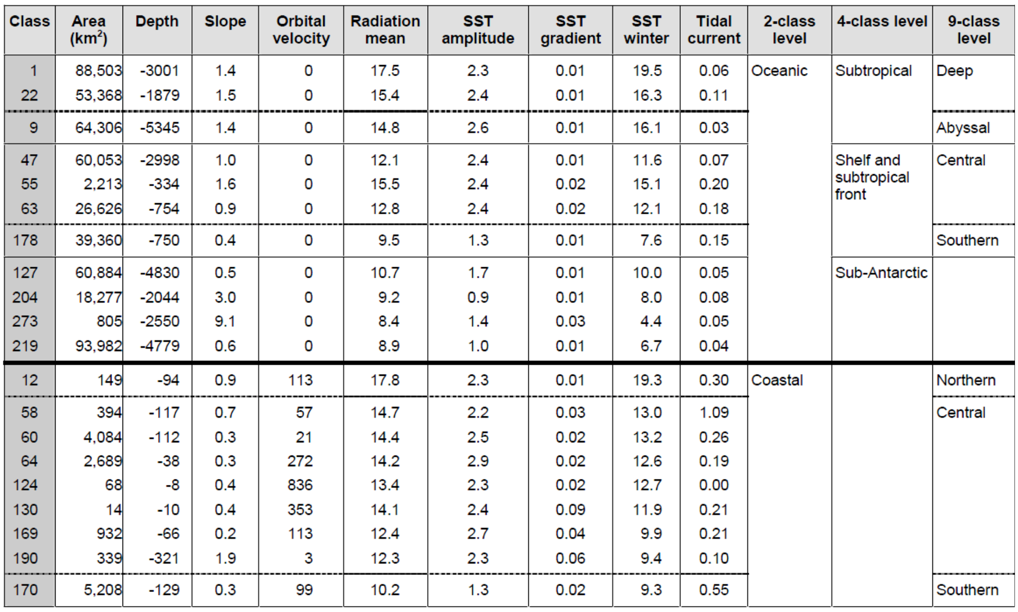
Figure 9.5: The 20-class version of the 2005 general purpose Marine Environment Classification (MEC, from Snelder et al 2005). The class numbers are nominal; for attributes of each class at this level, see Table 9.1.

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, 2006, 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 (Figure 9.6) 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.

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 (10s 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 hundres 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 and O'Driscoll 2003, O'Driscoll and 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), and Davies and 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. MPI project DEE2010/06 has been commissioned to design a monitoring programme to assess trends in deepwater benthic communities using information from trawl surveys, observers, and directed sampling. MPI project DEE2010/05 has been commissioned to develop a suite of environmental indicators for deepwater fisheries using, to the extent possible, existing data collection processes. This is an area of rapid change in the science and better techniques and data sets for predicting and mapping marine benthic habitats are likely to become available in the short to medium term. MPI project BEN2012/01will use existing information and classifications to describe the distribution of benthic habitats in the coastal zone. 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

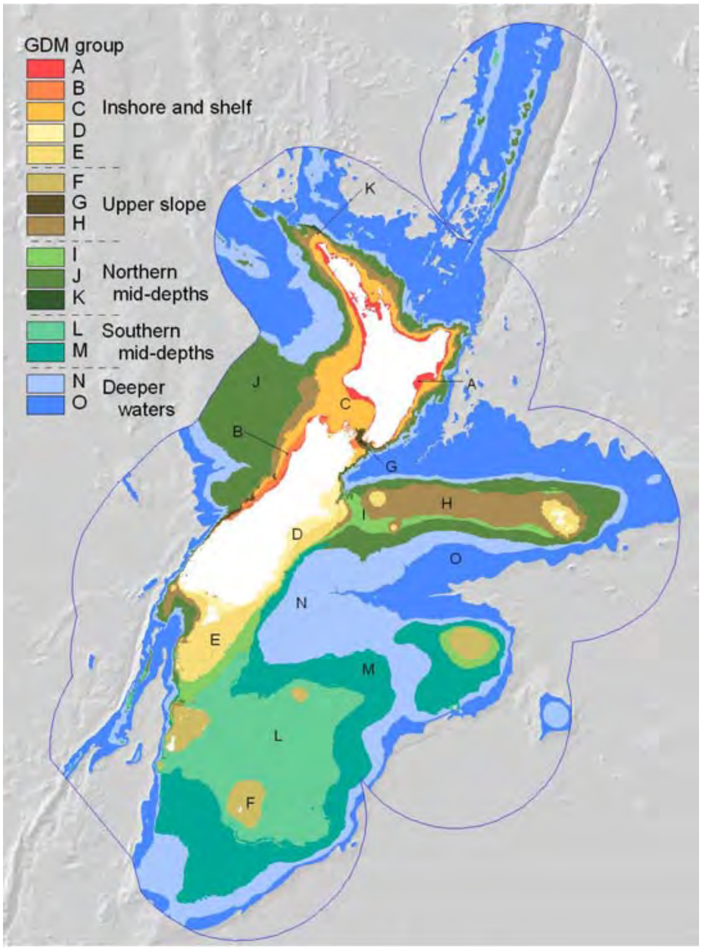


Figure 9.6: Map of the distribution of Benthic Optimised Marine Environment Classification (BOMEC) classes defined by multivariate classification of environmental data transformed using results from GDM analyses of relationships between environment and species turnover averaged across eight taxonomic groups of benthic species. From Leathwick et al 2010.

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 (Figure 9.8); 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). MPI project BEN2012/01will update the work in BEN2006/01 producing maps of swept area and footprint for more recent years.

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 (2001) 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. 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 SubAntarctic 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 and Hartill (2002) estimated that, in the Bay of Plenty, 78%, 75%, and 39% of trawl tows for tarakihi, gemfish, and hoki, respectively, were reported on CELR forms in the 1990s. Since 2007/08, almost all trawling effort has been reported on TCEPR or TCER forms.

Baird et al (2011) calculated three annual measures of fishing effort: the number of tows, the aggregate swept area (using assumed door spreads, see Figure 9.7), 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). Baird et al (2011) produced maps of the aggregate swept area by year for each of the 22 main target species or species groups, and various tables and figures describing trends. The annual number of trawls peaked in 1997–98 at 78 610 tows (swept area ~ 180 450 km^2). In 2007/08, fewer than 55 000 tows were reported on TCEPRs (~ 130 800 km^2)

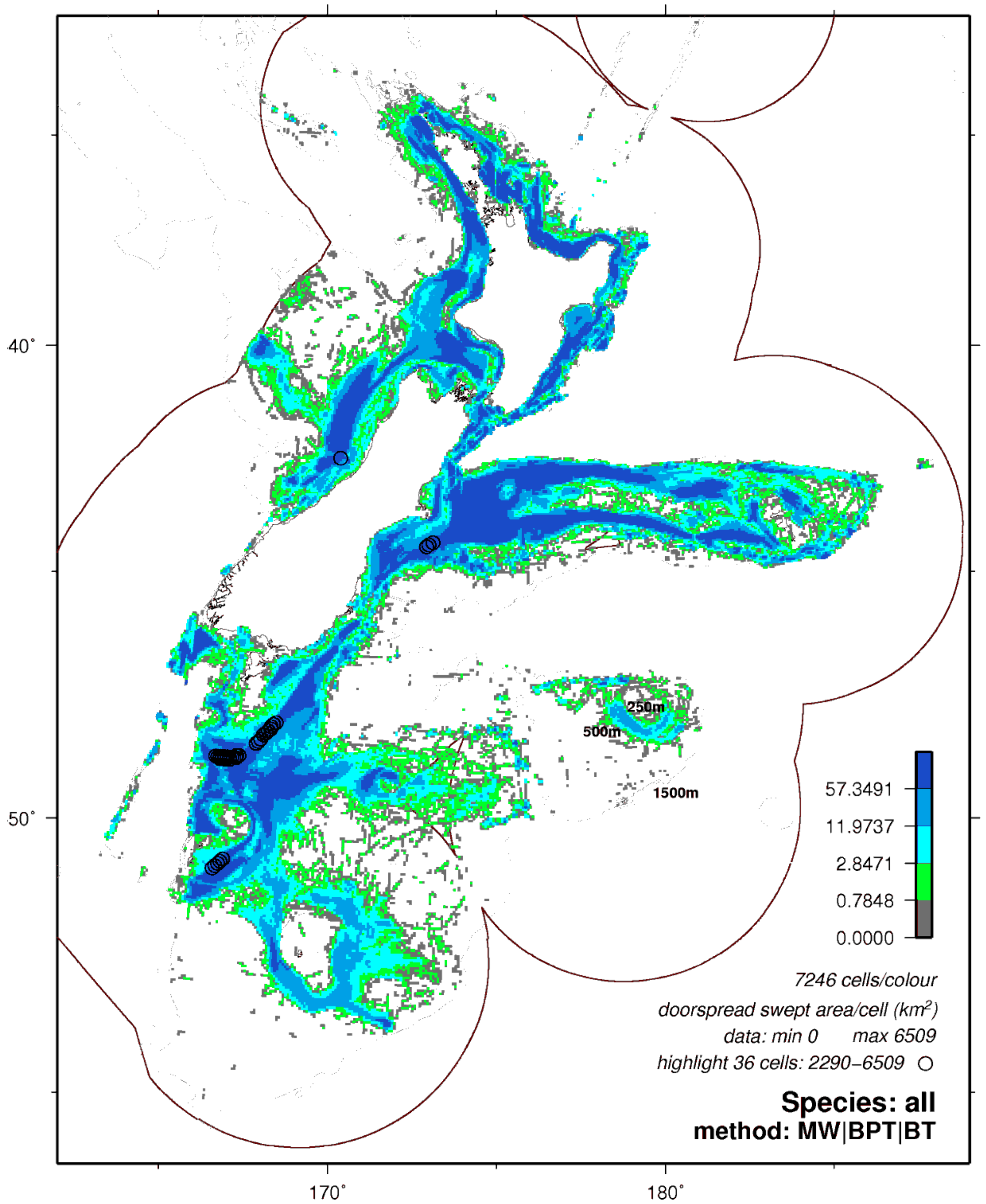


Figure 9.7: Map from Baird et al 2011 showing the intensity of bottom-contacting trawling effort reported on TCEPR forms 1989–90 to 2004–05. The colour scale indicates the aggregate swept area estimated by Baird et al for each 5 x 5 km cell, all target species combined (e.g., the 36 most intensively fished 25 km^2 cells all had an aggregate swept area of over 2290 km^2 over 16 years, which translates to the seabed in those cells being swept by some part of a trawl 92 times in 16 years, or an average of 5.8 or more times each year). Updates for deepwater trawl fisheries are expected in 2013.

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 9.7, yet can represent intense fishing effort on particular, small seamount features (e.g. Rowden et al 2005, O'Driscoll and Clark 2005).

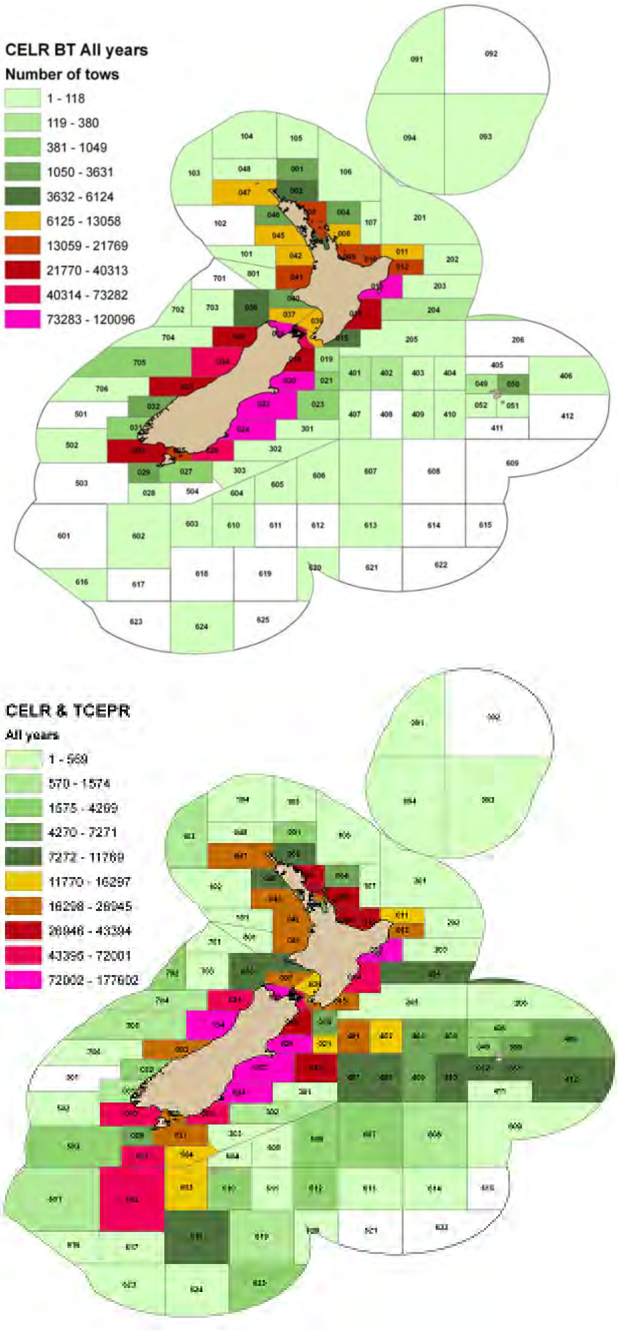


Figure 9.8: Broad-scale distribution from Baird et al 2011 of bottom trawl effort reported on CELRs (left) and on CELRs and TCEPRs combined (right), for all fishing years 1989–90 to 2004–05. Updates for deepwater trawl fisheries (but not inshore fisheries reporting on TCER) are expected in 2013.

After the peak of over 140 000 reported trawl tows in 1996/97 and 1997/98 (Figure 9.9) when slightly over half of all tows were reported on TCEPRs, overall trawling effort declined to less than 100 000 tows per year by 2006/07. The reported number of trawl tows has remained relatively stable at about

85–90 000 tows per year, only about 44% 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 9.10). 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 9.11).

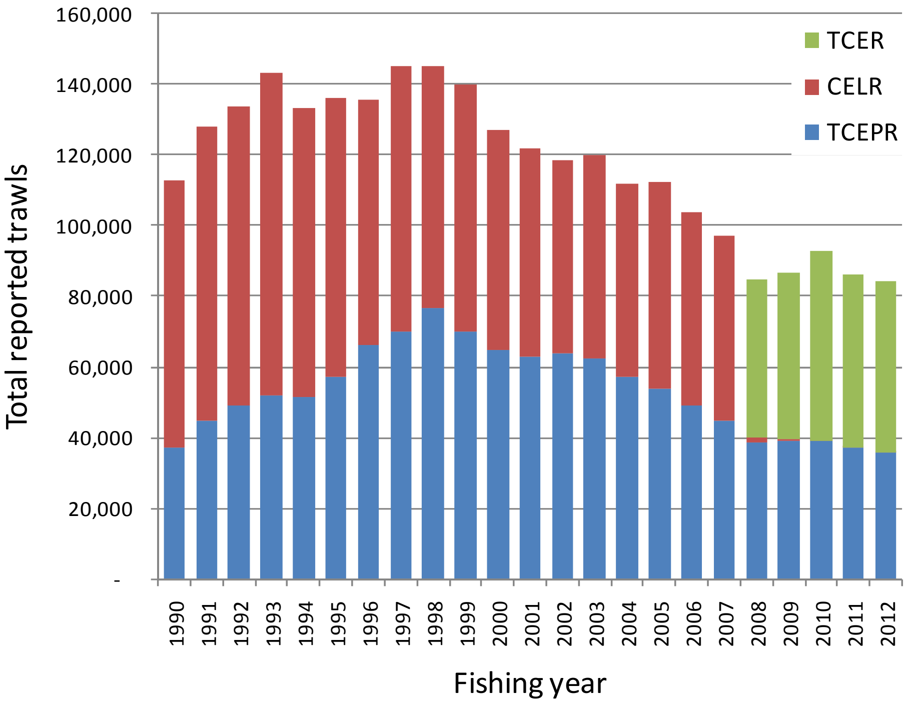


Figure 9.9: The number of trawl tows reported on Trawl Catch Effort and Processing Returns (TCEPR), Catch Effort and Landing Returns (CELR) and Trawl Catch and Effort Return (TCER) between the 1989/90 and 2007/08 fishing years. Data for the 2011/12 year may be incomplete.

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.

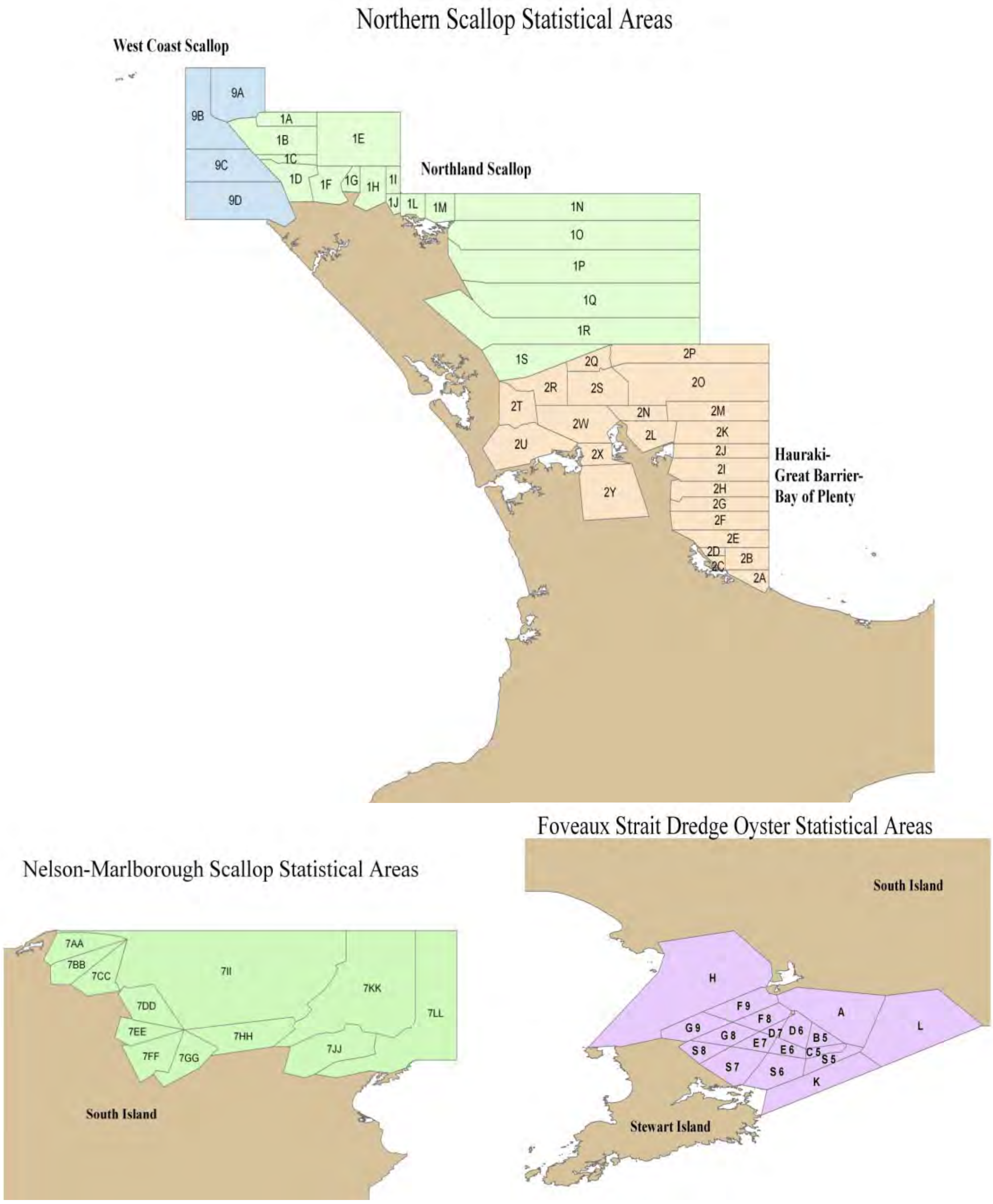


Figure 9.10: Maps taken from Baird et al 2011 of statistical reporting areas for the main oyster and scallop dredge fisheries (scales differ). Note that these reporting areas are generally much smaller than the standard statistical reporting areas used for most finfish reporting.

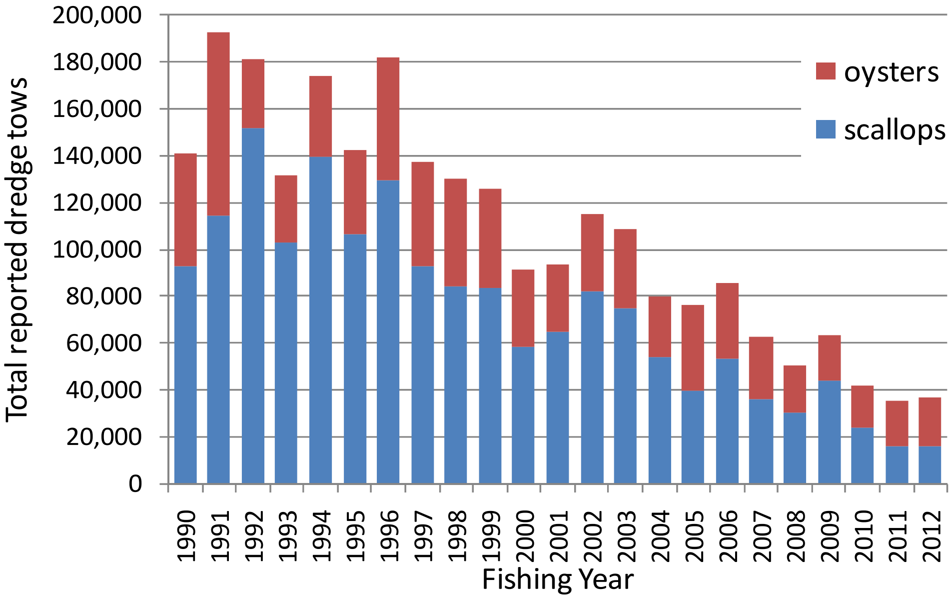


Figure 9.11: The number of dredge tows for scallop or oysters reported on Catch Effort and Landing Returns (CELR) between the 1989/90 and 2007/08 fishing years (data from Baird et al 2011 and MPI databases). Data for the 2011/12 year may be incomplete.

9.3.3. Overlap of Fishing and Predicted Habitat Classes

Baird and Wood (2010, project BEN200601) overlaid the 16-year trawl footprint up to 2004-05 on the 15-class BOMEC to estimate the proportion of each class that had been trawled (and reported on TCEPRs). They found that the size of the footprint and the proportion of each class trawled varied substantially between habitat classes (Figure 9.12, 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 about 70% of the total class area. Two contrasting classes, together with their trawl footprints, are shown in Figure 9.13. The cumulative trawl footprint from Baird and Wood's analysis overlaps about 8% of the 4.1 million km^2 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. This analysis is being updated for offshore (middle depth and deepwater) trawl fisheries under project DAE2010/04, *Monitoring the trawl footprint for deepwater fisheries*, and the results are expected to be available in early 2013. MPI project BEN2012/01, *Spatial overlap of mobile bottom fishing methods and coastal benthic habitats*, will update the work in BEN2006/01, particularly focussing on the overlap between fishing and habitats in the coastal zone.

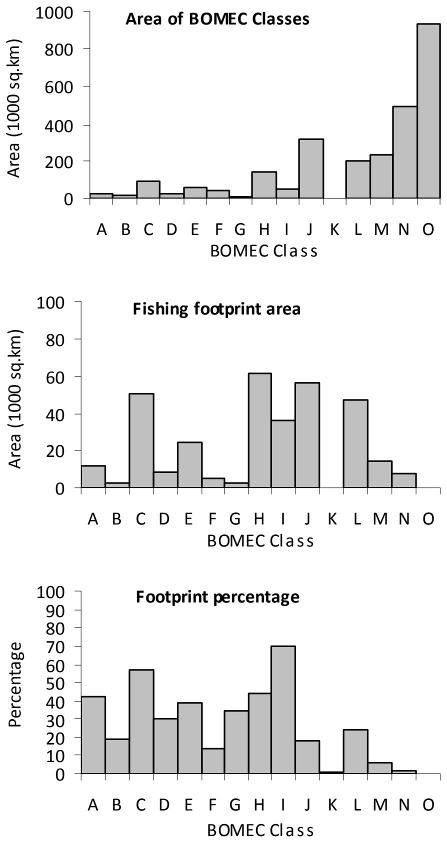


Figure 9.12: Plots from Baird and Wood (2010) of the areas of each BOMEC Class (top), the fishing footprint up to 2004/05 shown in Figure 9.8 (centre), and percentage of each BOMEC Class area covered by the fishing footprint (bottom).

Table 9.3: Estimated area of each BOMEC class (within the outer boundary of the EEZ), the minimum and maximum values for the trawl footprint in each, and cumulative footprint over the 16 years studied by Baird and Wood (2010).

BOMEC class	Area (km^2)	Min. annual footprint area (km^2)	Max. annual footprint area (km^2)	Cumulative (16 yr) proportion overlapped
A*	27 557	121	4 026	0.42
B*	12 420	40	484	0.19
C*	89 710	4 271	11 374	0.58
D*	27 268	377	1 602	0.30
E*	60 990	4 046	7 108	0.40
F	38 608	517	1 391	0.13
G	6 342	132	833	0.34
H	138 550	9 583	20 344	0.45
I	52 224	5 511	18 016	0.70
J	311 361	10 469	15 975	0.18
K	1 290	-	2	0.01
L	198 577	4 238	13 599	0.24
M	233 825	895	4 390	0.06
N	493 034	601	1 054	0.02
O	935 315	2	28	0.00
TS & EEZ	4 115 806	46 300	90 940	0.08

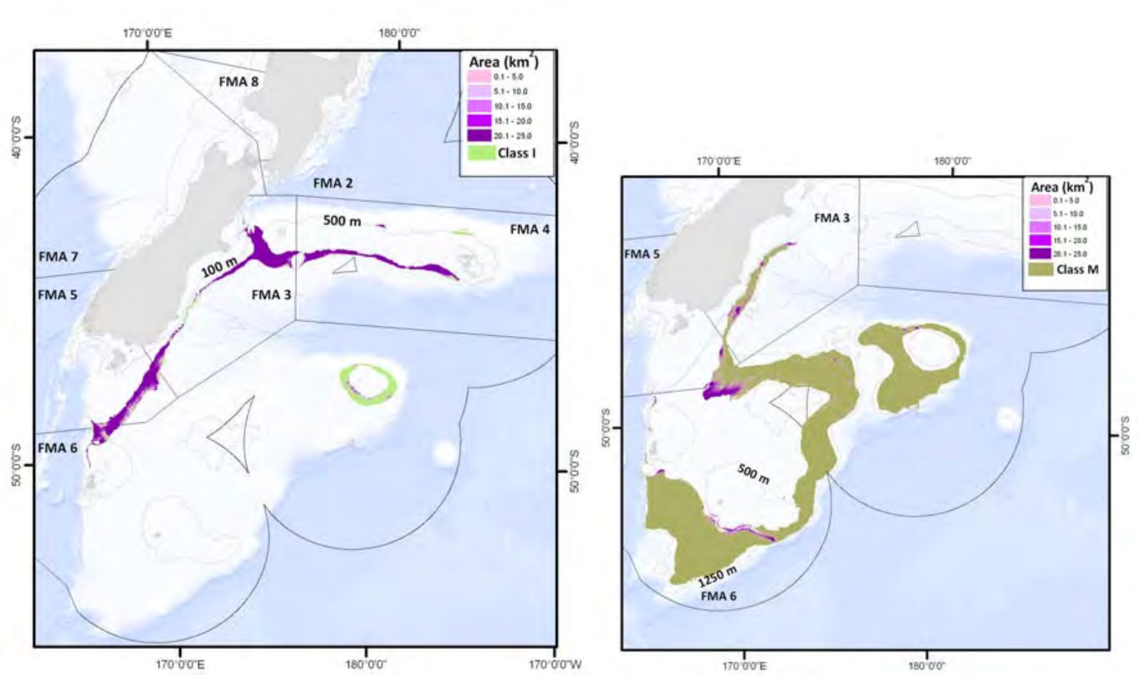


Figure 9.13: Maps from Baird and Wood (2010) showing BOMEC classes I (left) and M (right) overlaid with the footprint of trawls on or near the seafloor reported on TCEPR forms to 2004–05 for each 25-km^2 cell.

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 9.4). 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, however, 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 typical of 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 ceasing fishing) 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 9.4: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters.

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 & 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
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 & 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 &	Observational, gradient	In 1999, depth was found to be the most important explanatory variable for benthic community composition but a coarse index of	Cryer et al 2000

biogenic areas. Scallop dredge.	analysis	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 among 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.	Tuck et al 2009 Tuck & Hewitt 2012
Tasman & Golden Bays. Bottom trawl, scallop & 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
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 & 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.

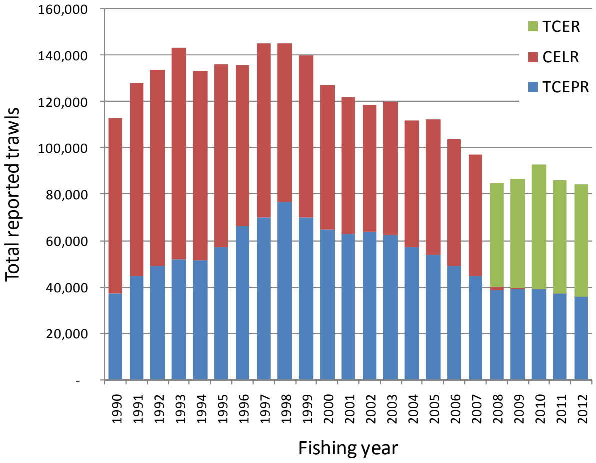
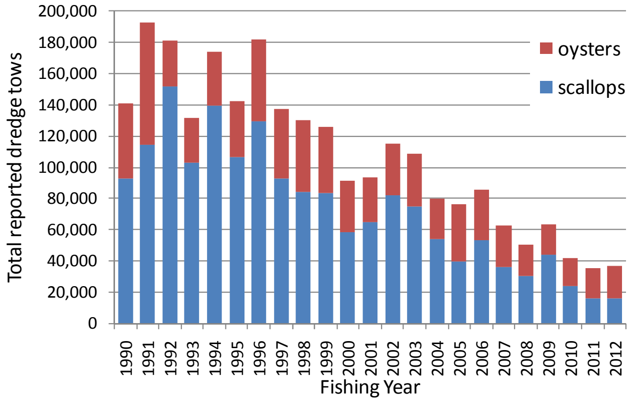
Project DAE2010/04 provides for an annual assessment of the “footprint” of middle depth and deepwater trawl fisheries, including the overlap of the footprint with various depth ranges and habitat classes. Inshore fisheries, including shellfish dredge fisheries, are not covered under this project, so the focus is on offshore fisheries and habitats.

Project DEE2010/05 provides for the development of a suite of ecosystem and environmental indicators for deepwater trawl fisheries. The focus of this study is on developing a cost-effective approach to monitoring ecosystem status (e.g., providing a mechanism to detect ocean climatic changes or regime shifts that could affect fisheries production) or the potential effects of deepwater trawl fisheries (such as changes to benthic invertebrate diversity). The suite could include information that may stem from project DEE2010/06 which provides for a desk-top assessment of the extent to which information can be collected cost-effectively on trends in benthic systems inside and outside of the trawled areas.

Project BEN2012/01will use existing data and classifications to describe the distribution of benthic habitats, estimate the sensitivity to fishing disturbance of the species within these habitats, and then describe the spatial pattern of fishing using bottom trawls, Danish seine and dredges, to assess the overlap with each habitat class.

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 effort stable, dredge effort decreasing:  

Annual and cumulative (16 year) overlap of BOMEC habitat classes up to 2004/05

This analysis will be updated for deepwater trawl fisheries in 2013

BOMEC class	Area (km^2)	Min. annual footprint area (km^2)	Max. annual footprint area (km^2)	Cumulative (16 yr) proportion overlapped
A*	27 557	121	4 026	0.42
B*	12 420	40	484	0.19
C*	89 710	4 271	11 374	0.58
D*	27 268	377	1 602	0.30
E*	60 990	4 046	7 108	0.40
F	38 608	517	1 391	0.13
G	6 342	132	833	0.34
H	138 550	9 583	20 344	0.45
I	52 224	5 511	18 016	0.70
J	311 361	10 469	15 975	0.18
K	1 290	-	2	0.01
L	198 577	4 238	13 599	0.24
M	233 825	895	4 390	0.06
N	493 034	601	1 054	0.02
O	935 315	2	28	0.00
TS & EEZ	4 115 806	46 300	90 940	0.08

* the trawl footprint and proportion overlapped in coastal classes A–E will be grossly underestimated because CELR data are excluded.

9.5. *References*

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THEME 4: ECOSYSTEM EFFECTS

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 covered	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 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 Fisheries 2030 and MPI's Our Strategy	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 issues and/or Chapters	• 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.

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).

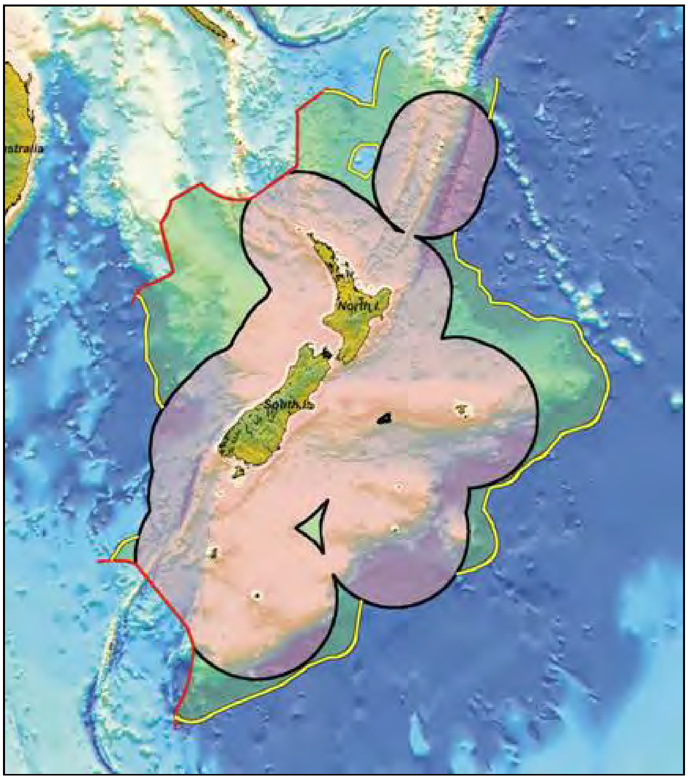

Figure 10.1: New Zealand land mass area 250 000 km^2; EEZ & territorial sea area (pink) 4 200 000 km^2; extended continental shelf extension area (light green) 1 700 000 km^2; Total area of marine jurisdiction 5 900 000 km^2. The black line shows the boundary of the New Zealand EEZ, the yellow line indicates 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.

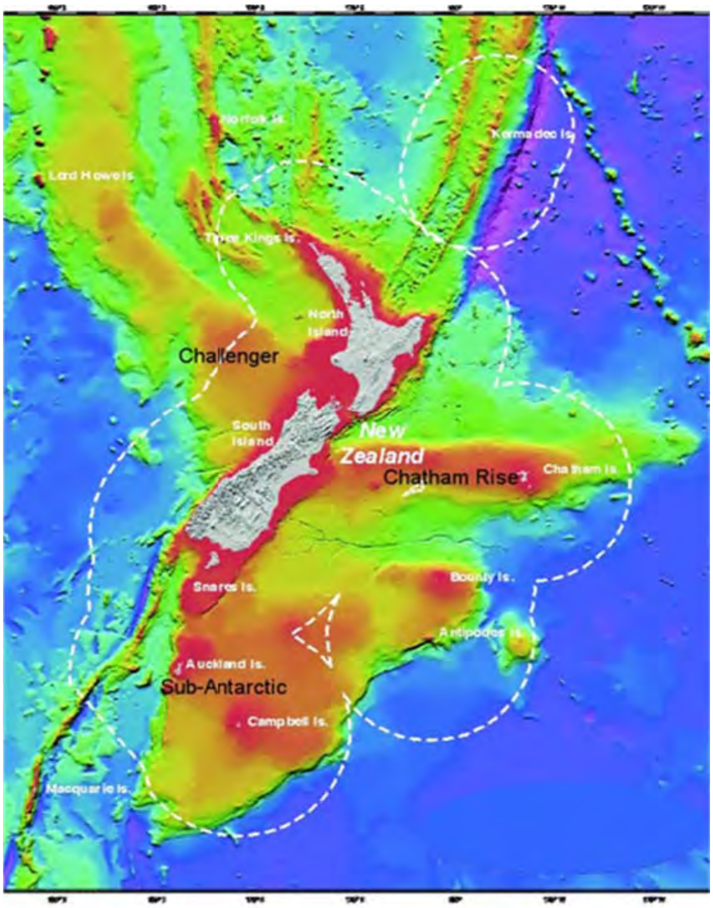

Figure 10.2 Undersea topography of New Zealand (red shallow to blue deep). White dashed line shows the EEZ boundary. Image courtesy of NIWA.

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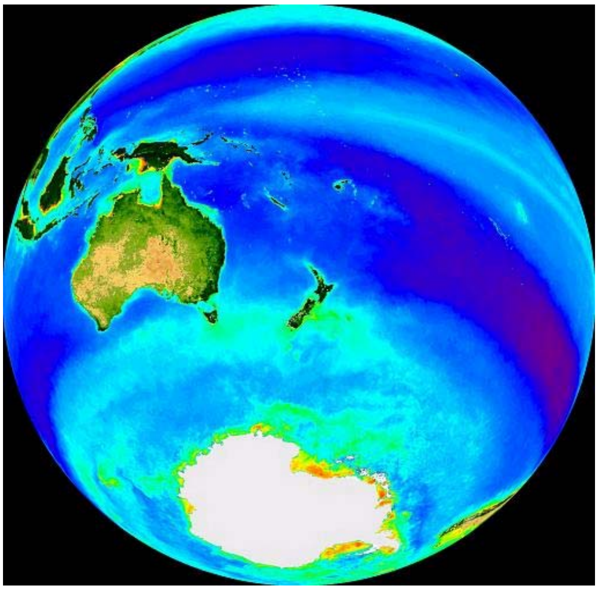

Figure 10.3: SeaWIFS image showing elevated chlorophyll a (green) near New Zealand. Image courtesy of NOAA.

The strongest chlorophyll *a* and ocean colour are associated with the coastal shelf around New Zealand and the Chatham Rise (Figure 10.3 and 10.4 left 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).

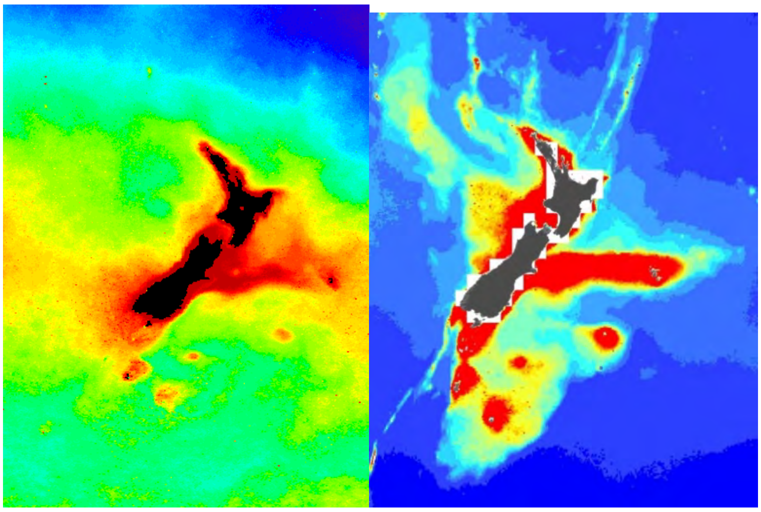

Figure 10.4: Left panel: Ocean colour in the New Zealand region from satellite imagery. Red shows the highest intensity of ocean colour typically associated with higher primary productivity. Right panel: The relative concentrations of particulate organic carbon (POC) that reach the seafloor. Red shows 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 right 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 right 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).

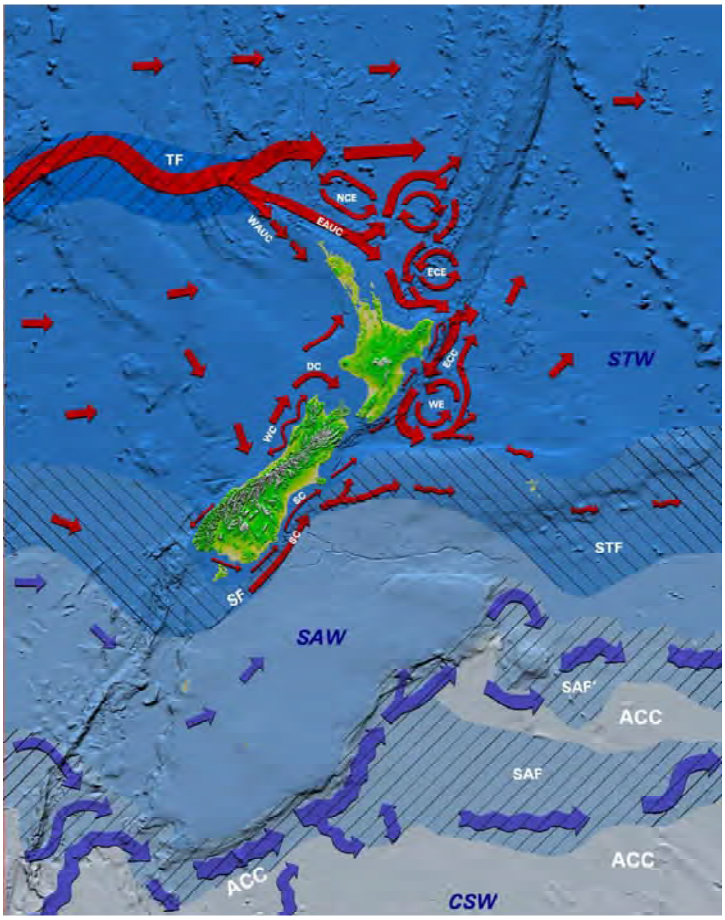

Figure 10.5: Circulation around New Zealand. TF Tasman Front (large red arrows), WAUC West Auckland Current, EAUC East Auckland Current, NCE North Cape Eddy, ECE East Cape Eddy, ECC East Cape Current, WE Wairarapa Eddy, DC D'Urville Current, WC Westland Current, SC Southland Current, SF Southland Front, 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).

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.

Indicators and trends

10.1.1. 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).

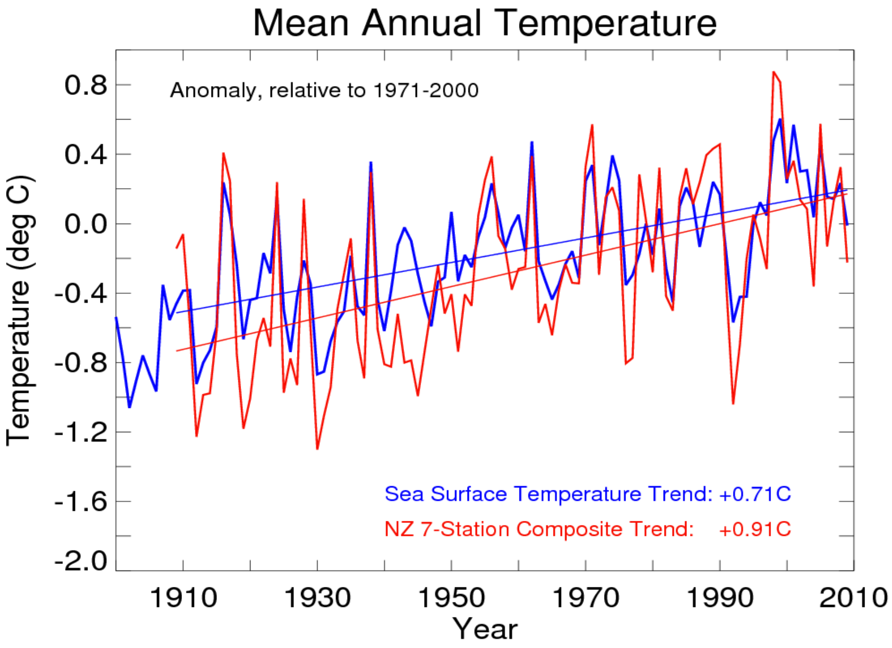

Figure 10.6: Annual time series in New Zealand. NOAA annual mean sea surface temperatures (blue line)[53] and NIWA's seven-station annual mean air temperature composite series (red line), expressed as anomalies relative to the 1971-2000 climatological average. Linear trends over the period 1909-2009, in °C/century, are noted under the graph. (Image Source Mullan et al 2010)

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

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[53] http://www.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php

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).

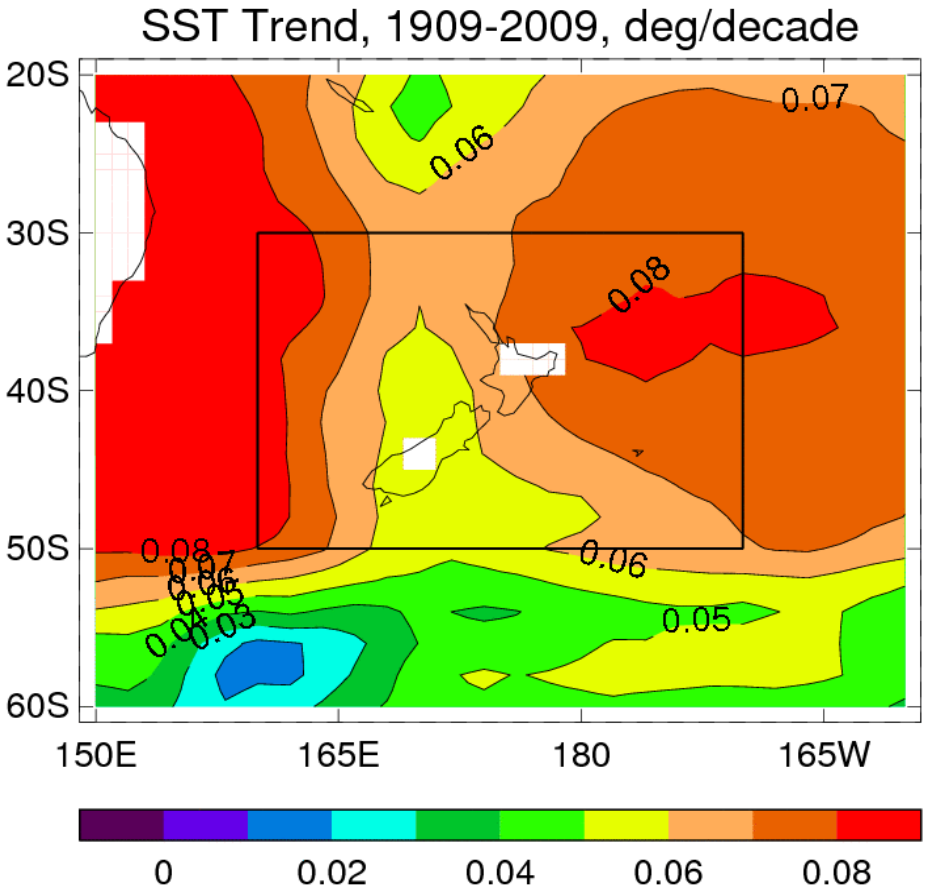

Figure 10.7: Trends in sea surface temperature, in °C/decade over the period 1909–2009, calculated from the NOAA_ERSST_v3 data-set (provided by NOAA's ESRL Physical Sciences Division, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/). The data values are on a 2° latitude-longitude grid. (Image Source Mullan et al 2010.)

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.

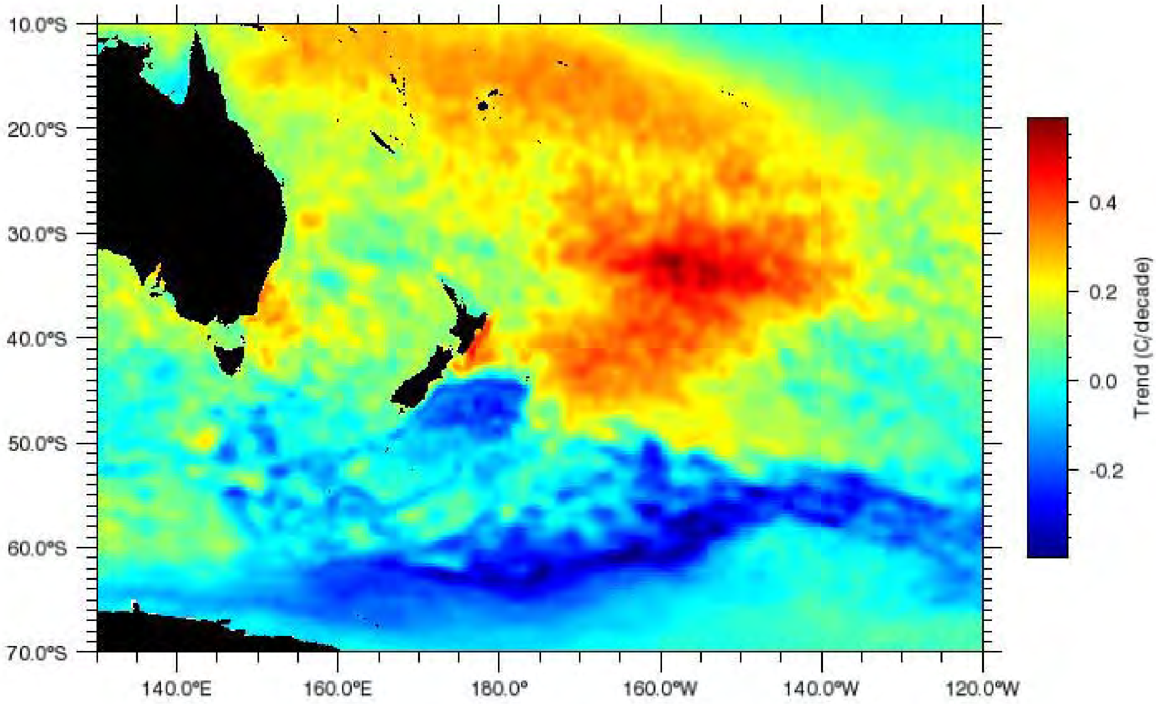

Figure 10.8: Trends in sea surface temperature, in °C/decade over the period 1982–2009. The data are from NOAA based on daily interpolated satellite measurements over a 0.25° grid. See http://www.ncdc.noaa.gov/oa/climate/research/sst/oi-daily.php. (after Reynolds et al (2007).

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).

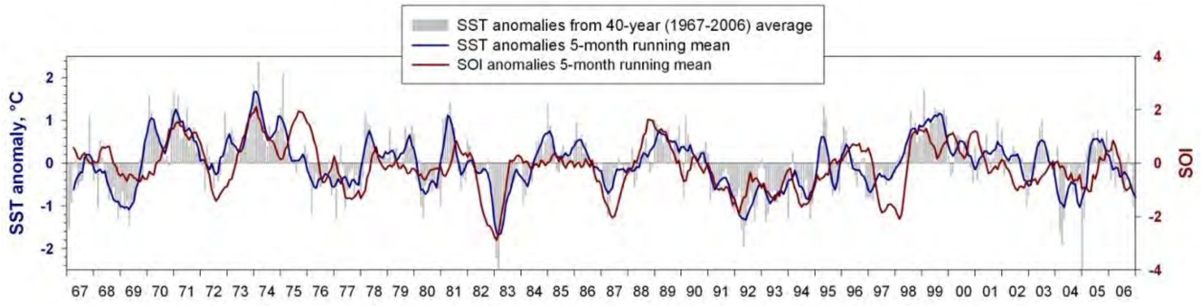

Figure 10.9: Sea surface temperature (SST) anomalies from SST measurements at Leigh (Auckland University Marine Laboratory) and Southern Oscillation Index (SOI) anomalies. (Image from Hurst et al 2012).

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.

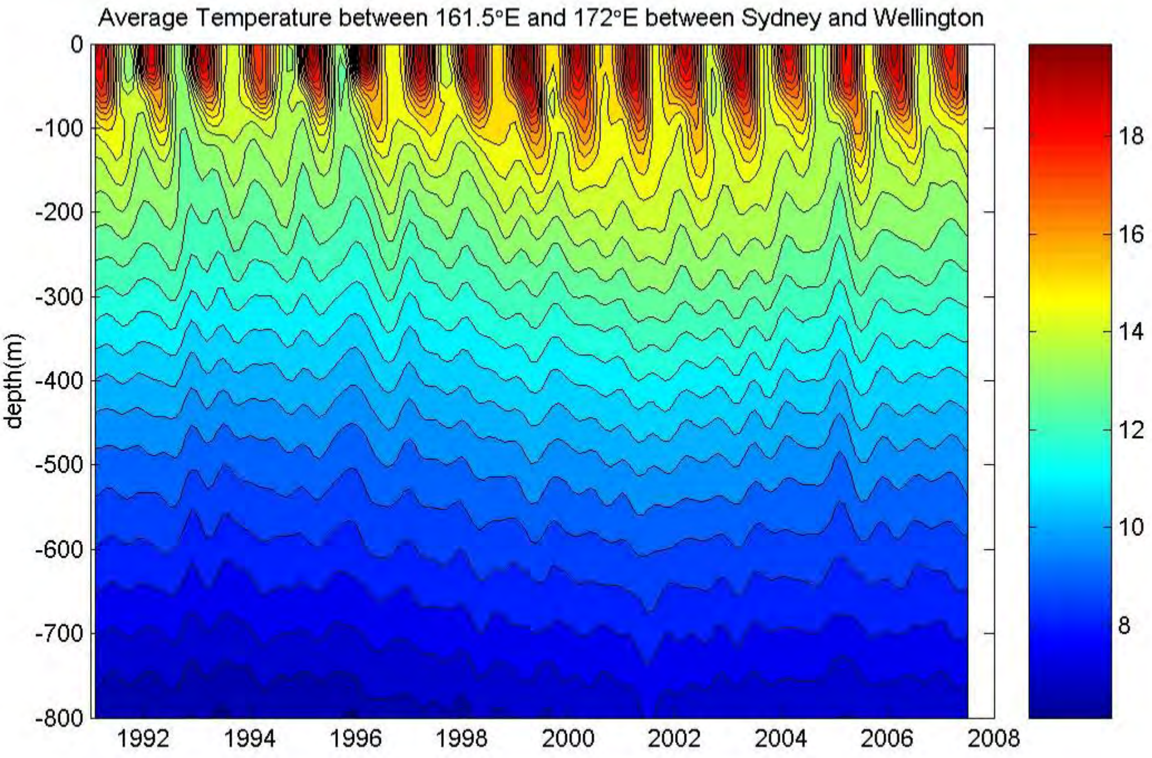

Figure 10.10: Eastern Tasman ocean temperature: Wellington to Sydney 1991–2008. Coloured scale to the right is temperature °C. (Image from Hurst et al 2012, after Sutton et al 2005).

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.

10.1.2. 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).

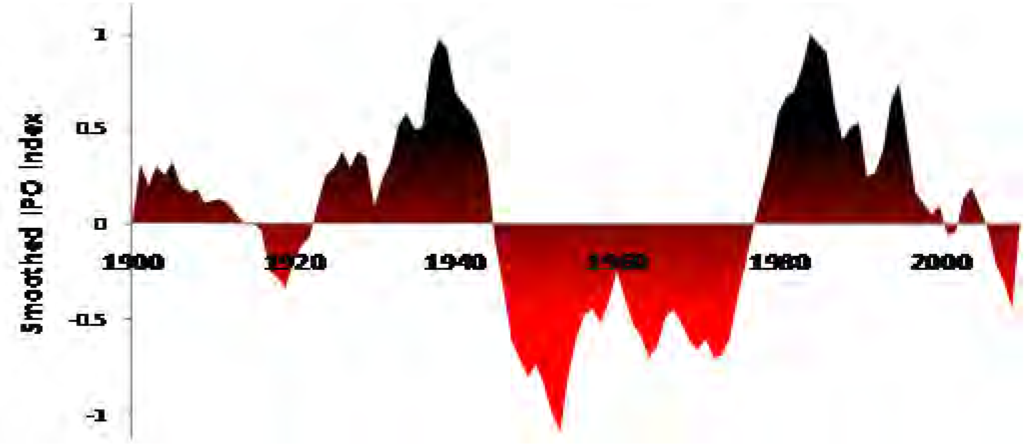

Figure 10.11: Smoothed index of the Interdecadal Pacific Oscillation (IPO) since 1900. (Image source NIWA based on data from the United Kingdom Meteorological Office, UKMO).

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).

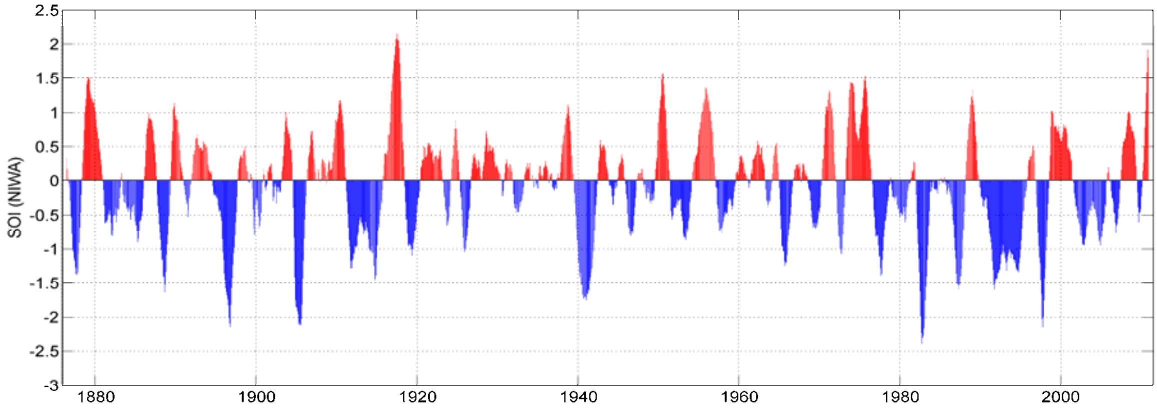

Figure 10.12: Southern Oscillation Index (SOI) 13-month running mean 1876–2010. Red indicates warmer temperatures, blue indicates cooler conditions for New Zealand. (Image courtesy of NIWA.)

10.1.3. Water Chemistry: Ocean acidification

An increase in atmospheric CO_2 since the industrial revolution has been paralleled by an increase in CO_2 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 CO_2 signal is apparent to an average depth of about 1000 m.

The increasing rate of CO_2 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 H_2O 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 CO_2 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 pCO_2 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 pCO_2 shows some indication of an increase although this is not linear and does not correlate with a rise in atmospheric CO_2 (Figure 10.13).

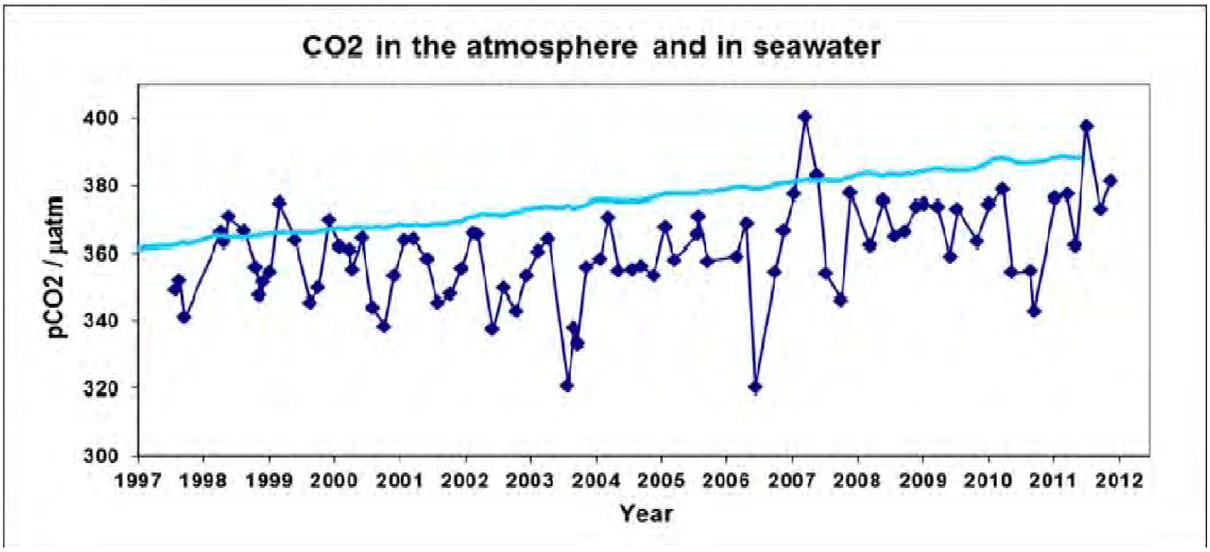

Figure 10.13: pCO_2 (partial pressure of $CO_{2)}$ in subantarctic surface seawater from the *R.V. Munida* transect, 1998–2012. (Image courtesy of K. Currie, NIWA).

The Munida time-series pH data shows a decline in subantarctic surface waters since 1998 (Fig 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 CO_2 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.

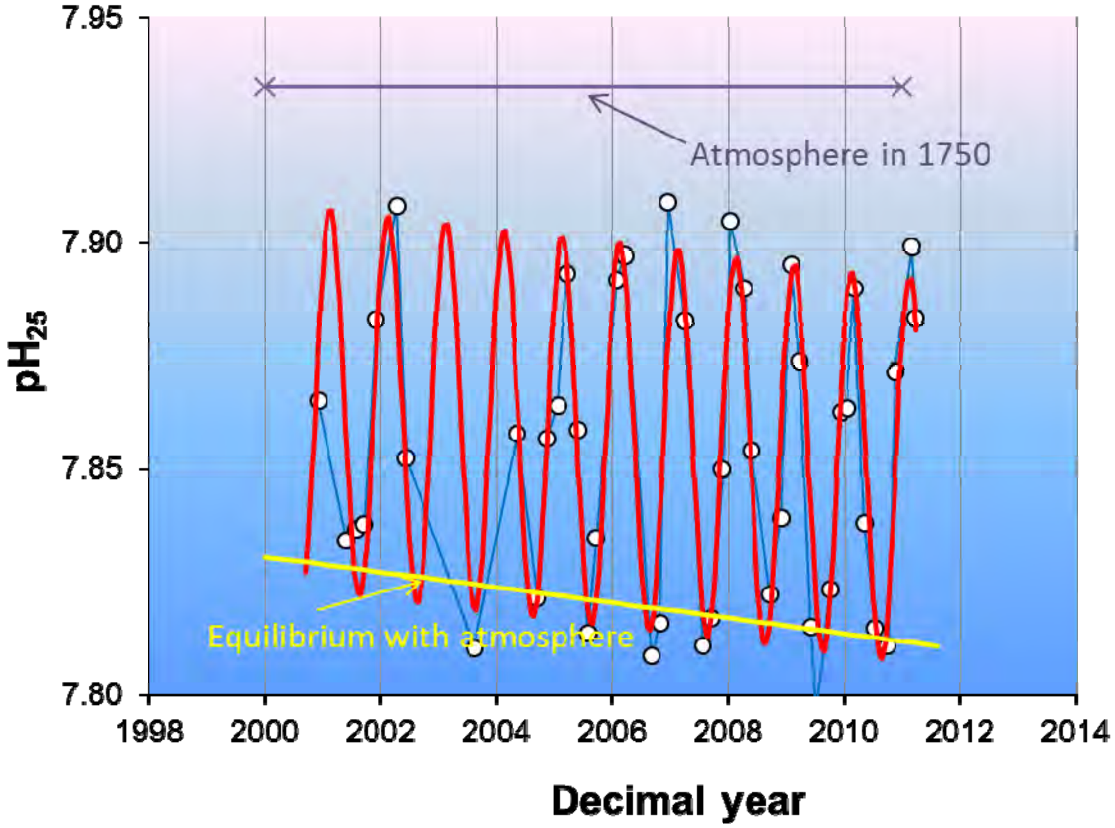

Figure 10.14: pH in subantarctic surface seawater on the *R.V. Munida* transect, 1998–2006. The blue points and joining lines are the actual measurements, and the red line a best fit to the points using a sine wave function (to represent seasonal change). The black line represents pH assuming equilibrium with the atmosphere concentration in

the Year 1750. The yellow line is the pH assuming equilibrium with actual CO_2 concentrations measured at the NIWA Baring Head Atmospheric Station. pH^{25} is the pH measured at 25^{o}C (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 pCO_2 (partial pressure of CO_2) and decreasing pH, with the pCO_2 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 CO_2 measurements, the short record of the Munida Subantartcic Water time series shows pCO_2 and pH in surface seawater (see Figure 10.14) tracking the atmospheric CO_2 (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).

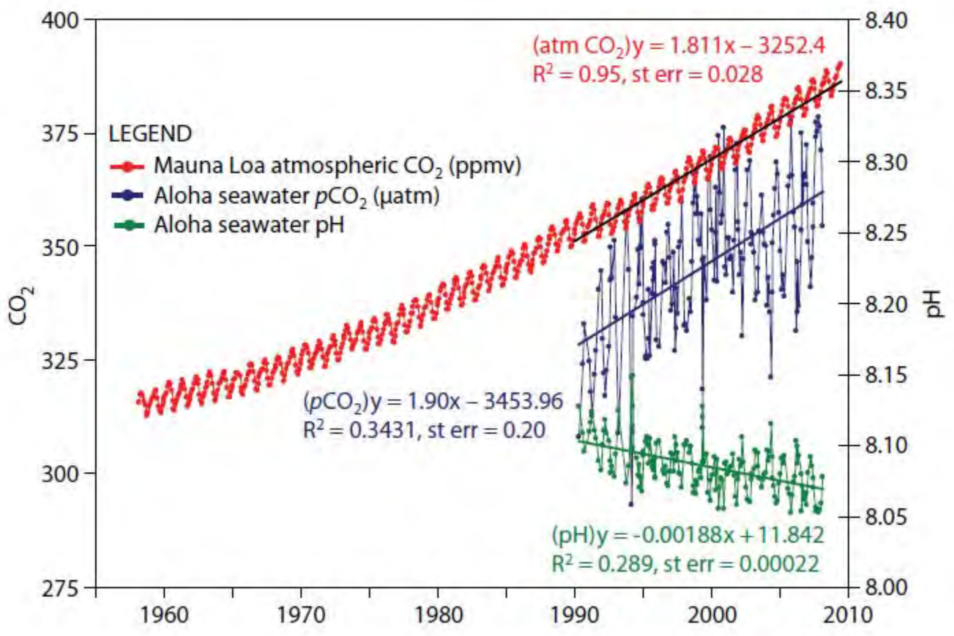

Figure 10.15: Time series of atmospheric carbon dioxide at Moana Loa, seawater carbon dioxide and surface ocean pH at Ocean station ALOHA in the subtropical North Pacific Ocean near Hawaii. pH is shown as *in situ* pH, based on direct measurements and calculated from dissolved inorganic carbon and alkalinity 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 pCO_2, 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 pCO_2 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.

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 CO_2 has been paralleled by an increase in CO_2 concentrations in the upper ocean, resulting in a decrease in pH. Maintenance of the one existing New Zealand monitoring programme for pH and pCO_2, 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.

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11. 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 inshorefinfish 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.

11.1. *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:*
> *(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:*

(c) 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 location or 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 the 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 that showed movement away from this area into nearby fished areas (Booth 1979).

- The largest legislated closure are the Benthic Protection Areas (BPAs) which protect ~ 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 (DeepWater 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 November the first until the 30th of April each year in Tasman Bay.
    - A closure to commercial potting exists for all of CRA3 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 implementing these outcomes and objectives.

11.2. *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.

11.2.1. **Habitats protected elsewhere for fisheries management**

Certain habitats have been identified as important for marine species: 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 2010). 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 (West 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 and Kendall 1991, Livingston 1990) these could also potentially qualify as HPSFM.

11.2.2. 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 as part of their structure, 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 and 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 uses estuaries as juveniles; e.g. blue grouper *Achoerodus viridis* (a large wrasse) (Gillanders and Kingsford 1996) and snapper *Pagrus auratus* (Hamer et al 2005) in Australia; and gag (*Mycteroperca-Microlepis*) in the United States (Ross and 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 (shrimp and menhaden (a fish)) followed wetland losses and, conversely, stock gains followed increases in the area of wetlands (Turner and 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 (< 200 m) and distant from (> 500 m) mangroves. They found seagrass beds closer to mangroves had greater fish densities and diversities than more distant beds, especially for 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 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 migrate 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 and 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 lead to the conclusion that spatial protection performs best at enhancing species whose adults are relatively sedentary but whose larvae are broadcast widely (Chiappone and 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.

11.3. *State of knowledge in New Zealand*

11.3.1. 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 (< 200 m) and one deepwater (> 200 m). Coastally, these HPSFM areas were identified for 35 important fish species by Hurst et al (2000). This report concluded that virtually all coastal areas were important for these functions for one species or other. 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 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 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 ~ 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.

11.3.2. 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 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 and 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.

11.3.3. **Current research**

Prior to 2007 research within New Zealand has not been 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 are underway, or planned, 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 ~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 that synergy, work on the connectivity and stock structure of grey mullet (*Mugil cephalus*) is underway in collaboration with MFish 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.

MBIE also funded in 2012 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 survys of a range of habiatts that may be important for various life-history stages of commercial fish species: seamounts, canyons, continental slope, hydrothermal vents, seeps.

11.4. *Indicators and trends*

As no HPSFM are defined this section cannot be completed.

11.5. *References*

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12. 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 and nutrients.
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)	Habitats of particular significance for fisheries management: Kaipara Harbour (ENV2009/07), Toheroa abundance (TOH2007/03), Biogenic habitats as areas of particular significance for fisheries management (HAB2007/01), 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)	Ministry of Business, Innovation and Employment (MBIE) funded programs: (After the outfall: recovery from eutrophication in degraded New Zealand estuaries (UOCX0902). NIWA Core funding in two areas. Firstly, 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)’. Secondly, in the ’Fisheries’ Centre programme 3 which deals with ecosytem-based management approaches in conjunction with the ’Coasts and Oceans’ centre.
Links to 2030 objectives	Objective 8: Improve RMA fisheries interface. Objective 4: Support aquaculture development
Related chapters/issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring.

Note: No update has been made to this chapter since the AEBAR 2012.

12.1. *Context*

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).

Aquaculture and 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. 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[54]' (lead by MfE and MPI) is addressing a range of issues through a water reform strategy that includes governance, setting objectives and limits, managing within limits (quality and quantity) and that better reflects Maori/Iwi rights and interests in water management. 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.

Land-based effects on seafood production and supporting 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). 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). Sediment inputs are now high by world standards and make up ~1% of the estimated global detrital input to the oceans (Carter et al 1996). By contrast New Zealand represents only ~ 0.3% of the land area that drains into the oceans (Griffiths and Glasby 1985, Milliman and 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.

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[54] http://www.mfe.govt.nz/issues/water/freshwater/fresh-start-for-fresh-water/

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, amongst other reasons, due to their perceived role as nursery grounds for a variety of coastal fish species in 1980 (Grange et al 2003). Recent work has suggested 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.

The New Zealand aquaculture industry has an objective of developing into a billion dollar industry by 2025 (Aquaculture New Zealand 2012). 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.

MPI mainly manage in the marine environment, therefore this topic area will be dealt with first. MPI also manages the freshwater eel fishery; this will be dealt with latterly within relevant sections.

12.2. *Global understanding*

12.2.1. **Land-based influences**

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 and Perrault 2006, Piola and Johnston 2008). Studies that research a realistic mix of influences are rare.

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-stages and are dependant upon factors that include the duration, frequency and magnitude of exposure, temperature, and other environmental variables (Servizi and 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). These 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 and 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 and 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[55], 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 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[56]. 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 (i.e. wetland reclamation for agriculture), concentrated around urban areas and can have a number of consequences on the marine environment (Bulleri and 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 dealt with under the habitats of particular significance for fisheries management (HPSFM) section.

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[55] Accessible on the www.os2020.org.nz website.

[56] 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

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 cause a mass mortality in the Caspian sea in 2000 (Kennedy et al 2000)

12.2.2. **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 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 to result in improved 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).

12.3. *State of knowledge in New Zealand*

Land-based effects will be most pronounced closest to the land, therefore it is freshwater, estuarine, coastal, middle depths and deepwater fisheries, in decreasing order, that will be most affected. The scale of land-use effects will, however, differ depending upon the particular influence. The most localised of these 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 subsequently 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 the multiple stormwater discharges into the Waitemata harbour in Auckland (Hayward et al 2006). The largest influence 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 6km 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 and Glasby 1985, Hicks and 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 Waipaoa 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 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 50m. 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".

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 Hectors 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[57].

12.3.1. Completed research

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,

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[57] http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-tmp-discussion-document-full.pdf

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.

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 and Creese 1998). 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 and 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 of three heavy metals (Copper, lead and Zinc) in combination compared to isolation on infaunal colonisation of intertidal estuarine sediments (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). Although 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 those estuaries (Thrush et al In Press).

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 and Parkinson 2008). Current thinking suggests 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). 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 more research was needed on the impacts of vehicle traffic on the intertidal (Stephenson 1999). A four day study over a fishing contest on 90 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 and 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).

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 this paper to better define the effects on eel populations.

Rhodolith beds have been surveyed in the Bay of Islands and high diversity 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.

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.

The review of land based effects (Morrison et al 2009) 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.

12.3.2. **Current research**

A number of ongoing research projects exist that will improve the knowledge of land-based impacts upon seafood production. Project ENV2009/07 investigates habitats of particular significance for fisheries management within the Kaipara Harbour and one objective is to assess fishing and land-based threats to these habitats. Current research is investigating the impact of a range of influences upon toheroa at Ninety-Mile Beach (project TOH2007/03). Environmental factors, including land-based impacts (particularly vehicle use and changing land-use patterns) are implicated in poor recovery of this population since the closure of this commercial and recreational fishery in the 1960s. A MPI biodiversity project also has components that address land-based effects; the threats to biogenic habitats are addressed in project ZBD2008/01.

Research is also ongoing on land-use effects at a national scale. A national scale threat analysis is also being carried out for biogenic habitats, given their likely importance for fisheries management (project HAB2007/01). A Ministry of Business, Innovation and Employment (MBIE) funded project[58] of particular relevance is (project number and lead agencies in brackets): 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

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[58] http://www.msi.govt.nz/update-me/who-got-funded/

effects of diverting all of Christchurch's treated wastewater discharge from the eutrophied Avon-Heathcote (Ihutai) Estuary and the subsequent earthquake induced disturbances to this diversion.

Although not current research, the Department of Conservations suggested research priorities in the *"Review of the Maui's dolphin Threat management plan: Consultation paper"* include objectives to determine the presence, pathways and possible mitigation of the threat from *Toxoplasmosis gondii*[59].

12.4. *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 running 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[60], or summary reports such as the Hauraki Gulf state of the Environment 2011 report[61]. Water quality and associated communities may also be monitored for a regional council as part of a consent application or as a stipulation for a particular marine development. 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 places, e.g., the United Kingdom[62] 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. Possible national scale proxies for coastal faecal contamination may exist after collating information from sanitation area monitoring for shellfish harvesting or shellfish harvesting closure information.

Marine water quality indicators are available nationally from 407 coastal bathing beaches which have been monitored for human health issues, rather than environmental purposes, over the last six years[63]. No temporal trends were detectable in this relatively short time period, however changes in sites monitored over this time may have confounded this analysis. Over the 2007-8 and 2008-9 summers, 79% of the swimming sites met the guidelines for contact recreation almost all the time. At least 95% of the samples at these sites had safe *Enterococci* levels (which is an indicator of human and animal sewage). Two percent of the sites (located within the Manukau harbour and on the West coast of Auckland), breached the guidelines more than 25% of the time. In general, the most polluted sites were embayed locations with poor natural flushing.

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 8 variables: temperature, dissolved oxygen, visual clarity, dissolved reactive and total phosphorous, and ammoniacal, oxidised and total nitrogen (Ballantine and Davies-Colley 2009). Dissolved oxygen showed few meaningful trends and the ammoniacal nitrogen

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[59] http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-tmp-discussion-document-full.pdf

[60] http://maps.auckland.govt.nz/aucklandregionviewer/?widgets=HYDROTEL

[61] http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Coastal%20and%20marine/hgfstateoftheenvreport2011.pdf

[62] http://www.cefas.co.uk/data/marine-monitoring/national-marine-monitoring-programme-(nmmp).aspx

[63] http://www.mfe.govt.nz/environmental-reporting/freshwater/recreational/snapshot/coastal.html#results

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 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)[64]. The main sources of Nitrogen and Phosphorous were from pastoralism (70%) and erosion (53%), respectively. The dairy herd in New Zealand has approximately doubled (increased 211%) since 1981 (whilst other grazer numbers have been relatively stable or declining)[9]. The amount of Urea and Superphosphate (New Zealand's most common nitrogen and phosphorous fertiliser) have increased 27.7 and 1.6 fold, respectively over the same period[65]. The use of Urea is currently around 100 kg.ha^{-1} for dairying and ~10 kg.ha^{-1} for sheep and beef farms (MPI 2012). The area in dairy farming is ~ 2 million hectares compared to 3.6 million hectares for sheep and 2 million hectares in beef farming (MPI 2012). Therefore Urea use in New Zealand is dominated by the dairy industry. These statistics provide strong circumstantial evidence that the expansion in dairying is primarily responsible for these declines in water quality from agricultural sources.

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 areas 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, e.g. Inner Pelorus sound is likely to be closed more frequently than outer Pelorus Sound (Marlborough Sounds)[66]. 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[67]. Certain fisheries may in practice be limited by the amount of time where water quality is sufficient to allow harvesting, e.g. the cockle fishery in COC1A (Snake bank in Whangarei harbour) was closed for 101, 96, 167, 96 and 117 days for the 2006-7, 2007-8, 2008-9, 2009-10 and 2010-11 fishing years, respectively due to high faecal coliform counts from sewage spills or runoff[68]. 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.

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[64] This is an underestimate because streams with catchments less than 10km^2 were excluded from this calculation.

[8] http://www.stats.govt.nz/infoshare

[10] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.

[11] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.

[12] Statistics supplied by New Zealand Food Safety Authority in Whangarei.

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13. 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 is new for the AEBAR 2013.

13.1. *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 13.1.

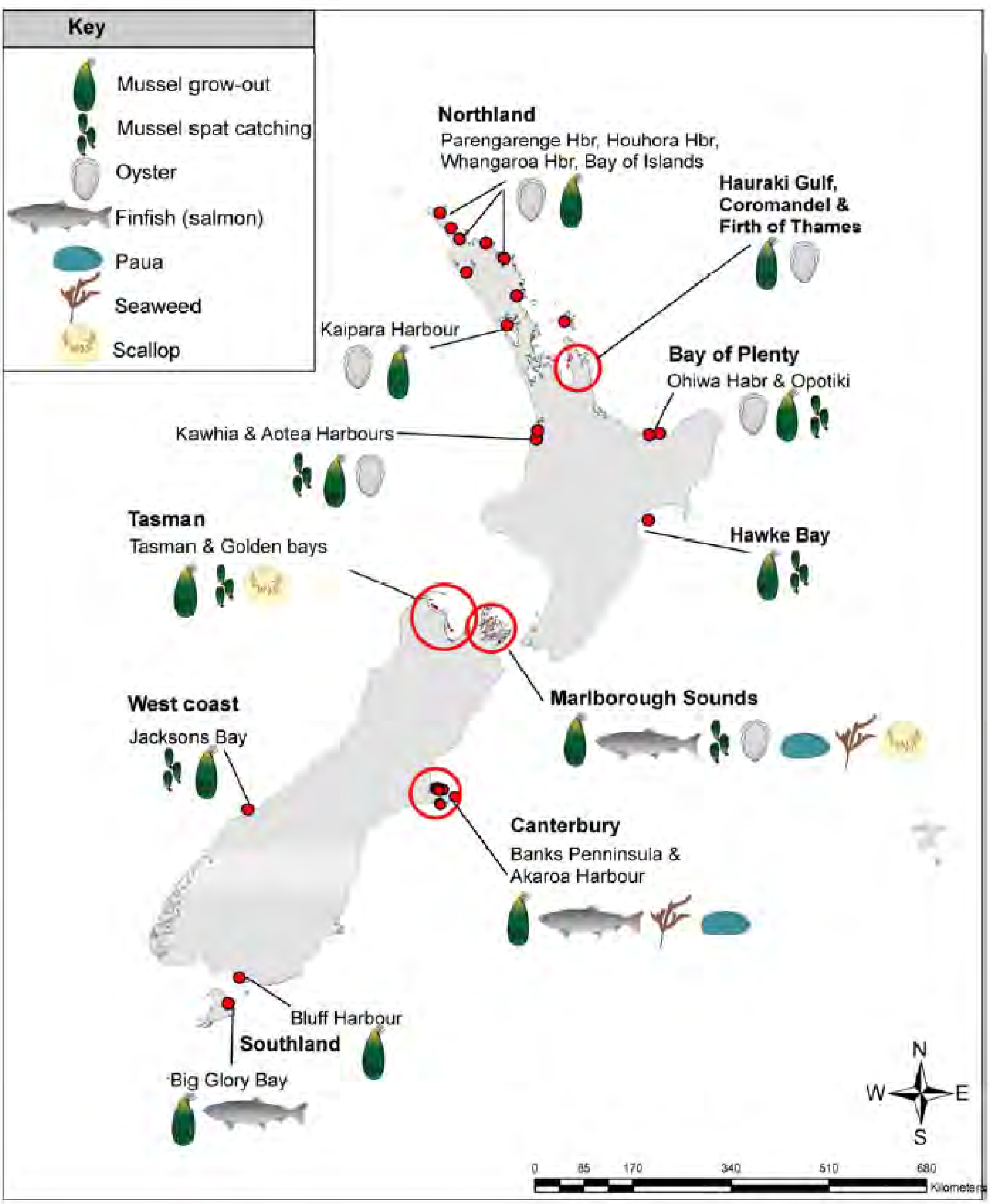


Figure13.1: Geographic locations of main marine farming areas in New Zealand (Keeley et al 2009).

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) and this should be referred to for further details, references or clarification.

13.2. *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 (13.3).

13.3. *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 Figures 13.2 to 13.3, respectively.

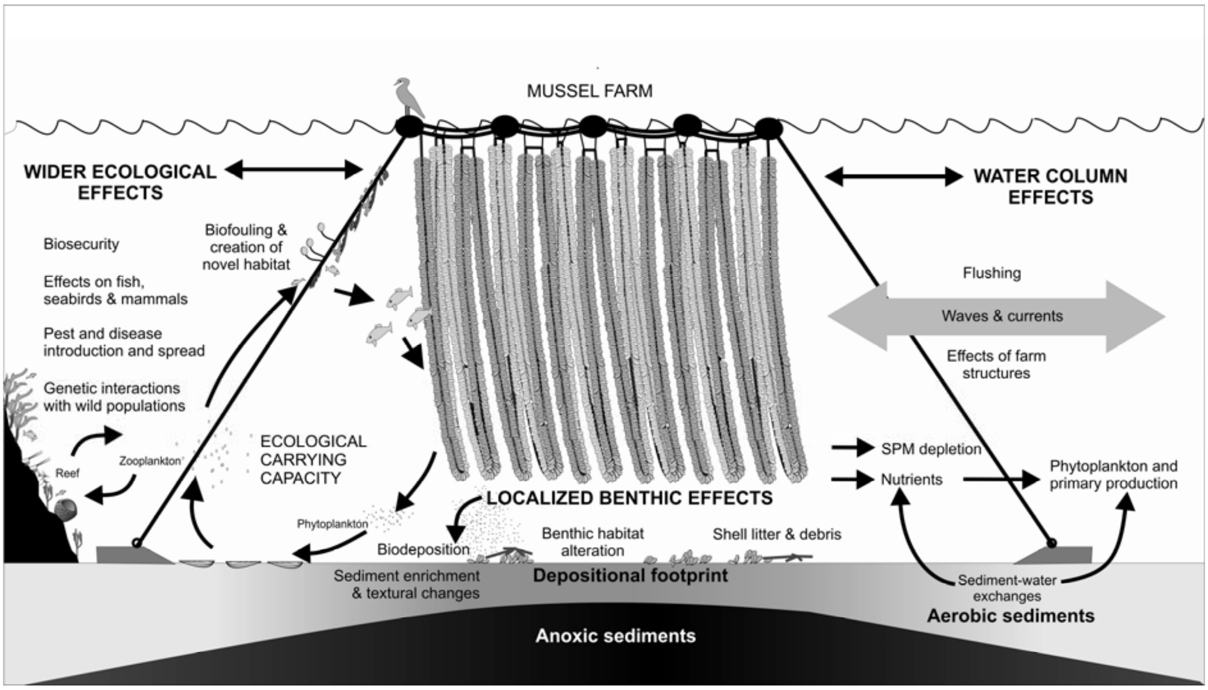


Figure 13.2: Schematic of actual and potential ecological effects from mussel farming (Keeley et al 2009).

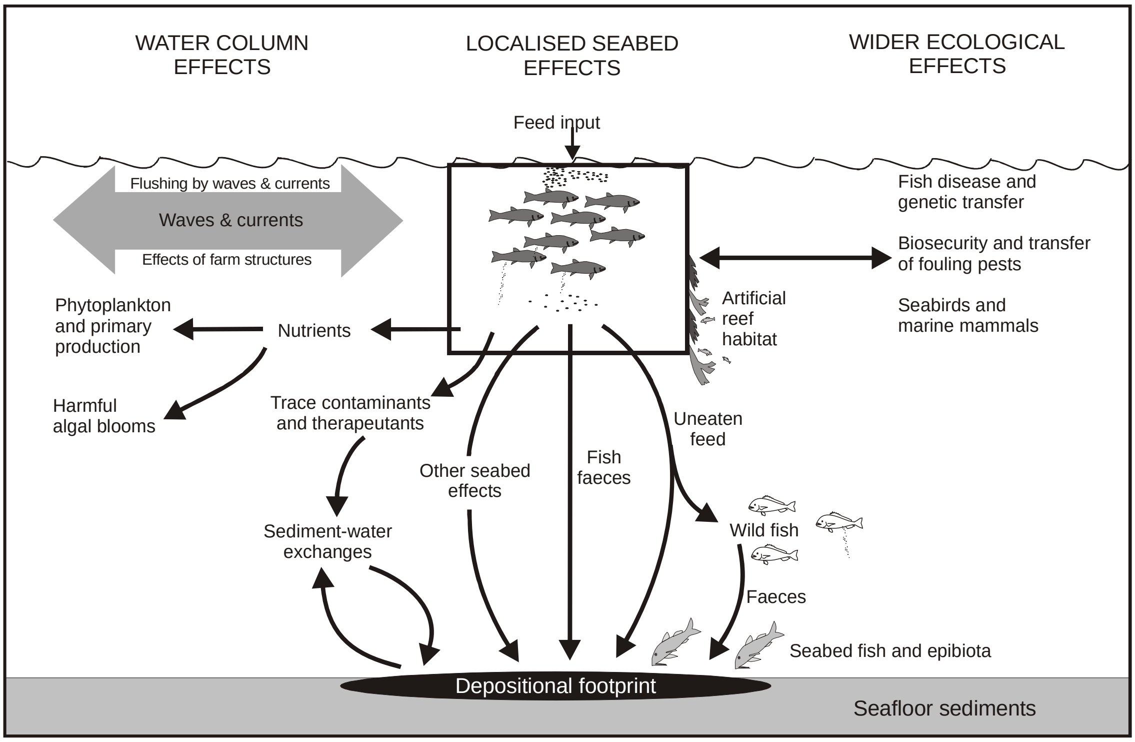


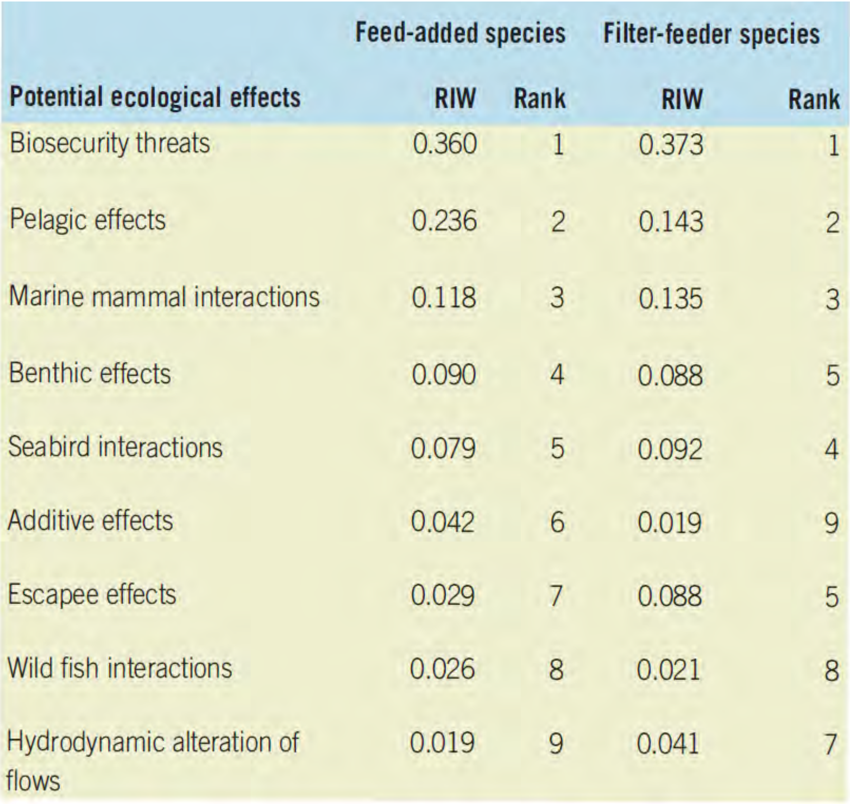
Figure 13.3: Schematic of actual and potential ecological effects from feed-added farming (Forrest et al 2007c).

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 13.1). 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 13.1: 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[69].



	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

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[69] 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.

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 13.3.10 of this chapter.

13.3.1. **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.

13.3.1.1. 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[70] 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,
- it was possible 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.

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[70] Defined here as an agent of disease, e.g. a bacterium or virus.

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, Askew1972, 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).

13.3.1.2. 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):

a. disruptions to entire ecosystem processes with wider abiotic influences,
b. disruptions to wider ecosystem function, and/or keystone species or species/assemblages of high conservation value (e.g. threatened species),
c. disruptions to single species with little or no wider ecosystem impact,
d. little or no disruption.

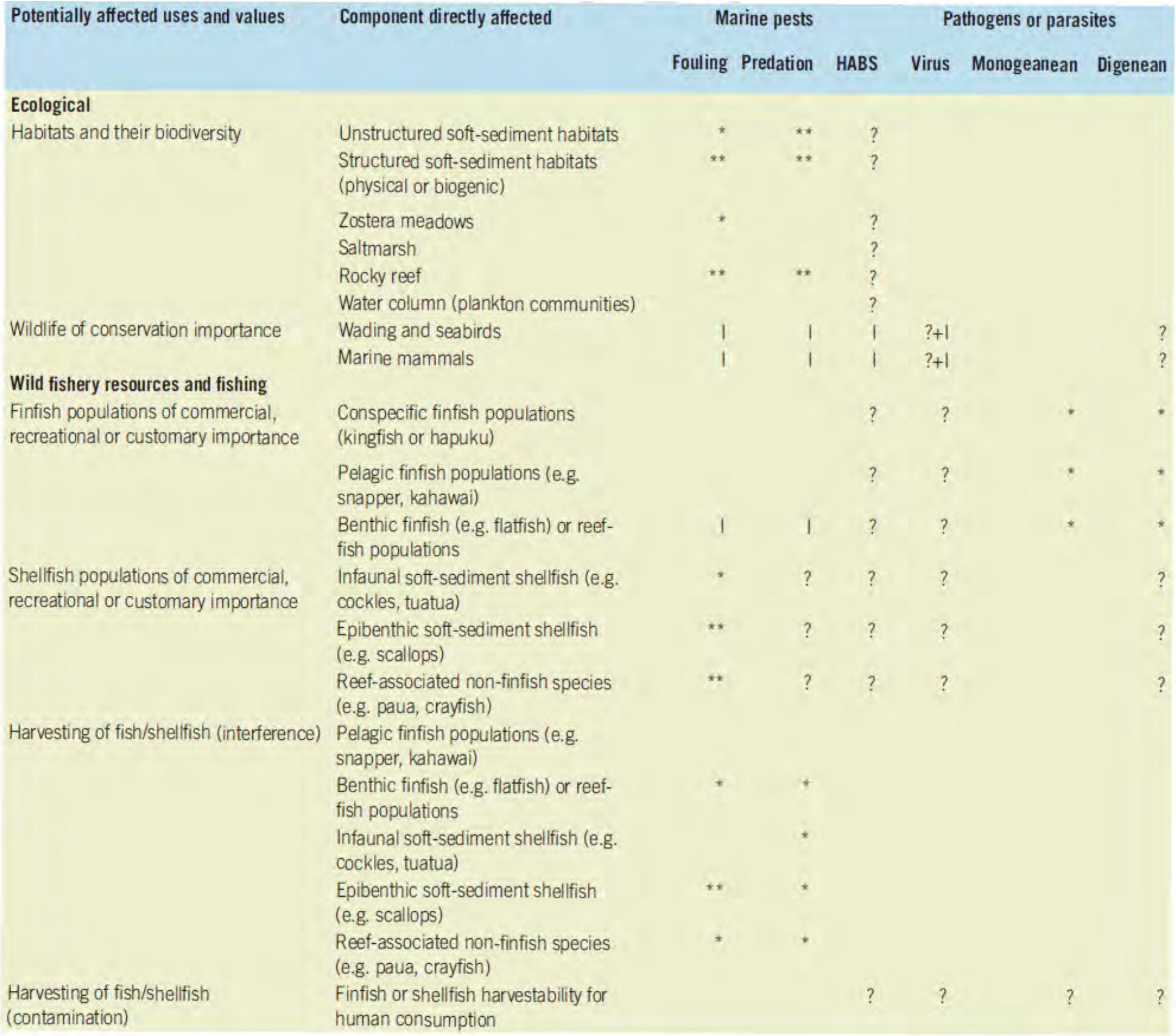
The infection of marine farms by pest organisms can lead to the development of significant infestations on farm structures, which may then:

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 13.2 for finfish aquaculture in the Waikato region.

Table 13.2: 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	Monogeanean	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			?	?	?	?

13.3.1.3. 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[71], 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 undertaken in the exporting country, during transit and on arrival. For example, current standards include:

- 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:

a. identifying existing and future pests that threaten the aquaculture industry,
b. implementing surveillance of farm structures and associated vessels and infrastructure,
c. developing coordinated response plans for high risk species before they become established,
d. 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.

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[71] 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).

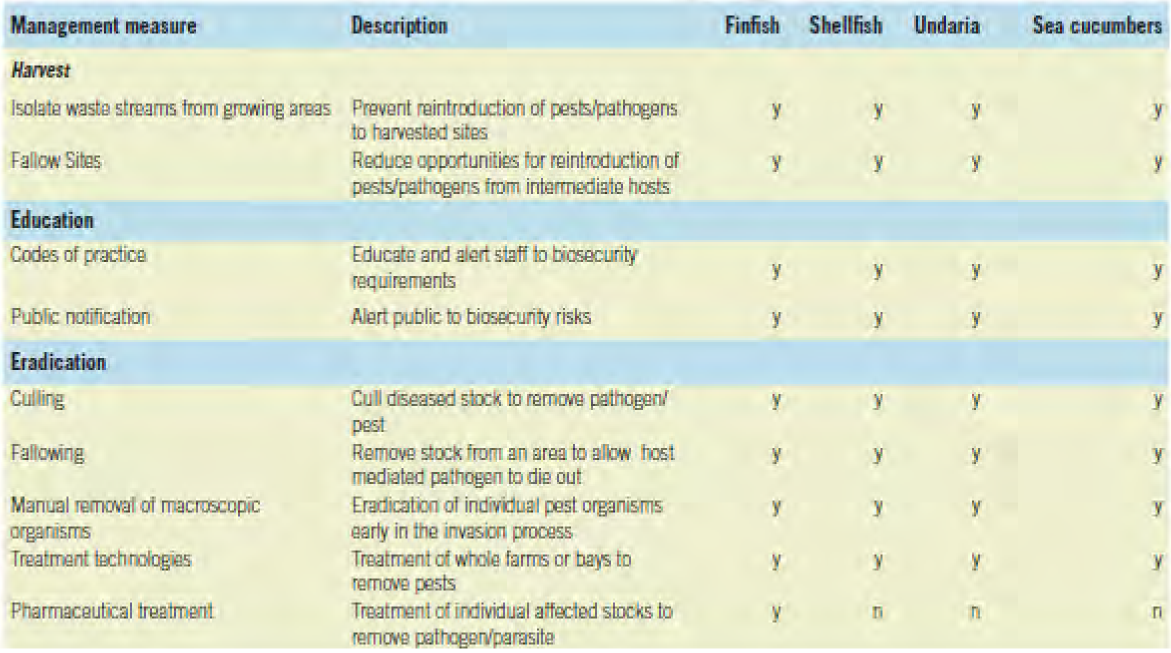
Perhaps the best method for controlling the spread of disease is through the use of management practices that call for the pathological inspection of animals to ensure that infected animals are not moved into areas that do not currently have endemic infections (WWF 2010). In New Zealand, in the absence 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 13.3.

Table 13.3: 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 13.3: 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

13.3.2. 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.

13.3.2.1. 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.

13.3.2.2. 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.

13.3.2.3. 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. compliant with The New Zealand Finfish Aquaculture Environmental Code of Practice (2007)[72]) 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.

13.3.3. Marine mammals

The reader is referred to MPI 2013 (and references therein) for more detail.

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[72] A copy of these codes can be obtained from Aquaculture New Zealand (www.aquaculture. org.nz)

13.3.3.1. 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.

13.3.3.2. 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 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.

13.3.3.3. 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).

13.3.4. **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.

13.3.4.1. 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).

13.3.4.2. 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).

13.3.4.3. Management options and knowledge gaps

Management measures for mitigating benthic impacts for aquaculture are similar to those for mitigating pelagic impacts (Section 13.3.2.3). 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-On-growing-Monitoring (MOM) approach are also potentially beneficial (MPI 2013).

13.3.5. **Seabird interactions**

The reader is referred to MPI 2013 (and references therein) for more detail.

13.3.5.1. 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.

13.3.5.2. 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).

13.3.5.3. 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.

13.3.6. 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.

13.3.6.1. 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).

13.3.6.2. 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).

13.3.6.3. 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.

13.3.7. **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.

13.3.7.1. 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), 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.

13.3.7.2. 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.

13.3.7.3. 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.

13.3.8. Effects on wild fish

The reader is referred to MPI 2013 (and references therein) for more detail.

13.3.8.1. 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).

13.3.8.2. 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).

13.3.8.3. 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).

13.3.9. Hudrodynamic effects

The reader is referred to MPI 2013 (and references therein) for more detail.

13.3.9.1. 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.

13.3.9.2. 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.

13.3.9.3. 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.

13.3.10. 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 13.2: Pelagic Effects. The reader is referred to MPI 2013 (and references therein) for more detail.

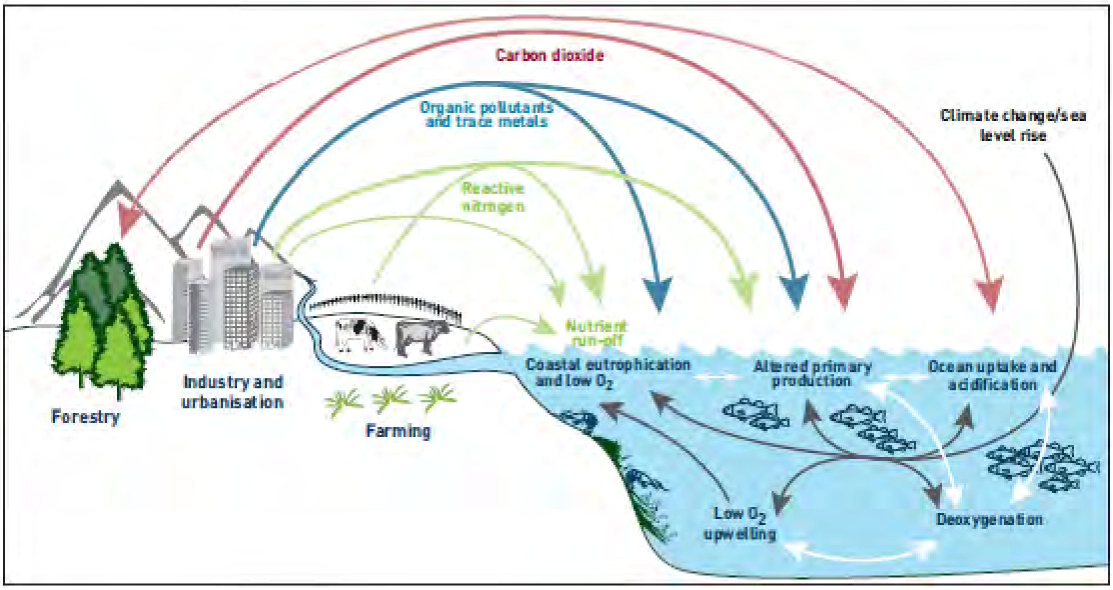
13.3.10.1. Introduction

The previous sections (13.3.1- 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 13.4 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).*

Figure 13.4: Conceptual diagram of anthropogenic influence in marine ecosystems.



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 13.3.4). 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 13.3.9).
- 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 13.3.1 provides comprehensive information on methods for minimising biosecurity risk that are applicable to wider, regional scales).

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.

13.3.10.2. 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 (NH_4). 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 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.

13.3.10.3. 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:

1. prepare an online inventory of repeated biological and abiotic marine observations/datasets in New Zealand,
2. 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). Addressing 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:

1. The use of models and existing data to gauge limits to development[73] within the context of a region's assimilation capacity (i.e. ecological carrying capacity).
2. Establishment of wider-ecosystem, long-term monitoring programmes that include establishment of baseline conditions of a region and adoption of limits of acceptable change.
3. Mitigation of effects through continual improvement of on-farm practices, potentially including improved feed technologies and the use of Integrated Multitrophic Aquaculture (IMTA, Figure 13.5). IMTA combines farming of different species to potentially ameliorate environmental effects.
4. 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 Thames[74]. 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).

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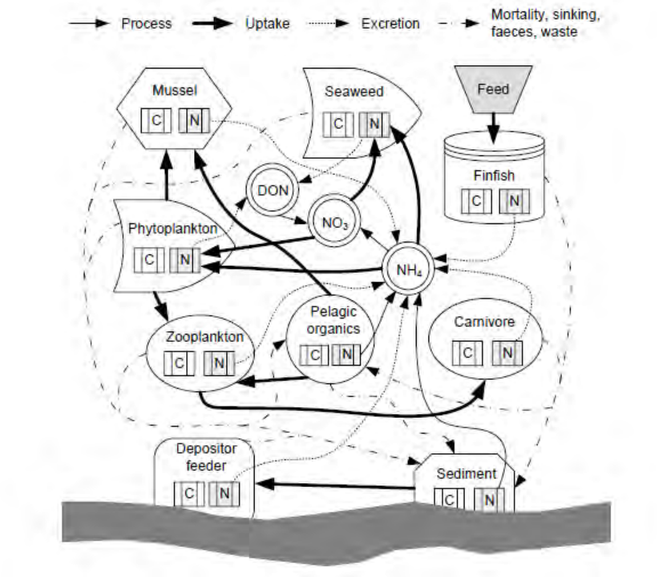
[73] In some cases, areas may not be suitable for any development of aquaculture.

[74] http://www.niwa.co.nz/publications/wa/vol14-no2-june-2006/limits-of-acceptable-change-a-framework-for-managing-marine-farming

Figure 13.5: Conceptual diagram of IMTA model in terms of carbon (C) and nitrogen (N) biomass (from Ren pers comms.).



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.

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THEME 5: MARINE BIODIVERSITY

Biodiversity

Scope of chapter	Provide an overview of the MPI Biodiversity Programme and address: National and global context of NZ marine biodiversity research; Research findings and progress of the MPI Biodiversity Research Programme from 2000–2012; 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)
Geographic area	New Zealand Territorial Seas, EEZ and Continental shelf extension (BioInfo); South-west Pacific Region associated with South Pacific Regional Fisheries Management Organisation (SPRFMO);Antarctic Ross Sea region (BioRoss)
Focal issues	New Zealand waters have globally significant levels of marine biodiversity, and productivity particularly in coastal habitats, offshore island habitats and on underwater topographical features such as seamounts, and canyons. With the exception of shallow sea ice impacted coastal habitats, these features apply also to the Ross Sea region. Adjacent international waters in the SPRFMO area contain areas likely to constitute Vulnerable Marine Ecosystems (VMEs).
Key progress *2011-12*	• Predictive habitat modelling has identified potential areas of VMEs in SPRFMO areas • Significant progress has been made on mapping deepsea fisheries habitat at risk from ocean acidification; research on shellfish has identified thermal stress and ocean acidification as two areas of concern for New Zealand in an increasing CO_2 world. • Progress has been made towards developing a national Marine Environmental Monitoring Programme • A major project on changes in marine shelf systems over the past 1000 years has almost reached completion. • IPY and Chatham Challenger projects have been completed with many outputs and leveraging opportunities
Emerging issues	• 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. • Keen interest in the development of ecosystem approaches to marine resource management is developing. • The nature and functional role of marine microbial biodiversity in large scale biogeochemical and ecosystem processes are important but not well understood. • Genetic and life-history stage connectivity between and within large scale habitats may be important to the size and placement of protection zones. • Apart from fisheries data, 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 addressed in extractive business models. • Marine biodiversity and its monitoring, loss reduction 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, e.g., IMOS, SOCPR ARGO, BIO-ARGO.
MPI Research (current)	55 biodiversity projects were commissioned over the period 2000-12; Currently in 5th year of a 5 year programme 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 Research and associated initiatives (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. Former MBIE programmes i.e., Coasts & Oceans OBI C01X0501, Marine Biodiversity & Biosecurity OBI C01X0502, are now part of Core Funding managed by NIWA through the Coast and Oceans Centre and MBIE projects: Protecting Ross Sea Ecosystems C01X1001, Climate Change Effects in the Ross Sea C01X1226, Coastal Conservation Management C01X0907, Impacts of resource use on vulnerable deep-sea communities C01X0906; DOC, MPI, NIWA and Landcare Research - NZ Organisms Register.
Links to Fisheries 2030 and MPI's Our Strategy 2030	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 cross government Natural Resource Sector discussions (MfE, DOC, MBIE, LINZ, EPA, MOT, Maritime NZ, Antarctica NZ, MFAT) and whole of government projects such as Ocean Survey 20/20 and International Polar Year.
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 2013.

Introduction

This chapter summarises the development and progress of the MPI Marine Biodiversity Research Programme 2000–2012 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).

14.0.1. 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[1]. 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 addressing Theme 3 of the Biodiversity Strategy was allocated across government departments with active roles in the management of the marine environment, including the Department of Conservation (DOC), the Ministry for Environment (MfE), and the Ministry of Fisheries (now MPI)[2]

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[1] 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

[2] https://www.biodiversity.govt.nz/picture/doing/programmes/index.html

14.0.1.1. 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[3]) is very large relative to the area of land[4] 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).

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[5]. 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[6]). The growing arrival of non-indigenous

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[3] http://www.mfat.govt.nz/Treaties-and-International-Law/04-Law-of-the-Sea-and-Fisheries/NZ-Continental-Shelf-and-Maritime-Boundaries.php

[4] 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

[5] 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

[6] : http://www.royalsociety.org.nz/publications/policy/yr2009/ocean-acidification-workshop/

(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 on 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. There are significant concerns with 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.[7] [8] 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 most recent introduction 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 been slow compared with other countries such as Canada, the UK, the USA and Australia (Peart et al 2011).

14.0.2. 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)[9], the administration of the MPI Biodiversity Research Programme, convening and chairing the Biodiversity Research Advisory Group[10], and developing a Marine Protected Area policy with DOC. DOC also surveys and monitors aspects of marine biodiversity, particularly in marine reserves[11]. MfE has encouraged Regional Councils to develop coastal monitoring programmes and with MPI and DOC, initiated an approach to Marine Environmental Classification[12]. 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[13].

Marine biodiversity research is also supported through public good funding and is conducted mainly by Universities and CRIs. Both have contributed to New Zealand's high profile on the international

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[7] 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

[8] New Zealand Coastal Policy Statement 2010 www.doc.govt.nz/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement/

[9] NABIS is an interactive database accessible at www.nabis.govt.nz

[10] www.fish.govt.nz/en-nz/Research+Services/Background+Information/Biodiversity+background.htm

[11] www.doc.govt.nz

[12] www.mfe.govt.nz/issues/biodiversity/initiatives/marine.html#regional

[13] www.biosecurity.govt.nz/biosec/research

scientific network for marine biodiversity 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 also at NIWA. Regional Councils give effect to NZBS; Coastal Biodiversity Policy Statement 2011, protected areas and spatial planning.

14.0.3. New 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[14]:

> "to improve New Zealand's economic performance while continuing to strengthen our society and protect our environment".

This goal is reflected in first progress report on "Building Natural Resources" as part of the Business Growth Agenda[15] 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".

The economy of the sea (currently largely fisheries and aquaculture, oil and gas, minerals) is a significant part of the overall economy and may have potential for growth (e.g. unlocking the potential of the fisheries sector–Fisheries 2030 (MPI 2009[16]). It is essential that the aquatic environment and biodiversity on which industry depends are not adversely affected by these or other impacting activities.

Bodies such as the Marine Stewardship Council (MSC[17]) require fisheries to satisfy stringent environmental requirements to achieve certification. Many fisheries management systems throughout the globe have begun to develop policies that are ecosystem based. Implementation has met with varied success, and measurement of success is a challenge.

The large scale threats to the marine environment posed by increasing global impacts of anthropogenic 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) remain.

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 New Zealand and Ross Sea marine ecosystems is well understood and available information has been used to assess the habitat types at greatest risk from disturbance, particularly fishing. However,

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[14] MoRST feedback document on New Zealand's research science and technology: www.morst.govt.nz/Documents/publications/policy

[15] https://www.mbie.govt.nz/what-we-do/business-growth-agenda/pdf-folder/BGA-Natural-Resources-report-December-2012.pdf

[16] MFish (2009). Fisheries 2030 report. New Zealanders maximising benefits from the use of fisheries within environmental limits available from http://www.fish.govt.nz/en-nz/Fisheries+2030/default.htm

[17] Marine Stewardship Council www.msc.org

the proportions of marine habitat types that should be or can be protected to maintain a healthy aquatic environment is unknown.

There is growing awareness of the likely importance of the huge 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).

Global understanding and developments

In April 2002, the Parties to the Convention on Biological Diversity (CBD) 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[18].

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[19]. 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[20].

The eleventh meeting of the Conference of the Parties to the Convention on Biological Diversity (held 8–19 Oct 2012)[21] 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.
- 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 will need to consider how to update the NZBS to better align with the Aichi Biodiversity targets.

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[18] 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/

[19] www.cbd.int/2010-target

[20] 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/

[21] 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.

14.1.1. The decade of biodiversity 2011–2020

The United Nations General Assembly at its 65th session 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). It 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 14.6 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."[22] 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[23]. The criteria used for identifying EBSAs and Vulnerable Marine Ecosystems were those recommended through UNGA and managed by Regional Fisheries Management Organisations[24]. The 2012 SPRFMO Science Working Group noted that the differing approaches to identifying VMEs and EBSAs could lead to conflicts in how areas possibly in need of protection are defined.

14.1.2. 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

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[22] www.cbd.int/marine/done.shtml

[23] www.cbd.int/doc/meetings/cop/cop-11/official/cop-11-03-en.doc

[24] http://www.un.org/Depts/los/consultative_process/documents/no4_spc2.pdf

on Biological Diversity (CBD) held in 2010 provide the first systematic overview at a sub-global scale of the state of knowledge of marine biodiversity, the pressures it faces currently and the management frameworks in place for addressing those pressures[25].

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. All regions report progress in the establishment of Marine Protected Areas but current levels of 1.2% of global ocean surface or 4.3% of continental shelf areas fall far short of the 10% target set by CBD COP7 in 2004. 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. The need to plan and implement ecosystem scale and ecosystem-based management of the seas is urgent.

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)[26]. 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)[27] 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[28].
- 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.

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[25] 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

[26] http://www.iucn.org/what/

[27] http://sustainabledevelopment.un.org/futurewewant.html Rio +20 outcome document

[28] 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

- 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 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).

14.1.3. Ocean climate change, ocean acidification

Ocean 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. The projected increases in temperature, acidity, severe storm incidence and sea level present major challenges for biodiversity management. This is reflected in changes on the Great Barrier Reef in Australia, which is a globally iconic marine ecosystem that has been subject to adaptive scientifically-based ecosystem-based management for more than 30 years. An Outlook Report by the Great Barrier Reef Marine Park Authority[29]concluded that “without significant additional management intervention, some components of the ecosystem will deteriorate in the next 20 years and only a few areas are likely to be healthy and resilient in 50 years.” Without strong ecosystem based management the global threats to marine biodiversity may be similar and their implications for food and physical security could be substantial.

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.

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 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 [30]". 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.

The Intergovernmental Panel on Climate Change (IPCC) is preparing material for the 5th IPCC Report in 2014 and for the first time includes chapters to explicitly address ocean climate change issues[31]. 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

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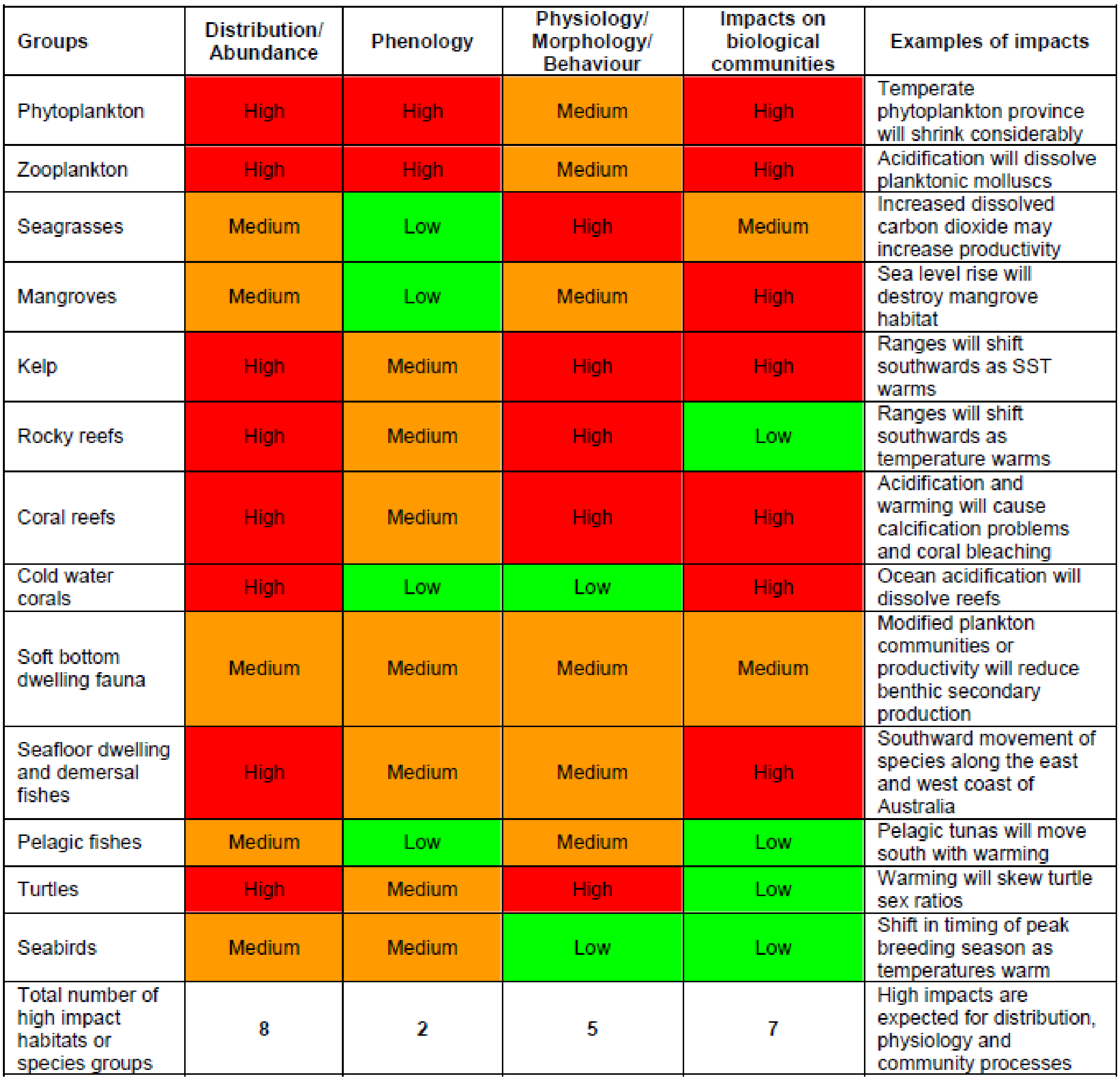
[29] Outlook report 2009: available at http://www.gbrmpa.gov.au/outlook-for-the-reef/climate-change

[30] 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?’

[31] http://www.global-greenhouse-warming.com/IPCC-5th-Report.html

Group I will consider "Ocean biogeochemical changes, including ocean acidification" in their Chapter 3 (Observations - Ocean), and "Processes and understanding of changes, including ocean acidification" in their Chapter 6 on "Carbon and other biogeochemical cycles". Working Group II will consider "Water property changes, including temperature and ocean acidification" in their Chapter 6 on "Ocean Systems". In addition, "Carbon Cycle including Ocean Acidification" has been identified as a "Cross-Cutting Theme" across (predominantly) WG1 and WG2.

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 14.1). 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 [32].



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 14.1: 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.

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[32] www.marinehub.org/

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[33.] 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[34].

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).

14.1.4. Census of Marine Life 2000–2010

In 2010, the international initiative to conduct a Census of Marine Life (CoML)[35] 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[36], 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 (http://www.iobis.org/) 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[37].

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.

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[33] www.marinehub.org/

[34] arnmbr.org/content/index.php/site/aboutus/

[35] www.coml.org/results-publications

[36] www.coml.org/global-census-marine-life-seamounts-censeam

[37] www.eol.org/

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 14.2).

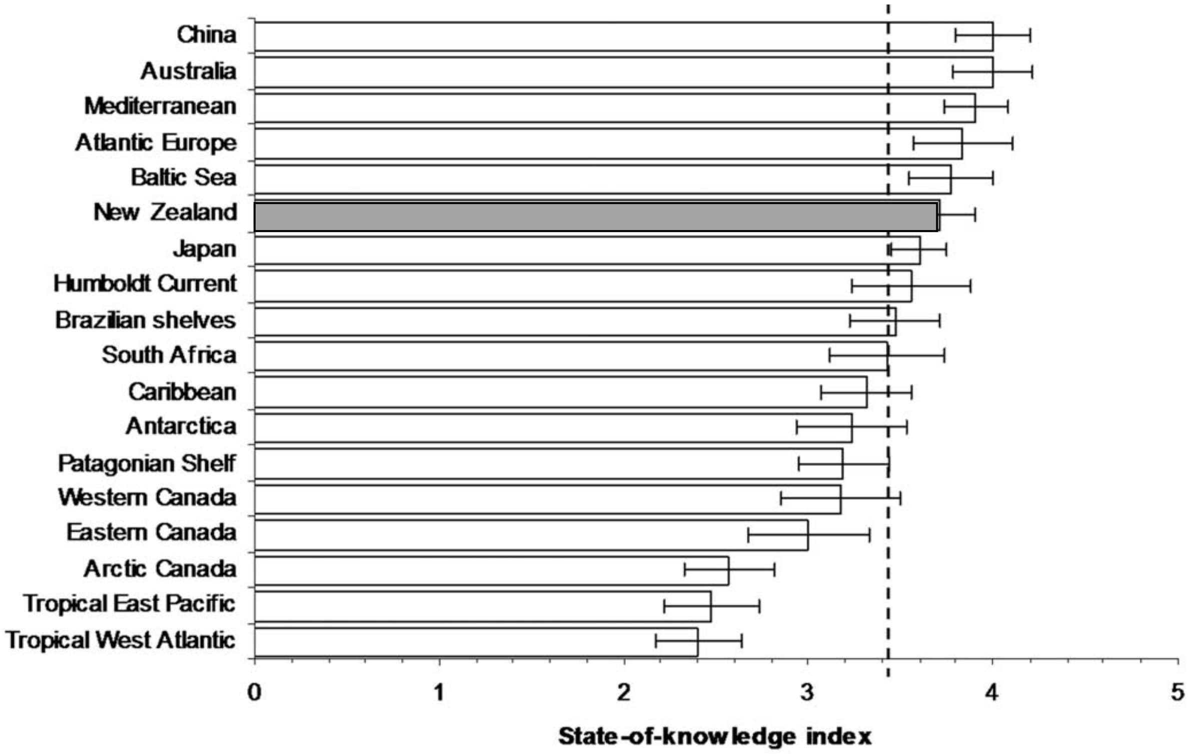

Figure 14.2: The regions are ranked by their state-of-knowledge index (mean ± standard error) across taxa. Dashed line represents the overall mean. (Image Source Costello et al 2010).

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 in New Zealand (Costello et al 2010).

14.1.5. 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[38]. 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[39]) which stimulates, encourages, coordinates and otherwise facilitates observations by national or international organizations. A Southern Ocean Observing System (SOOS) is under development.[40]

Others include:

- ARGO, an international deepwater monitoring system of free floating buoys that are part of the integrated global observation strategy[41].
- 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[42]. 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 other monitoring programs such as CCAMLR's Ecosystem Monitoring Program C- EMP and the developing Southern Ocean Observing System[43].
- 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[44].
- 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[45]) 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[46]) 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[47] is an initiative of the Natural Environment Research Council (NERC) funded Marine Research Centres. This addresses environmental issues that require sustained long-term observations.

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.

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[38] http://jncc.defra.gov.uk/page-4233

[39] www.ioc-goos.org/index.php?option=com_content&view=article&id=12&Itemid=26&lang=en

[40] http://www.scar.org/soos/

[41] http://www.qc.dfo-mpo.gc.ca/publications/science/evaluation-assessment-eng.asp.

[42] www.sahfos.ac.uk/

[43] www.sahfos.ac.uk/sister-survey/sister-surveys/-southern-ocean-continuous-plankton-recorder-survey-(scar).aspx

[44] http://www.mba.ac.uk/MECN/

[45] http://www.marbef.org/

[46] http://imos.org.au/

[47] http://www.oceans2025.org/

14.1.6. Economic valuation of biodiversity

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)[48] 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 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.

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.

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[48] 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/

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). Figure 14.3 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 (Figure 14.3).

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).

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.

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.

Figure 14.3: Diversity of marine species found in the New Zealand region (after Gordon 2010, 2012; Gordon et al **2010 and current unpublished NIWA data).**

14.2.1. 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[49] 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

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[49] Fisheries 2030 The full document can be downloaded from www.fish.govt.nz/en-nz/Fisheries+2030

other than fishing[50]. 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 55 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).

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 14.4.

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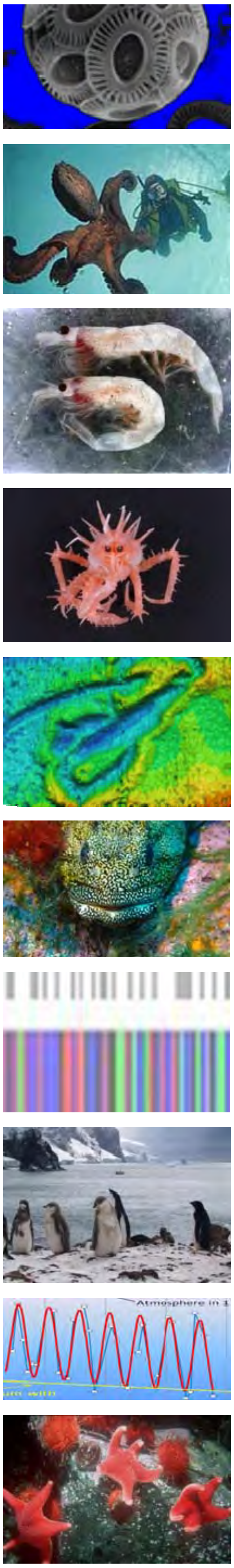
[50] MARBEF: The Valencia Declaration 2008 www.marbef.org/worldconference



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 barriers drive 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 14.4: Summary of MPI Biodiversity Research Programme 2000–2013.

ACHIEVEMENTS & KNOWLEDGE TO DATE	CURRENT WORK
• Taxonomy of coralline algae and bryozoans (2 ID Guides) • New species from surveys added to benthic ID Guides • 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 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	• finalisation IPY analyses • Uptake of biodiversity results to CCAMLR trophic modelling and biomass estimation, VMEs • New spp logged for CAML • Review of squids, octopus

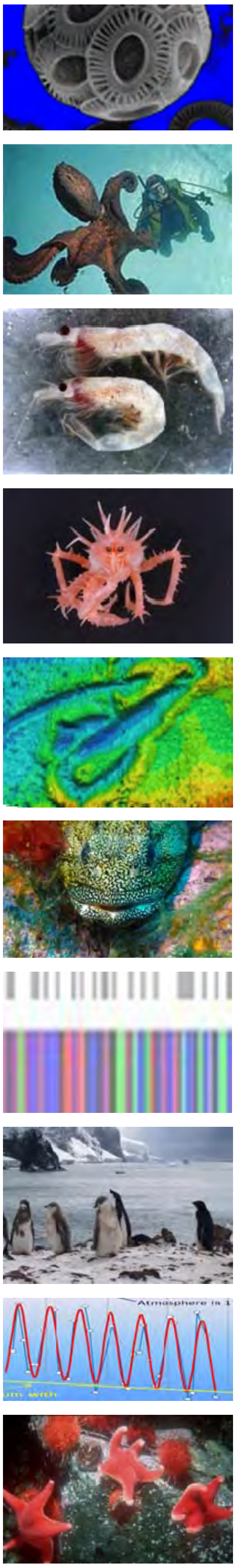


Figure 14.4: ***Continued*** **Summary of MPI Biodiversity Research Programme 2000–2013.**

14.2.2. Overall progress in MPI marine biodiversity research

The MPI Biodiversity Research programme has three overarching science goals:

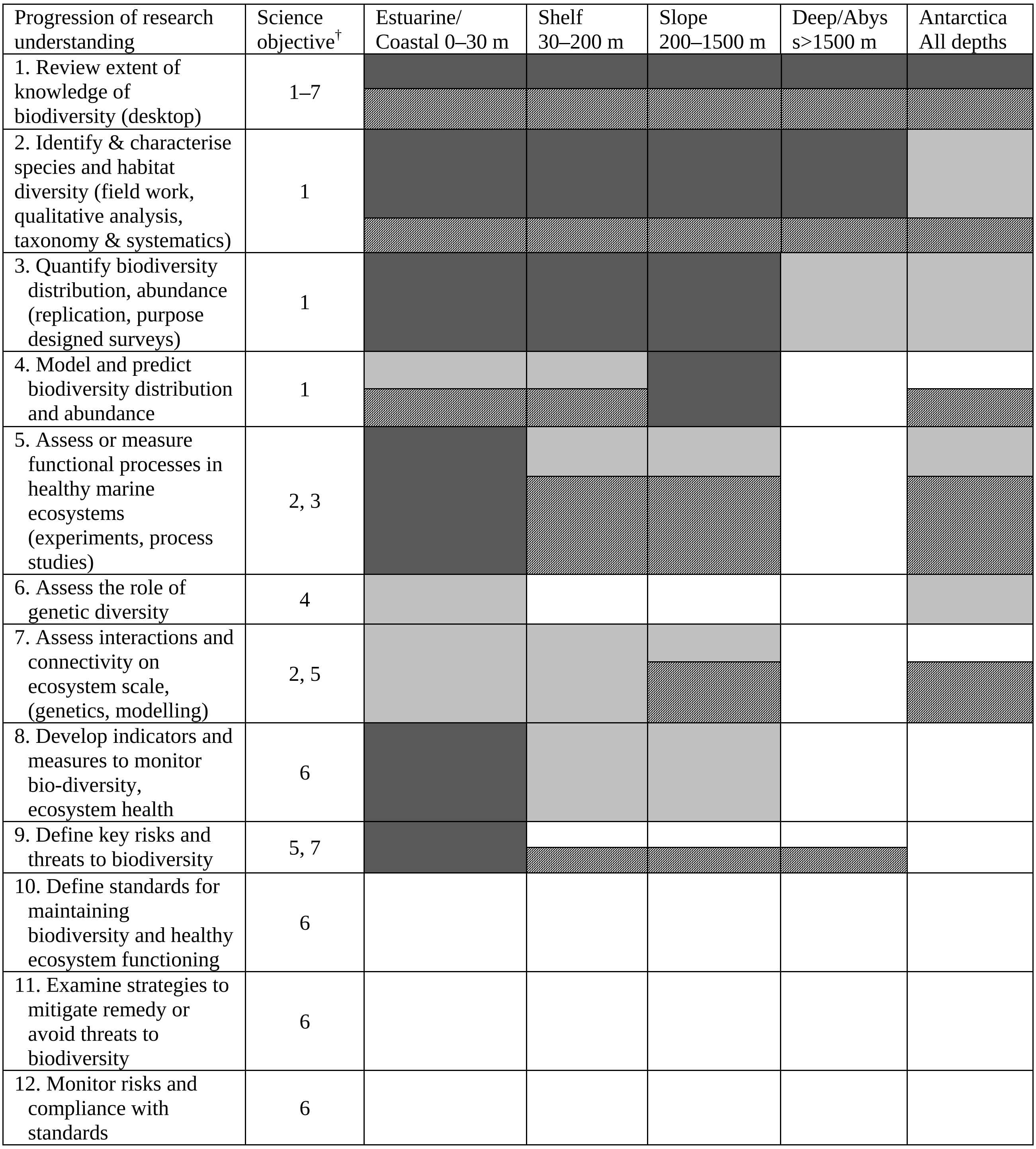
- To describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed.
- To determine the functional role of different organisms or groups of organisms 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, 55 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 Figure 14.5.



Progression of research understanding	Science objective†	Estuarine/ Coastal 0–30 m	Shelf 30–200 m	Slope 200–1500 m	Deep/Abys s>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	□	□	□	□	□

Figure 14.5. Progress on biodiversity research commissioned by MPI 2000–2010. 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 Outcome Based Investment projects, DOC Marine Coastal Services, MAFBNZ marine biosecurity research).

† 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.

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 the MPI Biodiversity Medium Term research programme 2010–2014.

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 here.

14.2.3. 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; the fish optimised MEC in project ZBD2005-02 (Leathwick et al 2006a, 2006b, 2006c), the benthic optimised MEC (Leathwick et al 2009) and Chatham-Challenger project ZBD2007-01 (Hewitt et al in prep, Bowden et al 2012, Compton et al 2012).

Progress has 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[51]) implemented on the basis of the Marine Environment Classification[52][53] to address broader statutory responsibilities on the environmental effects of fishing on biodiversity.

ZBD2007-01 Chatham-Challenger seabed habitats-post voyage analyses.

This large project has been completed. Progress for each objective is as follows:

1. To count, measure, and identify to species level (where possible, otherwise to genus) all macro invertebrates (>2 mm) and fish collected during Oceans Survey 20/20 voyages. Completed (Figure 7, Bowden 2011).
2. To count, measure and identify to species-level (where possible, otherwise to genus or family) all meiofauna (>45µm to <500 µm) from multicore samples collected during the Oceans Survey 20/20 voyages. [Collaborative venture MBIE-Otago University]. Completed (Leduc et al 2012a, 2012b, 2012c, 2013, Leduc et al in press)
3. 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 Survey 20/20 voyages. Completed. (Lorz 2011a,b, Bowden 2011).
4. To count, measure, and identify to species-level (where possible, otherwise to genus or family) all macrofauna observed on DTIS images collected during the Oceans Survey 20/20 voyages. The number of biogenic features (burrows/mounds) and habitat (spatial) complexity should also be estimated. Completed. (Bowden 2011, Compton et al 2012).
5. 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 Survey 20/20 voyages. Completed. (Bowden 2011, Compton et al 2012).
6. To calculate and compare the performance of a suite of diversity measures (species and taxonomic based) at varying levels of resolution. Completed. (Hewitt et al in prep).
7. To estimate particle size composition and organic content of sediment samples. Sediment samples should be aggregated over the top 5 cm of sediment. Completed. (Nodder et al 2011).
8. To measure the bacterial biomass (top 2 cm) of the sediment and in the sediment surface water samples, collected during the Oceans Survey 20/20 voyages. Completed. (Nodder et al 2011.
9. To elucidate the relationships, patterns and contrasts in species composition, assemblages, habitats, biodiversity and biomass (abundance) both within and between stations, strata and areas. Completed. (Floerl & Hewitt 2012).
10. 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. Completed (Hewitt et al in prep).
11. *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. Objective withdrawn*
12. 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. Modelling approaches as well as standard statistical procedures are anticipated. (Compton et al 2012).

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[51] www.fish.govt.nz/en-nz/Environmental/Seabed+Protection+and+Research/Benthic+Protection+Areas.htm

[52] Marine Environmental Classification. (2005). Can be viewed online at http://www.mfe.govt.nz/publications/ser/marine-environment-classification-jun05/index.html

[53] http://seafoodindustry.co.nz/bpa and use of MEC (2005)

13. To provide an interactive, high resolution mapping facility for displaying and plotting all data collected and derived indices. This would include environmental data, the abundance of individual species, indices of biomass or diversity, and statistically derived groupings. Completed in conjunction with Bay of Islands Ocean Survey 20/20 Portal[54].
14. 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 Survey 20/20 samples. Completed. (Bowden et al in press, Bowden et al 2011b, Compton et al 2012).
15. 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. Completed. (Bowden et al 2011b).
16. Collating all information and analysis from all objectives, devise a series of statistically supported recommendations for surveying marine biodiversity in the future. This should include, but may not be limited to, statistical analyses and modelling. (Bowden & Hewitt 2012).

ZBD2008-05 Macroalgal diversity associated with soft sediment habitats.

Although macroalgae normally require hard substrata for attachment and occur less frequently in soft sediment environments they contribute to biodiversity in a range of soft sediment environments providing structural complexity, modifying flow and sediment regimes, and contributing to productivity. Soft sediment habitats where macroalgae are found are physically highly diverse, ranging from harbours and estuaries (with varying sediment types and sizes, freshwater influence, tidal flushing, current flows), to coarse stabilised sediments (shell fragments, cobbles, coarse gravels), and biogenic habitats such as worm tubes, horse mussel beds, brachiopod beds, mangrove forests, rhodolith (maerl) beds and seagrass meadows.

The state of knowledge of macroalgal diversity, distribution and abundance is poor, and there are few examples of targeted collecting programmes for macroalgal assemblages, particularly in soft sediment habitats. This research conducted (a) a targeted collection programme across diverse soft sediment environments to develop a permanent reference collection of representative macroalgae, and (b) examined algal distribution in soft sediment habitats in relation to selected environmental variables.

Macroalgal sampling trips to Kaipara (1), Whangarei (3) and Otago (4) Harbours were completed. Further sampling trips were planned for 2010, however, no further collections will be made in Kaipara Harbour. Approximately 2400 collections of algae were made from soft sediments in these harbours. In Whangarei and Otago Harbours, collections were made from a range of soft sediment habitats including mud, sand, shell gravel, sea grass, scallop, pipi and horse mussel beds. At each site algae were collected opportunistically, quantitatively (i.e. by quadrats), or by both methods. Standard ecological methods (e.g. species area curves, count frequencies) were used to assess the appropriateness of the methods.

A database was developed for information about specimens and collection sites. Information was gathered on environmental variables within the target harbours. Identified algal distributions were analysed relative to these environmental variables.

Collections were made from three harbours with the primary focus on Whangarei and Otago Harbours where seasonal sampling programmes were conducted in spring and in autumn. In the Kaipara Harbour sampling was conducted only in spring. Two hundred and forty four taxa were sampled from intertidal and subtidal sites and a range of habitats: 146 (112 spring, 102

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[54] http://www.os2020.org.nz/

autumn) from Whangarei, 43 Kaipara, and 150 (107 spring, 115 autumn) from Otago. Diversity indices indicate that the collecting was not saturated and predict that there is higher diversity of macroalgae in these harbours than found in the samples obtained.

The flora composition in the harbours was found to differ markedly e.g., only 67 taxa (45%) of the Whangarei flora were found to be in common with Otago Harbour collections; 17 taxa (39%) of the Kaipara flora was in common with the Otago flora, in common (39% of Kaipara also found in Otago); 27 taxa (63%) of the Kaipara flora was also found in Whangarei. Nineteen non-indigenous species were found in the harbours, including two new records for the New Zealand algal flora (confirmed by sequence data), *Hypnea cornuta* and *Polysiphonia morrowii*. In Whangarei Harbour 8 non-indigenous species were found (4 new records for the harbour including *Hypnea*), in Kaipara Harbour 4 species were found including 2 new records for the harbour, and in Otago Harbour 11 non-indigenous species were found including 1 new record as well as *P. morrowii*. More taxa were collected in the subtidal (107) in Whangarei Harbour than in the intertidal (84), compared with Otago where the numbers of intertidal taxa (120) exceeded the subtidal taxa collected (83).

Two methods were employed to enable high resolution sampling and these provided differing outcomes in the two main harbours sampled, clearly indicating that there was value in collecting by both methods in order to adequately sample the diversity. In Whangarei Harbour 90 taxa were collected in quadrat sampling compared with 118 taxa via opportunistic collections, and in the Otago Harbour 107 taxa were collected in quadrat sampling and 118 taxa via opportunistic collections.

ZBD2008-27 Review of deep-sea benthic biodiversity associated with trench, canyon and abyssal habitats below 1500 m depth in New Zealand waters

The state of knowledge of benthic biodiversity and ecosystem functioning in deep-sea abyssal, canyon and trench habitats in the New Zealand Exclusive Economic Zone and the Ross Sea region, was summarised and recommendations for future deep-sea research in depths exceeding 1500 m were made. All biological information in scientific papers and reports from New Zealand below 1500 m was reviewed and an exhaustive search of multiple data sources was conducted.

The area of the deep seafloor below 1500 m covers more than 65% of New Zealand‘s Exclusive Economic Zone. A total of 1489 benthic gear deployments have been conducted by New Zealand-based sampling initiatives since 1955, most of which were focused on obtaining geological samples. Less than 0.002 % of New Zealand‘s deep-sea environment (i.e. in terms of seabed area) below 1500 m has been sampled. All taxonomy-based studies of all taxa reported in New Zealand waters below 1500 m have been reviewed. To date, 8 species of Bacteria, 293 species of Protozoa, 785 species of invertebrates, and 56 fish species have been recorded from water depths greater than 1500 m.

More than 8000 images are known to have been taken of the seafloor below 1500 m in the New Zealand region, covering an area of approximately 0.016 km^2. Over 4000 of the images held at NIWA exist either as paper prints or negatives and ideally should be digitised for future storage and access for analyses. Analysis of these photographic images should yield considerable information about deep-sea biodiversity and ecosystem function in the New Zealand region and could be used to answer a number of research questions (especially around deep-sea benthic biodiversity).

Recommendations on how to potentially further analyse existing data from images, databases and actual specimens were provided. The technical challenges, including gear requirements to sample deep-sea New Zealand benthos and potential future investments, were summarised. (see Coleman & Lörz 2010; Lörz 2011a, 2011b; Lörz et al 2012a, 2012b).

ZBD2008-50 Chatham Rise biodiversity hotspots.

This survey covered the "Graveyard Seamount Complex" and "Andes Seamount Complex" on the Chatham Rise. Objectives were to monitor changes over time on Graveyard hills subject to differing management regimes (some open to fishing, some closed), as well as to compare seamount biodiversity between different regions of the Rise. It was linked to the CoML CenSeam programme, and the former FRST Seamounts research, now under the MBIE Vulnerable Deep-sea Communities project. The data from that survey are being worked up under the latter project (see Clark et al 2009). Analyses comparing the three surveys of the Graveyard complex between 2001 and 2009 indicate that there are changes in some taxa following cessation of fishing operations on one of the features in 2001, but little sign of any recovery of stony coral species and associated benthic communities . Preliminary results were presented at the 2012 Deep Sea Biology Symposium[55] .

ZBD2009-03 The vulnerability of rhodoliths to environmental stressors and characterisation of associated biodiversity.

Rhodoliths are free-living calcified red algae. They occur worldwide, forming structurally and functionally complex benthic marine habitats. Rhodolith beds form a unique ecosystem with a high benthic biodiversity supporting many species, including some that are rare and unusual. Recent international studies show that these fragile algae are at risk from the impacts of a range of human activities e.g., physical disruption, reduction in water quality, alterations to water movement, and aquaculture installations. Impacts of fragmentation may be critical in terms of biodiversity and abundance associated with rhodolith beds.

The focus of this programme was to improve knowledge about the location, extent or ecosystem functioning of rhodolith beds in New Zealand. The ecology of subtidal rhodolith beds was investigated for the first time in New Zealand, characterising two rhodolith species, *Lithothamnion crispatum* and *Sporolithon durum*, examining the structure and physical characteristics of beds at two locations and documenting their associated biodiversity. In addition the responses of these rhodolith species to environmental stressors were investigated for the first time.

This study documented high biodiversity in two subtidal rhodolith beds sited in relatively close proximity in the coastal zone, with significant differences in biotic composition. The rhodolith beds studied (located in the Bay of Islands) differed significantly in terms of water motion, sediment characteristics and light levels. Biodiversity of the rhodolith beds was investigated sampling (1) invertebrates at three levels of association (epifauna, infauna, cryptofauna), (2) macroalgae, (3) fishes, as well as recording the biogenic and non-biogenic substrates:

- a number of undescribed taxa were discovered as well as new records for the New Zealand region, and range extensions of species known elsewhere,
- more than double the number of invertebrate taxa were present in the rhodolith beds than found outside the beds,
- both rhodolith beds harboured high diversity of associated macroalgae and invertebrates but with markedly different species composition,
- the floral and faunal composition differed significantly between sites.

Both species of rhodolith were found to be vulnerable to the impacts of increasing temperature and decreasing pH. There was a significant difference between the effects of treatments on the two species and further statistical analysis showed significant interaction

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[55] Presentation by Malcolm Clark at Deep Sea Biology Symposium, Wellington NZ December 2012; Closed areas for deep-sea habitat recovery: a case of shutting the door after the horse has bolted? http://www.confer.co.nz/dsbs2012/index_htm_files/13th

between temperature and pH level on growth. Overall the greatest effect on growth rate came with the combination of high temperature (25° C) and low pH (7.65) on *Lithothamnion crispatum* which showed negative growth, indicating probable dissolution. In experiments investigating other environmental stressors, temperature was found to be more important for the survival and growth of the rhodolith species examined than the effects of burial, light and fragmentation.

The extent of rhodolith beds in other parts of the New Zealand region remain to be documented, including those in coastal areas (including intertidal beds) and subtidal beds on the shelf.

ZBD2010-40 Predictive modelling of the distribution of vulnerable marine ecosystems in the South Pacific Ocean region.

In January 2010 New Zealand and the United States held their second Joint Commission meeting (JCM) on Scientific and Technological Cooperation. The meeting was to share knowledge about common interests and capabilities and identify areas for future collaboration. The JCM consisted of six workshops held simultaneously around the North Island and an officials meeting held in Wellington. One of the six workshops, ocean and marine sciences, identified an area of interest in a joint project in the South Pacific Regional Fisheries Management Organisation (SPRFMO) area to map and groundtruth vulnerable marine ecosystem (VME) distribution.

The 3rd New Zealand and United States Joint Commission on Science and Technology Cooperation (JCM) met on 19 and 20 September 2012 in Washington. Building on several recommendations from the previous JCM (held in January 2010), and on the Marine Conservation Think Tank VME Workshop report 3: Science requirements for effective High Seas governance, held on 2–5 December 2011 (Lundquist et al 2011) 1, Topic 1 for the Oceans and Marine Workshop and the 3rd JCM meeting was again Vulnerable Marine Ecosystems (VMEs). Several actions were developed at the workshop and these included: ‘Increase in situ deep-sea exploration and VME studies in regions of common interest by exploring options for NOAA/WHOI participation (including use of ROV/AUV technologies) in New Zealand funded initiative and voyage to explore and ground-truth VMEs in the South Pacific’ and ‘Facilitate U.S. researcher involvement in NIWA Louisville Ridge Exploration.’

There are relatively few data available on the distribution of VME species or taxa in the South Pacific Ocean (Parker et al 2009a) although studies have been conducted in Antarctica (Tracey et al 2010, Parker et al 2009b) to use for the objective planning of spatial protection measures to protect those taxa, particularly in the SPRFMO Area. It is therefore becoming increasingly important to develop robust predictions of where VMEs are likely to occur, using habitat prediction and species distribution models. Such models have recently been developed and/or are in the process of being refined for certain VME taxa on a global scale (e.g. Actinaria, Guinotte et al 2006; Scleractinia, Tittensor et al 2009). However, the spatial resolution of existing models is coarse (larger than the scale of the topographic features typically targeted during demersal high seas fishing), and the level of uncertainty around the predictions is variable or still unknown.

Phase 1 a project to use modelling to predict the location of VMEs in the SPRFMO area was initiated between the US and New Zealand (ZBD2010-40) and has now been completed (Rowden et al 2013). The objectives of the project were to:

1. To develop and 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 data sets and evaluate modelling approaches which are likely to be useful to predict the distribution of vulnerable marine ecosystems in the South Pacific Ocean region.

Data for ten Vulnerable Marine Ecosystems (VME) taxa were compiled from different data sources to produce a single groomed dataset for VME indicator taxa in the New Zealand region. Regional-tuned environmental data layers and global environmental data layers were obtained from available data sources. Using these data, three types of predictive models were made for each VME indicator taxon. Two models were made using regional-tuned environmental data layers, using maximum entropy analysis (MaxEnt) and boosted regression tree (BRT) techniques to provide a comparison of the different model approaches. The third type of model used the MaxEnt approach, but used globally available environmental data layers. Having a third model meant that model performance could be compared based on the use of different environmental data layers. Three model types for all VME taxa have been completed and the performance of the different modelling approaches and usefulness of the environmental data sets described.

The next phases of the project will be undertaken as part of a MBIE-funded project that will revise models that predict the sites of Vulnerable Marine Ecosystems from existing data by conducting a ground truthing survey of benthic biodiversity on the Louisville Ridge in 2013/14 (Ministry of Business Innovation and Employment project code C01X1229). This will be used to inform New Zealand and South Pacific Regional Fisheries Management Organisation initiatives on spatial management in the South Pacific region, and potentially the New Zealand EEZ.

Other research relevant or specifically linked to the projects above, is listed in Table 14.1.

Table 14.1: Other research linked to Objective 1 habitat classification and characterisation.

MPI	HAB2007-01 Biogenic habitats as areas of particular significance for fisheries management ZBD2006-02 NABIS ongoing development 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	C01X501 Coasts & oceans Centre (NIWA) ecosystem based management, habitat model development with Auckland Regional Council C01X0907 Coastal Conservation Management (fish habitat classification) (NIWA)C01X502 Biodiversity & Biosecurity (NIWA) C01X0508 Seamount fisheries (linking acoustic backscatter to habitat type and biota) (NIWA) CO1X0906 Vulnerable deep-sea communities (mapping and sampling a range of deep-sea habitats (seamounts, slope, canyons, seeps, vents) (NIWA) CO1X0702 Kermadec Arc minerals (mapping and sampling the biodiversity of several Kermadec Arc seamounts) (NIWA)
DOC	MEC development and application to MPAs, Regional surveys
OTHER	University studies, Regional Council studies
ZBD2010-40	Mapping VMEs in the SPRFMO area Part 1. Predictive modelling desktop study
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? Can ecological mapping used in OS20/20 projects to date be extended to other areas of New Zealand?	

14.2.4. 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 2010. 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. Project completed. (see 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)

Other research relevant or specifically linked to the projects above, is listed in Table 14.2.

Table 14.2: 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
CRI Core purposes	C01X501 coasts & oceans productivity plankton-mesopelagic fish trophic relations Chatham Rise IO 2. Second Fisheries Oceanography voyage to Chatham Rise: mesopelagics and hyperbenthics
OTHER	AUT deepsea and subtidal food web dynamics; offshore & coastal biodiversity post graduate studies

14.2.5. 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[56]. 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.

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[56] See MFish Biodiversity Research Programme 2010: Part 4. Reference Materials and Other research

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 consequent to an increase in lobster abundance may not necessarily occur in another area.

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) 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 $\delta^{13}C$ values at the furthest inshore and offshore sites (e.g. Poor Knights and Long Bay) and the highest $\delta^{13}C$ 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 $\delta^{13}C$ of taxa from offshore sites is the result of a pelagic source of C and the enriched $\delta^{13}C$ 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 benthically-derived enriched $\delta^{13}C$. There were no obvious effects of marine reserve status on the isotopic signatures of study taxa with the exception of slightly enriched $\delta^{13}C$ 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, our 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.

ZBD2008-07 Carbonate Sediments: The positive and negative effects of land-coast interactions on functional diversity (complete):

Land-coast interactions can profoundly influence coastal biodiversity and ecosystem function. Estuarine primary productivity derived from phytoplankton, resuspended phytobenthos, aquatic vegetation and fringing habitat plant material is exported to the adjacent coast on outgoing tides and contributes to secondary production in the vicinity of the estuary mouth. However, land-derived sediments and contaminants that are discharged from estuaries can also stress open coastal populations. The balance of these competing processes was evaluated using a combination of laboratory and field investigations. A survey of two coastal locations (outside Whangapoua and Tairua harbours on the Coromandel Peninsula, New Zealand) quantified shifts in community structure in mollusc-dominated habitats and demonstrated that both distance from the mouth of the estuary and the size and density of large shellfish living in the sediments affect the composition and functionality seafloor communities. Tracing the importance of different estuary-derived food resources (seagrass, mangrove, estuarine phytoplankton and phytobenthos) using stable isotopes emphasized the importance of estuarine productivity to coastal bivalves. The work in the field has been supplemented with laboratory feeding trials, with the goal of verifying isotopic uptake rates in bivalve body tissues in a carefully controlled experimental setting. Trophic connections have important effects on coastal biodiversity. Understanding ecosystem processes and dynamics and their implications for functional biodiversity emphasises the importance of shifting the management focus from exploitation to resilience. Enhancing or maintaining this biodiversity will require more integrative ecosystem-based management focused on maintaining the resilience of coastal ecosystems.

Other research relevant or specifically linked to the projects above, are listed in Table 14.3.

Table 14.3: Other research linked to investigation of the role of biodiversity in the functional ecology of nearshore and offshore marine communities.

MPI	ZBD2005-04 Information on benthic impacts in support of the Foveaux Strait Oyster Fishery Plan ZBD2005-15 Information on benthic impacts in support of the Coromandel Scallops Fishery Plan ENV2005-23 Monitoring recovery of the benthic community between North Cape and Cape Reinga BEN2007-01 Assessing the effects of fishing on soft sediment habitat, fauna, and processes HAB2007-01 Biogenic habitats as areas of particular significance for fisheries management
CRI Core purpose	C01X1005— Management Of Cumulative Effects Of Stressors On Aquatic Ecosystems ; CO1X0907 Coastal Conservation Management, Freshwater and Estuaries and Coasts and Oceans
DOC	Conservancy surveys
BNZ	Biosecurity surveys
OTHER	Universities
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; pollution in offshore	
Ecosystem-based management and integrative governance	
Defining marine ecosystem services, linking them to ecosystem function and societal values	

14.2.6. 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.

Projects

ZBD2002-12 Molecular identification of cryptogenic/invasive marine species – gobies.

Project complete. (Lavery et al 2006.)

ZBD2009/10 Multi-species analysis of coastal marine connectivity.

An extensive literature review of published and unpublished information about connectivity of New Zealand coastal biota has been completed. Reviews were made of 58 studies of 42 taxa to identify the taxon or taxa studied, the habitat where each study took place, and geographic location of sampling sites used by each study. From these data, gaps in knowledge about taxa, habitats and spatial coverage of sampling were identified. Recommendations about four species to be studied, habitats that they should be collected from, and location of sampling sites were made. Recommendations included a standardised collecting protocol and for the development and application of microsatellite markers to quantify the population genetic structure and the coastal connectivity of these taxa (Gardner et al 2010).

Two PhD students have been carrying out field work, genetic analyses, and the writing up (in the form of theses) of this research. Both studies are now complete and both theses have been submitted for examination (dates in early 2014 to be confirmed). Fieldwork focussed on two flatfish species and two species of shellfish. The 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 use of microsatellite markers for the four species already under investigation in the original ZBD2009-10 project). First, the extension work focuses on scallops in the Hauraki Gulf and Coromandel Peninsula region. Scallops have been collected from several populations in this region and further samples will be added in the next year. Second, the extension work focuses 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. In both cases, genetic connectivity will be assessed to determine linkages among populations at the two different spatial scales. The smaller spatial scale information will be of particular relevance to the scallop fishery in the Hauraki Gulf and Coromandel Peninsula region, whereas the larger scale work will complement ongoing studies of coastal connectivity at the national scale already under examination as part of the project. A PhD student has been recruited for this work and a suite of microsatellite markers has been developed for the New Zealand scallop and testing of population genetic variation is underway.

Other research relevant or specifically linked to the projects above, are listed in Table 14.4.

Table 14.4: 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
MBIE	C01X0502 Biodiversity& Biosecurity
MPI	Base line surveys for non-indigenous species
OTHER	Universities **[?]**
BRAG PROJECTS FOR 2011-12	
Extension to ZBD2009-10 to include subtidal shellfish	
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?	

14.2.7. 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[57] 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). 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.

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[57] http://www.un.org/apps/news/story.asp?NewsID=36941&Cr=emissions&Cr1 Downloadable Report The Environmental Consequences of Ocean Acidification

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[58] and has been identified as a gap in biodiversity research in New Zealand[59]

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.

Fifteen reports stemming from this project have been submitted to the Ministry and are at various stages of review, acceptance and publication. Four reports are still to be delivered. The report most relevant to this section is Pinkerton (submitted). Other reports include: Carroll et al (submitted); Jackson et al (submitted); Lalas et al (submitted) a; b; Lalas & MacDiarmid (submitted); Lorrey et al (2013); MacDiarmid et al (submitteda; b); Maxwell & MacDiarmid (submitted); Neil et al (submitted); Paul (2012); Parsons and Smith (2011).

ZBD2008-11 Predicting plankton biodiversity & productivity with ocean acidification.

This multi-year project is inter-linked with the Coasts and Oceans OBI and has the following objectives:

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 algorithm for *E huxleyi* for future application in New Zealand waters.
4. To determine the sensitivity of, and response of *E. huxleyi* and other EEZ coccolithophores to pH under a range of realistic atmospheric CO_2 concentrations in perturbation experiments, using monocultures and mixed populations from in situ sampling.

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[58] http://biodiversity-l.iisd.org/news/ungas-second-committee-considers-biodiversity-and-sustainable-development/

[59] Green, W.; Clarkson, B. (2006). Review of the New Zealand Biodiversity Strategy Themes

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 New Zealand.
6. To determine the sensitivity of diazotrophs to ocean acidification composition in sub-tropical waters north of New Zealand.

The project is proceeding according to plan and is still primarily in the sample collection phase with some data analysis but limited interpretation to date. The biodiversity record of coccolithophore species in New Zealand waters has been extended, with a transect across the Tasman Sea and a number of transects across the Chatham Rise. A bloom of the coccolithophore *Emiliana huxleyi* on the Chatham Rise was extensively characterised in terms of surface water biogeochemistry, and subsequently successfully cultured in the lab. Seasonal and interannual variability of *E. huxleyi* blooms were further characterised by extending the true colour satellite image analysis of presence/absence of coccolithophore blooms in the New Zealand EEZ. This was augmented by sample collection for ground-truthing of published calcite algorithms (for satellite detection of coccolithophore blooms) and application of a published calcite algorithm to New Zealand waters for 2002–03. Coccolithophore acidification sensitivity experiments were run in the Tasman Sea and the Chatham Rise region, with preliminary analysis indicating a decline in coccolithophore abundance under high CO_2, but not when accompanied by elevated temperature as predicted under future climate change scenarios. Analysis of sediment trap samples for pteropod and foraminifera identification and abundance was completed for 2000–2010, with significant interannual variability noted in both, but also some indication of a recent decline in pteropod abundance in Sub-Antarctic water. Sample analysis from the 2010 Tasman Sea voyage identified the presence of nitrogen-fixing unicellular cyanobacteria and significant nitrogen fixation south of the Tasman Front, in contrast to previous observations. In acidification sensitivity experiments on this voyage nitrogen fixation did not change or decreased under high CO_2 concentrations, in contrast to published data. Outputs to date include Boyd et al (2011).

ZBD2009-13 Ocean acidification impact on key NZ molluscs.

Ocean acidification associated with increased atmospheric CO_2 levels is a pressing threat to coastal and oceanic ecosystems. The chemical reaction which occurs when this CO_2 is dissolved in seawater results in a well documented decrease in seawater pH (and an increase in seawater acidity), which may physically dissolve $CaCO_3$ shells and/or skeletons and affect the shell/skeleton generation, as well as influencing many other physiological processes. Flow on effects to the viability of populations and the economic benefit that can be derived from commercially important species are likely. There is very little information on how key New Zealand calcifying species will respond to this change.

This project is using laboratory experiments to quantify responses of key New Zealand mollusc species (paua, *Haliotus iris*, cockles, *Austrovenus stutchburyi*, and oysters *Tiostrea chiliensis*) to levels of ocean CO_2 saturation predicted to occur in New Zealand waters over the following decades. Results will be combined with information on the role of these key species in influencing ecosystem structure and function, to assess local and ecosystem-scale implications of acidification of New Zealand coastal waters expected in the following decades.

ZBD2010-41. Potential effects of ocean acidification on habitat forming deep-sea corals in the New Zealand region.

Specific Objectives of this research were to 1. Determine the carbonate mineralogy of selected deep-sea corals found in the New Zealand region, 2. Assess the distribution of deep-sea coral species in the region relative to improved knowledge of current and predicted aragonite (ASH) and calcite saturation horizons (CSH), and 3. Assess potential locations vulnerable to deepwater upwelling and areas of key deep-water fishery habitat. Through a literature search and analysis, the project aimed to determine the most appropriate tools to age corals 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 of declining ocean pH on these key fauna.

Under Objective 1, new results of investigations into the carbonate mineralogy of selected deep-sea corals found in the New Zealand region were presented, and previous work on coral mineralogy summarised. The mineralogy and trace element concentration (Sr and Mg) of the five branching stony coral species (Order: Scleractinia) *Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*, and the endemic *Oculina virgosa,* and for the key habitat forming gorgonian coral species (Order: Alcyonacea) *Keratoisis* spp., *Lepidisis* spp., *Paragorgia* spp. and *Primnoa sp*., was ascertained. Stony branching corals are all aragonitic with high Sr and low Mg while most of the gorgonian corals are made of high Mg and low Sr, with high Mg calcite (>8 mol% Mg). The gorgonian sea fan, *Primnoa sp*., is aragonitic.

Under Specific Objective 2, up to date position and depth data were used to produce distribution maps for the study species. Data compare well with previous publications from biodiversity research, research trawl, and observer sampling effort on wide regional distribution, but individual species display variations within the region. The peak depth distributions are unimodal at about 800–1000 m for most of the above species, but *G. dumoas*, *E. rostrata*, and *Lepidisis* spp. show bi-modal distributions and *O. virgosa* occurs primarily in shallow depths. In the second year of the project these distribution data will be compared with existing and predicted aragonite and calcite saturation horizons, particularly in areas of key deepwater fishery habitat.

Also under Specific Objective 2, on-going opportunistic water sampling analyses are being carried out to determine alkalinity and dissolved inorganic carbon (DIC), and modelling to determine aragonite (ASH) and calcite saturation horizon (CSH) data is in progress. The aim is to compare water carbonate chemistry with regional biogeochemistry models and future scenarios to identify areas potentially at risk from ocean acidification.

Under Specific Objective 3, at-sea sampling of live corals for aquarium studies was carried out to investigate the feasibility of keeping the corals alive for growth and ocean acidification experiments. A literature search and analysis to determine the most appropriate tools to age and measure the effects of ocean acidification on deep-sea habitat-forming corals is complete (Tracey et al 2013).

Other research relevant or specifically linked to the projects above, are listed in Table 14.5.

Table 14.5: 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
EMERGING ISSUES (this objective)	
What papers can be generated on the effects of climate change on marine biodiversity in NZ in time for 5th IPCC report? 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)	

14.2.8. 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[60] 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[61]. A new international initiative launched in 2010 "Biodiversity Indicators Partnership[62]" 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 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

ZBD2004-10 Development of bioindicators in coastal ecosystems.

Project complete (Savage 2009). Agricultural and urban development can increase run-off and lead to excessive nutrient loadings in fragile coastal environments that are nursery grounds for a diverse array of coastal and estuarine species, as well as other resident organisms. This project investigated the development of bioindicators to strengthen the ability of managers to detect and quantify changes in anthropogenic nitrogen inputs to coastal and estuarine ecosystems by comparing six study sites with different levels of development ranging from pristine through to fully urban. The results show a strong positive relationship between the percent agricultural land in surrounding catchments and total nitrogen (TN) loading to nearshore environments.

These results also hint at differences in dissolved and particulate nitrogen source pools, and highlight the importance of using complementary components of food webs and high spatial replication to show linkages between watershed land use and chemical markers in biota. The effects of nutrient enrichment were transmitted up the food web, with growth of secondary consumers, *Notolabrus celidotus* (spotties) and *Grahamina nigripenne* (estuarine triplefins) generally enhanced in nutrient enriched coastal areas. Benthic prey dominated the diets of these fish species, with amphipods and brachyurans being the most important prey items for triplefins and spotties, respectively. However, there were site-specific differences in prey importance and diet diversity. Both triplefins and spotties consumed considerably more diverse prey items at pristine than nutrient-enriched coastal areas. Food web models based on stomach content analyses and dual isotope ratios suggest that there are shifts in the relative importance of the different organic matter sources supporting food structure among the different coastal ecosystems due to nutrient enhancement from land-based activities.

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[60] 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

[61] http://www.mfe.govt.nz/environmental-reporting/about/tools-guidelines/indicators/core-indicators.html

[62] www.bipnational.net/IndicatorInitiatives

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 and tender evaluations are underway.

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[63].

ZBD2008-15 Continuous Plankton Recorder Project: implementation and identification.

This project is complete. (Robinson et al. In prep 2013) This project adopted the methods used in a long-term 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[64]. 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 enroute 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* 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.

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[63] The Department of Conservation Biodiversity Monitoring and Reporting System Fact Sheet July 2010

[64] Southern Ocean CPR programme http://data.aad.gov.au/aadc/cpr/

ZBD2010-42 Marine Environmental Monitoring Programme.

This project continues from ZBD2008-14. A starting point to the assessment and reporting of broad-scale changes in New Zealand's marine environment is to define basic criteria and locate all existing and past time series of marine environmental data to improve awareness and access to these data. After this, these data can be evaluated as to their fitness-for-purpose for contributing towards a national Marine Environmental Monitoring Programme (MEMP). To date an online catalogue has been designed and a portal to this is available at http:\geodata.govt.nz. Questionnaires were developed to determine what marine environmental time series data were available within New Zealand. Information to date gives us 131 databases, 50% of these are listed as having ongoing funding (although not necessarily for all locations), and another 19% are listed as likely to continue. Over 70% are publically available. Most cover more than one location, although this is dependent on how the databases are constructed, e.g., DOC at present has a separate database for each marine reserve, while regional councils tend to have separate databases for different subjects (e.g., contaminant monitoring, ecological monitoring). Around 95 estuaries and harbours are being sampled, which is not surprising given that the majority of the information comes from Regional Councils. There are 78 coastal locations and 33 marine reserves.

The second phase, determining fitness-for-purpose, was begun at a workshop held at NIWA on 11th June (see objective 3). Priority variables for inclusion in a national monitoring programme have been identified from responses to a questionnaire sent to scientific experts and central and regional government departments involved in monitoring and/or reporting. Core reference sites and major gaps in the spatial network are presently being determined and the requirements for spatial and temporal sampling determined.

Other research relevant or specifically linked to the projects above, are listed in Table 14.6.

Table 14.6: Other research linked to bbiodiversity 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) DEE2010-05 DEE2010-06
MBIE	Core funding for Coasts and Oceans Centre
DOC	Conservancy projects-Hawke's Bay;
OTHER	Regional Councils, Universities
EMERGING ISSUES	
Monitoring coastal waters and New Zealand's oceans to report on a national scale remains a major gap	
There is little long-term commitment to direct monitoring of the marine environment	

14.2.9. 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[65].

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 ENV200515, 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 ENV200516, 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. The objectives of this project are to:

1. Further develop landscape/seascape ecological models of disturbance/recovery dynamics in marine benthic communities, incorporating habitat connectivity, based on an existing model by Lundquist et al (2010).
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.

The baseline model, incorporating connectivity, has been created in Matlab. Objective 2 (predictions for functional biodiversity based on model) is underway. Some progress has been made on objective 3 (quantify functional biodiversity from existing data) through familiarisation of the programmers with the datasets of the Ocean Survey 2020 Chatham/Challenger project (ZBD2007-01) and biodiversity analyses to date for objective 8 of that project. Objective 4 is in progress, with the majority of the field test funded by BEN2007-01. Researchers from both projects have met to discuss and modify the draft sampling design in order to best allocate sampling to test the predictions of the functional diversity model. The field testing took place in March-April 2010 in Tasman/Golden Bay.

Other research relevant or specifically linked to the projects above, are listed in Table 14.7.

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[65] 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

Table 14.7: 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
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.	

14.2.10. 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

ZBD2002-02 Whose larvae is that? Molecular identification of planktonic larvae of the Ross Sea. Completed. (See Sewell et al 2006, Sewell 2005, Sewell 2006.)

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.

This project is 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.

Project 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.

Project 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).

IPY2007-01 NZ International Polar Year Census of Antarctic Marine Life

Overall science objectives for the Project were developed by MPI, NIWA and other interested and participatory parties in discussions held through the Ocean Survey 20/20 Science Working Group.

1. To measure and describe the relationships between patterns of marine organisms, their biodiversity and environmental variables between longitudes ~170°E and ~175°W, and depths down to ~3500-4000m in the Ross Sea region.

2. To assess the trophic interrelationships of the major functional groups in the Ross Sea and regional ecosystem, with particular reference to improving inputs to ecosystem modelling.

3. To obtain baseline measures of the marine environment and identify a suite of ecosystem or environmental indicators that could potentially be used to monitor change in response to environmental or anthropogenic forcing in the Ross Sea region

All specific objectives apart from objective 2 have now been completed.

Specific Objective 1: To measure seabed depth and rugosity using the multibeam system (whenever possible) to identify topographic features such as bottom type, iceberg scouring, seamounts etc and to determine areas for targeted benthic fauna sampling. (not funded in this project). Objective Completed. (Mitchell 2008, Hanchet et al 2008a)

Specific Objective 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. (Draft report completed.)

The distributions of the seabird and marine mammal taxa reported from two RV *Tangaroa* voyages (TAN200602 and TAN200802) have been mapped. These represent the count data of seabirds recorded during the 2006 Ross Sea voyage and the locations of images of seabird taxa (recorded opportunistically) from the 2008 IPY-CAML voyage and records from observers from the toothfish fishery. The distributions include the presence data of taxa over waters south of about 60° S to the Ross Sea (Baird et al. In press)..

Specific Objective 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.

The Continuous Plankton Recorder (CPR) was deployed during the IPY voyage, both during the transit to and from Wellington, and within the Ross Sea itself. CPR silks collected during transit were preserved in formalin and sent to Australian Antarctic Division where they were analyzed for zooplankton species composition and abundance. CPR silks collected within the Ross Sea were preserved in ethanol for the analysis of epipelagic meroplankon. In addition to the zooplankton, sampling, water samples were collected for phytoplankton analysis using the underway water sampling system from a depth of 7 m, corresponding to the approximate depth of CPR sampling. In addition to the work described above, ICOMM (International census of marine microbes) samples collected during the IPY-CAML survey (10 m depth × 4 stations) have been analysed by collaborators in the USA (Ghiglione et al 2012).

Specific Objective 4: To analyse underway and station data collected on salinity, temperature and chlorophyll *a* data, spot optical measurements with the SeaWiFS Profiling Multichannel Radiometer (SPMR), surface samples for chlorophyll *a*, nutrients and particle analysis as well as underway nutrient observations to allow ground-truthing of data collection from satellites and identify water masses (e.g. surface seawater temperature, and chlorophyll concentration).

This objective addressed background physical and surface biological conditions at the time of the IPY-CAML survey. The objective was split into two parts 1. Characterisation of the biological environment and bio-optical regime using continuous underway sampling, and 2. Identification of thermohaline fronts using discrete and underway sampling of temperature, salinity and nutrient profiles. The combined dataset was used to validate satellite data of temperature and surface chlorophyll distributions, providing a synoptic overview of physical and biological conditions during the survey.

Specific Objective 5: To identify and determine the spatial distribution, abundance (biomass), diversity, and size structure of epipelagic, mesopelagic (and possibly bathypelagic) species using acoustics data, target strength estimation techniques and net sampling.

This objective addressed samples collected using the mesopelagic trawl and acoustic data collected from midwater marks using the ship's echosounders. Results were presented at five conferences: 1) CAML-IPY Symposium in Genoa, Italy, May 2009; 2) CCAMLR SG-ASAM meeting in Genoa, Italy, May 2009; 3) Antarctic New Zealand conference in Auckland, July 2009; New Zealand Marine Sciences' Society conference in Stewart Island, July 2011; and International Polar Year Symposium, Montreal, Canada, April 2012. Results were also presented to the Ross Sea Bioregionalisation workshop in Wellington in June 2009 (see below) and were incorporated in the bioregionalisation reports prepared for CCAMLR (SC-CAMLR-XXIV-BG-25) and the Antarctic Treaty Consultative Meeting (ATCM). Reports include those by Koubbi et al (2011), O'Driscoll (2009), O'Driscoll et al (2009, 2011), Pinkerton et al (2013), and Hanchet et al (2013).

Specific Objective 6: To identify and measure diversity, distribution and densities of mesozooplankton, macrozooplankton and meroplankton.

This objective addressed the samples taken by Multiple Opening/Closing Net and Environmental Sampling System (MOCNESS) from the sea surface to the sea floor. The samples were quantitatively divided at sea to allow several complementary analyses to be performed. In terms of the mesozooplankton community in the Ross Sea, copepods were the dominant zooplankton collected in most samples, and this was primarily calanoids and cyclopoids (i.e., *Oithona* spp.). However, in certain cases pteropods (*Limacina helacina antarctica*) and salps (*Salpa thompsoni*) made important contributions to mesozooplankton abundance. Total water column mesozooplankton biomass ranged between 0.6 and 9.1 g C m^{-2} and was usually highest close to the surface. Mesozooplankton biomass in the Ross Sea was generally higher than expected, and can rival that of productive Sub-Antarctic regions (e.g., South Georgia). Salps were the main macrozooplankton species recorded in the MOCNESS samples and a paper describing the population ecology and distribution of *Salpa thompsoni* on the continental slope and around the seamounts to the north of the Ross Sea has been published by Pakhomov et al (2011).

Samples were also preserved in ethanol for the analysis of meroplankton species composition and DNA sequencing. Larvae from at least eight phyla were found, with a remarkable dominance of annelids in both abundance and diversity. Overall, larval abundances observed were lower than other Antarctic studies, which is likely to be attributable to the late summer sampling, months after Ross Sea’s phytoplankton bloom and the main trigger of spawning in many benthic invertebrates. Analysis of variation in meroplankton community composition showed significant differences among geographic regions (Shelf, Slope and waters of the Antarctic Circumpolar Current - ACC), among water masses (Shelf Water, Antarctic Surface Water, and Circumpolar Deep Water), and among depth strata (upper, midwater and bottom). Overall, near surface waters showed greater larval abundances, and these values decreased from the continental shelf to the slope, declining further in the deeper waters of the ACC. Differences between these locations were due not only to the presence or absence of certain taxa, but also a result of changes in OTU abundance.

Specific Objective 7: To determine diversity, distribution and densities of viral, bacterial, phytoplankton and microzooplankton species in the water column.

The full data sets have been completed and loaded into an MPI database and to the South western Pacific OBIS node (Gordon 2000). Phytoplankton and nanoplankton cell counts have revealed that there is a significant difference between shelf and abyssal site water column assemblages, both in terms of cell numbers, diversity and density. These data now have to be integrated with the water column data to help understand what may be driving the changes in these compositions.

Specific Objective 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.

This objective had three key tasks; (i) to identify specimens, update the Ross Sea species list and determine biodiversity, (ii) to identify fish assemblages and relate them to environmental data, and (iii) to compare estimates of fish density and abundance between trawls, visual (video & still images) and acoustic sampling techniques. A fourth key task, to determine density and abundance of demersal fish using a bottom trawl survey, was funded under MPI project ANT2007-02. Results have been published as three scientific journal papers with an additional paper in review, and have been submitted to several CCAMLR working group meetings.

A paper on the distribution and diversity of demersal and pelagic fish species in the Ross Sea region including results from both the BioRoss and IPY surveys and collections from the toothfish fishery will soon be published (Hanchet et al 2013). A diverse collection of over 2500 fish specimens was obtained from the BioRoss and IPY-CAML surveys representing 110 species in 21 families. When combined with previous documented material this gave a total species list of 175, of which 137 were from the Ross Sea shelf and slope (to the 2000 m isobath). Demersal species richness, diversity and evenness indices all decreased going from the shelf to the slope and the seamounts. In contrast, indices for pelagic species were similar for the slope and seamounts/abyss but were much lower for the shelf.

A paper on the variation of demersal fish assemblages in the western Ross Sea including results from both the BioRoss and IPY surveys has been published (Clark et al 2010b). The distribution and abundance of 96 species able to be identified to species level collected in these surveys were examined to determine if demersal fish communities varied throughout the area, and what environmental factors might influence this. Three broad assemblages were identified, in the southern Ross Sea (south of 74ºS), central–northern Ross Sea (between latitudes 71º–74ºS), and the seamounts further north (65º–68ºS) where some species more typical of sub-Antarctic latitudes were observed. Multivariate analyses indicated that environmental factors of seafloor rugosity (roughness), temperature, depth, and current speed were the main variables determining patterns in demersal fish communities.

Acoustic data collected during the demersal survey suggest that there may be potential to use fisheries acoustic methods to obtain estimates of grenadier abundance (O'Driscoll et al 2012). The acoustic target strength distribution of single targets close to the bottom was very similar to that predicted based on the measured size range of grenadiers. There are also positive correlations between acoustic backscatter and trawl catches of grenadiers.

Photographic data collected using NIWA's Deep Towed Imaging System (DTIS) suggest that there may be potential to use photographic methods to obtain estimates of community structure and grenadier abundance (Bowden et al 2012).

Twenty-three sites spanning the continental shelf, northern continental slope, abyssal plain, and two seamounts were sampled using the towed camera and either demersal trawl or beam trawl, allowing direct comparisons between sampling methods. Patterns of species turnover between sites were similar across all methods. Estimates of fish population densities from the towed camera and beam trawl data were also comparable but those from the demersal trawl were consistently lower than for the other methods. *Macrourus* spp. grenadiers were about eight times less abundant in the demersal trawl than the video data but more large individuals were sampled by the trawl than the video and biomass estimates were similar.

Specific Objective 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 the Ross Sea.

Using cameras, corers, epibenthic sleds, and trawls, benthic bacteria, macro-infauna, macro-hyperbenthic fauna, and mega-epifauna were sampled at sites on the continental shelf and previously unsampled areas on the northern continental slope of the Ross Sea, the abyssal plain, and seamounts to the north. Photographic data from seamounts in the northern Ross Sea region revealed a diverse and abundant fauna. Particularly striking were benthic communities comprised of stalked crinoids and brachiopods on Admiralty Seamount and the flanks of Scott Island which are reminiscent of an archaic fauna that may have survived through the isolation of these seamounts and reduced predator species (Bowden et al 2011b).

Taxonomists in New Zealand and around the world identified more than 150 000 individual specimens representing more than 700 species, many undescribed, across sixteen phyla for the mega-epifauna groups alone (e.g. Lörz 2009, 2010, Eléaume et al 2011). At least three genera and sixty-two species are new to science. All eukaryotic components of the benthic fauna showed similar broad-scale distributional trends across the study region. Total abundances and numbers of taxa were orders of magnitude higher on the continental shelf than on the slope or abyss plain, and shelf, slope, and abyssal samples were distinct from each other in multivariate analyses. Diversity, however, was comparable between shelf and abyssal sites and lowest on the slope. Bacterial diversity was highest in abyssal and slope samples, but abundance, biomass, production, and activity of all enzymes except proteinase, which was highest in the abyss, were significantly higher in shelf samples. Benthic mega-epifaunal community composition was more strongly correlated with depth and seabed current speed than either water column productivity or seasonal ice cover, indicating that local hydrodynamics and their influence on advection of primary production are more important in determining distributions across the shelf than are local variations in production. Fauna on the seamounts were distinct from all other samples and were comprised of both Antarctic and Southern Ocean species, including remarkable populations of a new hyocrinid species on Admiralty seamount (Bowden et al 2011b, Eléaume et al 2011).

Published research to date has provided new insights into the distributions of several taxonomic groups (Lörz et al 2009; Lörz & Coleman 2009) , raised questions about the history of the northern seamount fauna over evolutionary time (Bowden et al 2011c), and contributed to a meta-analysis of the relationship between productivity and diversity in the deep sea (Leduc et al 2012). In combination with molecular phylogenies and existing data from around Antarctica, results from this project represent a major contribution to knowledge of the Antarctic marine ecosystem.

*Specific Objective 10:*_To describe trophic/ecosystem relationships in the Ross Sea ecosystem (pelagic and benthic, fish and invertebrates).
Progress has been made on obtaining data from which to elucidate trophic relationships between organisms in the Ross Sector of Antarctica collected on the IPY-CAML survey in February–March 2008. Two methods have been used. First, 1081 stomachs from 22 species of Antarctic fish were examined and the contents of the full or partially-full stomachs (comprising 776 fish) were identified to 68 prey codes. Index of Relative Importance (IRI) has been calculated from these data and diet overlap between fish species is presented. Second, stable isotope and elemental composition analysis of samples were carried out for carbon and nitrogen. In total, nearly 2000 samples were analysed. Samples include:

- Fish (N=662 muscle, N=377 liver samples, 22 species);
- Cephalopods (N=193);
- Pelagic invertebrates (N=407);
- Benthic sediments (N=36);
- Phytoplankton (N=92);
- Benthic invertebrates (N=200 completed, 95 pending analysis);

Results have already been used to assist in parameterising and validating the quantitative model of the food web of the Ross Sea (paper accepted by CCAMLR Science). Research on the shrinkage of Antarctic silverfish carried out as part of this objective contributed to a paper presented to the Ministry of Fisheries Antarctic Fisheries Working Group and accepted for submission to the CCAMLR working group on fisheries assessment in September 2010 (Pinkerton et al 2007, 2009a, 2009b).

Specific Objective 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 for all fish and multi-cellular invertebrate species by sequencing reference specimens in conjunction with Canadian Barcoding Centre, for specimen identification in gut content, plankton, and in taxonomic and population genetic projects.

DNA data sets generated for selected Ross Sea taxa were combined with parallel data sets generated by other Institutes in order to estimate divergence within and among regions in the Southern Ocean. High levels of divergence, indicative of cryptic speciation, were found in all major groups tested to date. Fishes: DNA sequencing of the COI gene revealed four well supported clades among the three recognized species of *Macrourus* in the Southern Ocean, indicating the presence of an undescribed species (Smith et al 2011). A conclusion subsequently supported by meristic and morphometric examination of specimens with the description of a new species by McMillan et al (2012). DNA barcodes also showed high sequence divergence among specimens of the slender codling *Halargyreus johnsonii* from New Zealand and the Southern Ocean, indicative of a cryptic species in this cosmopolitan species (Smith et al 2011). A study of snailfishes collected during the IPY survey and from the toothfish fishery showed high species diversity with more than 34 Ross Sea liparid species in three genera; 18 of them new to science (Stein 2012).

Invertebrates: A combined NZ-BAS data set on the octopod genus *Pareledone* provided one of the largest barcoding studies on a Southern Ocean genus. Ross Sea specimens provisionally identified as *Pareledone aequipapillae* appeared in a discrete clade to specimens from the Antarctic Peninsula, with a barrier to gene flow to the west of the Antarctic Peninsula (Allcock et al 2010). Large numbers of echinoderms have been tissue sampled and sequenced for COI and include the Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, and the crinoids (Dettai et al 2011). In the Ophiuroidea two dominant patterns emerged: a. widely distributed species showing shallow divergence by location and b. species with deeper divergence associated with location or depth, that represent cryptic species. A similar pattern emerged in the smaller set of Asteroid sequences, with deep divergences within some Ross Sea taxa. Preliminary results for the amphipod genus *Rhacotropis* showed 5 well supported clades, indicative of cryptic taxa; while for the genus *Epimeria* (27 specimens from the Ross Sea) there were two well supported clades for specimens identified as *Epimeria robusta*, and likewise for specimens identified as *E. schiaparelli*, indicative of cryptic taxa (Lörz 2009, 2010, Lörz et al 2012). These taxa show shallow morphological differences.

IPY2007-02 NZ IPY-CAML Cephalopoda.

This project will report on the diversity of Antarctic Cephalopoda (Octopus and Squid), including a complete inventory of taxa, and reports on ontogenetic and sexual variation in species, their systematics, diversity, distribution, life histories, and trophic importance. A MAppSc thesis has been completed as part of this project (Garcia 2010).

Other research relevant or specifically linked to the projects above, are listed in Table 14.8.

Table 14.8: Other research linked to MPI Ross Sea Antarctica biodiversity programme.

MPI	ANT2011-01 Stock modelling, fishery effects and ecosystems of the Ross Sea
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
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)	

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 55 projects were commissioned and managed within this 10 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. 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[66], 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 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.

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[66] http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/environment-domain-plan-stocktake-paper.aspx

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.

Concluding remarks

New Zealand is moving into an era of unprecedented and increasing interest in the utilisation of marine resources. 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 drafted (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. The newly released Coastal Policy statement and proposed Policy Statement on Indigenous Biodiversity demonstrates an awareness by Government that much of New

Zealand's primary production based economy is dependent on clean "green" policies supporting effective environmental management both on land, freshwater and in the sea.

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. 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.

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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.

15. APPENDICES

15.1. Terms of Reference for the Aquatic Environment Working Group in 2013

Terms of Reference for the Aquatic Environment Working Group (AEWG) in 2013

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[141] (the Research Standard), and that research and science information is reviewed by the Working Group against the *PRIOR* 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.

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[141] Link to the Research Standard: http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm

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.

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.

15.2. AEWG Membership 2013

Convenors: Martin Cryer (protected species) and Rich Ford (other issues)
Members: Present: Ed Abraham, Owen Anderson, Ian Angus, William Arlidge, Lou Askin, Chris Baigent, Suze Baird, Barry Baker, Brett Beamsley, Biz Bell, Roger Belton, Michelle Beritzhoff, Katrin Berkenbusch, Trevor Bills, Jenny Black, Laura Boren, Christine Bowden, Erin Breen, Paul Breen, Niall Broekhuizen, Stephen Brouwer, Tania Cameron, Jodie Campbell, Don Carsen, Martin Cawthorn, Alastair Childs, Simon Childerhouse, Louise Chilvers, David Clark, Malcolm Clark, Tom Clark, Rebecca Clarkson, Deanna Clement, Chris Cornelison, Paul Crozier, Rohan Currey, Steve Dawson, Igor Debski, Ian Doonan, Matt Dunn, Ursula Ellenburg, Jack Fenaughty, Dave Foster, Chris Francis, Malcolm Francis, Allen Frazer, Dan Fu, Jim Fyfe, Shane Geange, Hilke Giles, Paul Gillespie, David Goad, Graeme Granger, Tane Gray, Rose Grindley, Tim Haggit, Sean Handley, Neil Hartstein, Jeremy Helson, Judi Hewitt, Julie Hills, Steph Hopkins, Rosie Hurst, Kerry Huston, Aaron Irving, Catherine Jones, Colin Johnston, Emma Kearney, Nigel Keeley, Ben Knight, Anna Kraack, Craig Lawson, Mary Livingston, Dave Lundquist, Pamela Mace, Darryl MacKenzie, Rob Mattlin, Vidette McGregor, Bruce McKinley, Peter McMillan, Tania McPherson, Stefan Meyer, David Middleton, Laura Mitchell, Reyn Naylor, Tracey Osborne, Milena Palka, Johanna Pierre, Matt Pinkerton, Irene Pohl, Marine Pomarede, Kris Ramm, Will Rayment, David Redshaw, Vicky Reeve, Pat Reid, Yvan Richard, Jim Roberts, Bruce Robertson, Pete Russell, Paul Sagar, Bruce Scott, Carol Scott, Ben Sharp, Derek Slooten, Liz Slooten, Tony Stafford, Brian Stewart, Kevin Stokes, Katrina Subedar, Alex Thompson, David Thompson, Finlay Thompson, Geoff Tingley, Di Tracey, Ian Tuck, Ben Tuckey, Beth Tupara-Katene, Brent Twist, Dominic Valieres, Nathan Walker, Bill Wallace, Barry Weeber, Richard Wells, John Willmer, Hamish Wilson, John Wilson, Brent Wood, Ray Wood, Kirsty Woods.

15.3. Terms of Reference for the Biodiversity Research Advisory Group (BRAG) 2013

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 processes142;"

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 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.

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[142] See MFish Biodiversity Research Programme 2010: Part 1. Context and Purpose

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:

8. To develop ecosystem-scale understanding of biodiversity in the New Zealand marine environment
9. To classify and characterise the biodiversity, including the description and documentation of biota, associated with nearshore and offshore marine habitats in New Zealand
10. To investigate the role of biodiversity in the functional ecology of nearshore and offshore marine communities.
11. To assess developments in all aspects of biodiversity, including genetic marine biodiversity and identify key topics for research
12. 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.
13. To develop appropriate diversity metrics and other indicators of biodiversity that can be used to monitor change

14. 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 a 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[143] (the Research Standard), and that research and science information is reviewed by the Working Group against the *PRIOR* principles for science information quality (page 6) and the criteria for peer review (pages 12-16) in the Standard.

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[143] Link to the Research Standard: http://www.fish.govt.nz/en-nz/Publications/Research+and+Science+Information+Standard.htm

- 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.
- 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
    - 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
    - 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.

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). This information quality ranking must 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 must be included in Working Group reports. In particular, the quality shortcomings and concerns for moderate/mixed and low quality information must be documented.

* 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.

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.

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
- 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.
- 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.

15.4. BRAG attendance 2013

Convenor: Mary Livingston (MPI chair),

Members: Malcolm Clark, Mark Morrison, Wendy Nelson, Cliff Law, Di Tracey, Dennis Gordon, Anne-Nina Lorz, Stuart Hanchet, Richard O'Driscoll, Jonathon Gardner, Simon Thrush, David Bowden, Matt Pinkerton, Els Maas, Ashley Rowden, Carolyn Lundquist, Judi Hewitt, Drew Lohrer, Alison MacDiarmid, Julie Hall, Vonda Cummings, Kate Neill, Tracy Farr, Di Tracey, Alistair Dunn, Barb Hayden (all NIWA), David Middleton (Seafood NZ), , Rich Ford (MPI), Mark Costello (Auckland University)

15.5. 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.

15.6. 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

15.7. *OUR Strategy 2030: growing and protecting New Zealand*

Also available at: http://www.mpi.govt.nz/Portals/0/Documents/about-maf/strategy.pdf

OUR STRATEGY 2030
Growing and protecting New Zealand

WHY THIS STRATEGY?

This is a critical time for New Zealand. After decades of economic growth based on debt and consumption, the economy is seriously unbalanced.

A re-balancing of the economy towards more productive sources of growth is required.
New Zealand must trade its way to greater growth and prosperity.

The primary sectors (from producers through to processors and exporters) are absolutely crucial to this, and strong environmental performance will be fundamental to their long-term success.

The new Ministry's role has to be focused on the success of the primary sectors for the benefit of all New Zealanders. We need to enable:

- innovation and growth;
- access for more New Zealand products into new offshore markets;
- the sustainable use and protection of the natural resources of New Zealand.

We will contribute to New Zealand's prosperity by delivering robust policy and better facilitating sustainable primary production and trade.

The new Ministry will be focused on enabling the primary sectors to be as successful as possible for the benefit of all New Zealanders.

OUR FOCUS

MAXIMISE EXPORT OPPORTUNITIES AND IMPROVE SECTOR PRODUCTIVITY

- Grow the value of New Zealand's primary products.
- Ensure the primary sectors can access the world's fastest growing and highest value markets.
- Focus on the primary sectors with the greatest potential for sustainable growth.

WE WILL ACHIEVE THIS BY:

- Partnering with the primary sectors to identify and seize opportunities for improved productivity and market returns.
- Removing unnecessary barriers to trade and increasing our use of international standards to enhance value.
- Encouraging and co-investing in industry innovation and adoption.

INCREASE SUSTAINABLE USE AND PROTECTION OF NATURAL RESOURCES

- Foster the sustainable use of New Zealand's natural resources by the primary sectors.
- Enable the protection of New Zealand's natural resources from biological risks.
- Protect and enhance the integrity and reputation of New Zealand's primary products, including food.

WE WILL ACHIEVE THIS BY:

- Identifying and managing risks to New Zealand's natural resources.
- Partnering innovative approaches to environmental challenges.
- Better understanding the challenges to sustainable use of New Zealand's natural resources.

OUR APPROACH

ENABLING

- Help people to identify and seize opportunities to add value, access markets and manage risks.
- Deepen understanding of the importance of primary sectors to New Zealand's medium to long-term prosperity.

WE WILL ACHIEVE THIS BY:

- Producing information and analysis to support a whole-of-government focus on primary sector growth.
- Connecting the public and private sectors to facilitate action on high-value opportunities.
- Providing information and tools to enable the primary sectors to develop systems for the timely management of risks.
- Connecting primary sectors with one another.

PARTNERING

- Support the primary sectors, including Māori, to maximise the benefits from the sustainable use of their primary sector assets.
- Deliver on our obligations to Māori.

WE WILL ACHIEVE THIS BY:

- Engaging with the primary sectors, including Māori, to increase economic returns from their primary sector assets.
- Working with the primary sectors to improve resilience and the timely management of risks.
- Understanding Māori values to protect and enhance the well-being and potential benefits from the use of New Zealand's natural resources.
- Providing the primary sectors with a gateway to the whole of government.

OUR ORGANISATION

FOCUS ON RELATIONSHIPS

WE WILL ACHIEVE THIS BY:

- Designing programmes and policy in partnership
- Enabling others to manage risks
- Setting joint priorities for sector growth
- Building long-term relationships with key primary sector players, including Māori, who can make a difference
- Having a view
- Leading courageous conversations

DEVELOP OUR PEOPLE

WE WILL ACHIEVE THIS BY:

- Rewarding top performers and investing in their success
- Attracting, retaining and developing top talent
- Taking greater responsibility for our performance
- Fostering our future leaders

MAKE INFORMED DECISIONS

WE WILL ACHIEVE THIS BY:

- Leveraging quality information as a core Ministry asset
- Making robust decisions with good evidence
- Delivering results based on quality information
- Being risk and intelligence led

BE INNOVATIVE

WE WILL ACHIEVE THIS BY:

- Creating new ideas and ways of working
- Being future-focused
- Learning from our mistakes
- Utilising knowledge and technology

OUR CULTURE

CONNECTED

FOCUSED ON RESULTS

DELIVERING ON OUR OBLIGATIONS TO MĀORI

LEAN AND AGILE

TAKING INFORMED RISKS

SUCCESS

WE WILL KNOW WE'VE SUCCEEDED WHEN WE HAVE CONTRIBUTED TO:

- ↑ primary sector contribution to GDP
- ↑ primary sector productivity
- ↑ access of products into new and changing markets
- ↑ sector investment in innovation
- ↑ productivity of Māori primary sector participants
- ↑ export returns
- ↓ negative environmental impacts
- ↓ risk to and from the primary sectors

AND WHEN THE MINISTRY ACHIEVES:

- ↑ staff engagement
- ↑ stakeholder engagement and partnership
- ↑ proportion of risk managed by others
- ↑ understanding of our work
- ↑ value for money
- ↑ delivery on our obligations to Māori
- ↓ regulatory instruments
- ↓ costs.

THURSDAY 16 JUNE, 12.27AM

15.8. Other strategic policy documents

15.8.1. 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.*"

15.8.2. 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.

15.8.3. 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

15.8.4. 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).

15.8.5. 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).

15.8.6. 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.

v. 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.
vi. 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.
vii. 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.
viii. 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.

15.8.7. 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 was approved by the Minister of Fisheries on 13 October 2008. 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/NR/rdonlyres/F0530841-CD61-4C3E-9E50153A281A4180/0/NPOAsharks.pdf

Note that the NPOA-Sharks is currently under review with a draft revised edition available at http://www.fish.govt.nz/en-nz/Consultations/npoa+sharks+2013/default.htm.

This 2013 revision has been consulted upon, but at the time of publication no final decision has been announced.

15.8.8. National Science Challenges

The National Science Challenges will tackle some of the biggest science-based issues and opportunities facing New Zealand. The Challenges are designed to take a more strategic approach to our science investment by targeting a series of goals which, if they are achieved, would have a major and enduring benefit for New Zealand. The 10 research areas identified as New Zealand's first National Science Challenges were announced on 1 May 2013.

The ten research areas were identified as New Zealand's first National Science Challenges and five of them are of potential relevance to fisheries and the marine environment.:

- New Zealand's biological heritage – protecting and managing our biodiversity, improving our biosecurity, and enhancing our resilience to harmful organisms
- Our land and water – Research to enhance primary sector production and productivity while maintaining and improving our land and water quality for future generations
- Life in a changing ocean – understanding how we can exploit our marine resources within environmental and biological constraints
- The deep south – understanding the role of the Antarctic and the Southern Ocean in determining our climate and our future environment
- Resilience to nature's challenges – research into enhancing our resilience to natural disasters

http://www.msi.govt.nz/update-me/major-projects/national-science-challenges/ten-challenges/

15.9. *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	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	Ongoing analysis: 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.	Will be commissioned early in 2014	
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.	Ongoing analysis	
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.	Will be commissioned early in 2014	
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	Uncertain whether required	

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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 2014	
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.	Delayed slightly to incorporate the results of a 2014 survey	
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.	Ongoing analysis	
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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.	Approved but not contracted	
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	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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	Approved but not contracted	
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
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.* 2013
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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
PRO	SRP2010-05	Fur seal interaction with an SLED excluder device	• 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) • Using a small number of collision tests, verify that the HIC for a glancing blow can be predicted with sufficient accuracy by resolving vectors • Calculate the maximum possible sensitivity to different boundary conditions using the relative masses of the SLED grid and sea lion heads • 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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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
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.* 2012
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
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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 (100%) 2. Examine strike rates and capture rates on warps and mitigation devices (100%) 3. Determine the relative efficacy of mitigation devices tested in the trial (100%) 4. Make recommendations regarding future trials (100%) 5. Compare seabird warp strike data for 2005 and 2006 (100%) 6. Work with SeaFIC and the mitigation trials TAG to produce analyses and outputs (100%)	Completed	Middleton & Abraham 2007
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

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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
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

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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
PRO	ENV98-01	Estimation of nonfish 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	Nonfish 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 inhence 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

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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
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	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 analysis	

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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).	In the process of publication	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

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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
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

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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
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

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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	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.	Approved but not contracted	
BEN	BEN2012-01	Spatial overlap of mobile bottom fishing methods and coastal benthic habitats	Assess the spatial overlap of inshore trawling, Danish seining, and dredging and benthic habitats in the coastal zone	Ongoing analysis	
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	
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
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

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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.	In the process of publication	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^{o}00' – 57^{o}30'S, 157^{o}00'E – 167^{o}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).	Ongoing analysis	
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.	Approved but not contracted	
ECO	ZBD2012-06	Ocean status: trends in NZ marine environment and Tier 1 statistic	1. To provide an up to date overview of climatic trends and cycles and how they affect New Zealand oceanographic conditions, and highlight key changes since the previous assessment. 2. To identify candidate oceanographic variables for potential development as part of the proposed Tier 1 Statistic, Atmospheric and Ocean Climate Change	Approved but not contracted	
ECO	ANT2012-01	Antarctic research	Antarctic research	Ongoing analysis	
ECO	SEA2012-17	NPOA Sharks extension work	NPOA Sharks extension work	Completed	Clark *et al.* 2013
ECO	ANT2011-01	Antarctic fisheries	1. To develop, implement and refine approaches for assessing the stock status of toothfish (Dissostichus spp.) in the Ross Sea region. 2. To develop, implement and refine approaches for assessing and monitoring the status of non-target fish species, and dependent and related species. 3. To develop, implement and refine approaches for understanding and managing the ecological relationships between the toothfish (Dissostichus spp.) fishery and the Ross Sea ecosystem.	Ongoing analysis	

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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.	Ongoing analysis	
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.	Ongoing analysis	
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.	Ongoing analysis	
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	Ongoing analysis	
ECO	ENV2010-05A&B and SEA 2010-15	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. In Press
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	
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.	Completed	Clark *et al.* In Press; Mormede & Dunn 2013

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ECO	ANT2009-01	Antarctic fisheries	1. To explore the biology of fishes captured in the toothfish fishery to underpin future stock assessment and ecosystem modelling research 2. To develop and refine stock assessment approaches for toothfish in the Ross Sea 3. To assess the status of toothfish stocks in the Ross Sea 4. To explore the Ross Sea toothfish fishery at an ecosystem level 5. To review and further develop procedures for the ageing of Antarctic toothfish (Dissostichus mawsoni) and Patagonian toothfish (D. eleginoides). 6. To review and update the species profiles for toothfish 7. To characterise the toothfish fishery in the Ross Sea up to 2009/10 8. To further develop toothfish biological and modelling parameters 9. To assess the status of the Ross Sea toothfish stock(s) with respect to CCAMLR performance measures 10. To further develop approaches to assessing the status of skates in the Ross Sea region with respect to CCAMLR performance measures 11. Further develop the SPM approach 12. To develop new approaches and refine existing approaches to understanding the impacts of fishing on potential VMEs 13. To further develop ecosystem monitoring through the analysis of the diet of toothfish in the north and slope fisheries. 14. To refine the draft data collection plan for the Ross Sea region fisheries and undertake associated preliminary reviews of fishery and observer performance against targets immediately post-season	Completed	Parker & Bowden 2010; Parker *et al.* 2009c; Tracey *et al.* 2010
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
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.	Ongoing analysis	

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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	ANT2007-01	Biology of fishes in the toothfish fishery	3. To develop an identification guide for observers of benthic invertebrate species (especially sponges, corals etc) caught in the Ross Sea region fisheries.	Completed	Parker *et al.* 2008
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	
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

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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
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	Ongoing analysis	
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

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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
ECO	ANT2005-02	Aspects of the biology of fishes in the toothfish fishery	1. Estimate length and age at maturity for Antarctic toothfish in the Ross Sea 2. Examine TOA length at age by depth and area 3. Estimate biological parameters for TOA (M, growth rates corrected for selectivity, h, r) 4. Determine stock structure of TOA based on parasite data 5. Determine length-weight relationships, diet, reproduction, age and growth of C.dewitti 6. ID and speciation of Antarctic skates 7. Develop an ID guide for scientific Observers of fish in the Ross Sea fishery 8. Identify heavy metal contents of selected fish species in the Ross Sea fishery	Completed	McMillan *et al.* 2007; Smith *et al.* 2007; Sutton *et al.* 2006
ECO	ANT2005-04	Ecosystem modelling of the Ross Sea	1. Carry out stable isotope analysis of TOA and 3 key fish prey to determine trophic links 2. Determine squid diet by analysis of squid beaks for stable isotope analysis 3. Participate in the design of an IPY survey 4. Participate in EMM as required	Completed	Pinkerton *et al.* 2007b
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

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ECO	ANT2004-01	Characterisation of the toothfish fishery	1. update descriptive analysis of toothfish fishery in the Ross Sea to 04/05 2. analyse age, LF and sex ratio for toothfish and rattails for 04/05 3. update and refine the CPUE for TOA in Ross Sea for 04/05 4. determine diet of sub-adult TOA in the Ross Sea 5. review the TOA parasite collection protocol 6. document TOA tagging protocol 7. review approaches to monitoring and assessing rattails and skates in the Ross Sea 8. descriptive analysis of stake tagging programme in the Ross Sea 9. determine factors affecting bycatch of rattails and skates between vessels 10. carry out risk assessment for M. whitsoni and A. georgina in the Ross Sea	Completed	Smith & Notman 2005; Stevens 2006
ECO	ANT2004-05	Modelling of the ecosystem effects of fishing in the Ross Sea	1. develop an effects of fishing model based around toothfish fishery 2. investigate possible consequences of different management strategies 3. make recommendations for future research to decrease uncertainty in the model	Completed	Pinkerton *et al.* 2005; 2006
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

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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	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 analysis	
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.	Ongoing analysis	
BIO	ZBD2012-02	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 analysis	
BIO	SRP2011-02	IDG 2009-01 field guide completion	1. IDG 2009-01 field guide completion	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

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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 ecosystmes 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.	Ongoing analysis	
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	Ongoing analysis	Tracey *et al.* 2011b
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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
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.	Ongoing analysis	Cummings 2011; Cummings *et al.* 2011b

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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	In the process of publication	Robinson *et al.* 2013
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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; 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.* In Press; Heimeier *et al.* 2010; Hemery *et al*. In prep; Koubbi *et al.* 2011; Leduc *et al.* 2012a; b*; c; 2013; In Press;* Linse *et al.* 2007; Lörz 2009; Lörz 2010a; 2010b; 2010c; Lörz & Coleman 2009; Lörz et al. 2007; 2009; 2012a; b; In Press; 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. In Press; O'Loughlin *et al.* 2011; Pakhomov *et al*. 2011; Pinkerton *et al*. 2007a; Pinkerton *et al*. 2009a; b; Pinkerton *et al*. In review; In press; Schiaparelli *et al*. 2006; 2008; 2010; Smith *et al.* 2011a; b; Stein 2012; Strugnell *et al.* Submitted

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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 sediment. 11. To measure the bacterial biomass (top 2 cm) of the sediment and in the	Completed	Bowden 2011; Bowden *et al.* 2011 ; In press; 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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
			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.		

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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

Theme	**Project Code**	**Project Title**	**Specific Objectives**	**Status**	**Citation/s**
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 ex isting 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. In Press;* Jackson *et al.* In Press; Lalas *et al.* In Press a; b; Lalas & MacDiarmid In Press; Lorrey *et al. In Press;* MacDiarmid *et al.* In Press a; b; Maxwell & MacDiarmid In Press; Neil et al. In Press; Paul 2012; Parsons *et al.* In Press; Pinkerton In Press; 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.* In Press c
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 2010;
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	
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

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