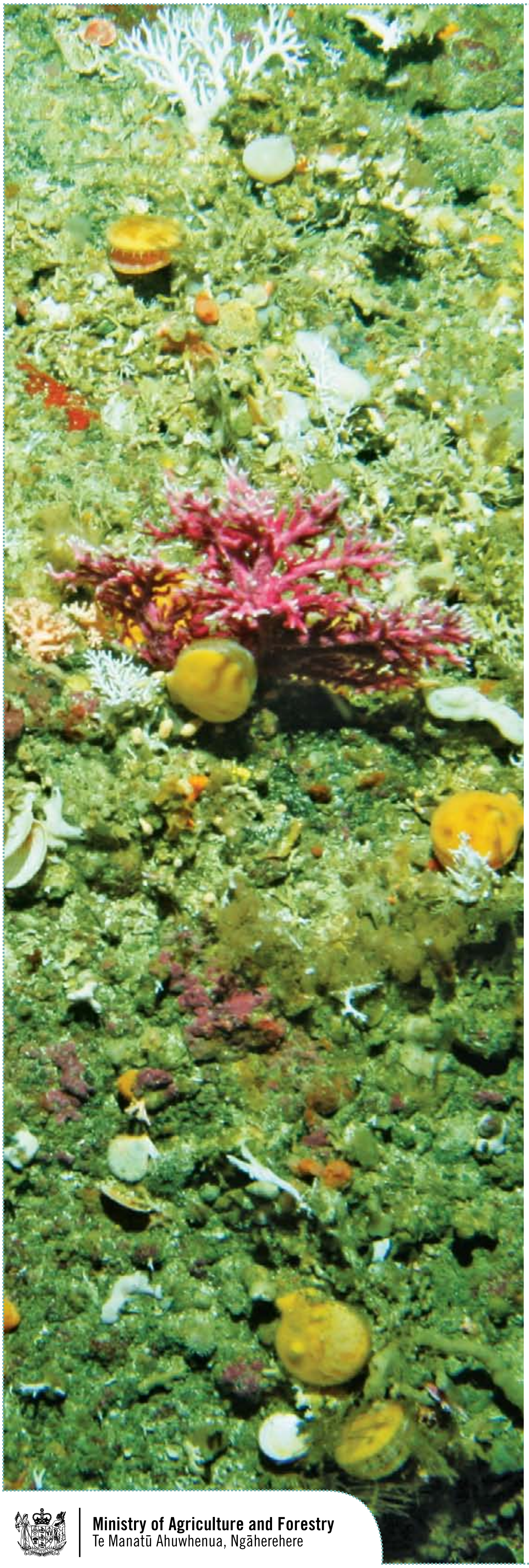

Aquatic Environment and Biodiversity Annual Review 2011

A summary of environmental interactions between fisheries and the aquatic environment

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

Acknowledgements

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Contents

PREFACE

This, the first Aquatic Environment and Biodiversity Review, summarises information on a range of issues related to the environmental effects of fishing and aspects of the marine environment and biodiversity of relevance to fish and fisheries. This review has been developed over the past three years and is a conceptual analogue of the Ministry's Reports from the Fisheries Assessment Plenary. The review 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 Review is organised by issue (for example, 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 Review. These are the Aquatic Environment Working Group (AEWG) and the Biodiversity Research Advisory Group (BRAG). However, a wider variety of research is summarised in the Aquatic Environment and Biodiversity Review than in the Reports from the Fisheries Assessment Plenary, 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 issues, and the Ministry of Science and Innovation funds a wide variety of research, some of which is relevant to fisheries. Where that research is relevant to fisheries it will be considered for inclusion in the review.

As has happened with the Reports from the Fisheries Assessment Plenary, continual future expansion and improvement of the Aquatic Environment and Biodiversity Review is anticipated. Over time, additional chapters will be developed to provide increasingly comprehensive coverage of the issues, and chapters for seabirds and Hector's/Maui's dolphins have been identified as priorities for development in 2012. 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 in understanding the issues and making informed decisions.

The development of this, the first version of this review, has been led by the Science Team within the Fisheries Management Group of the Ministry of Fisheries (primarily Martin Cryer, Rohan Currey, Rich Ford, Mary Livingston, Eric Mellina, and Nathan Walker) but has relied critically on the input of members of the Ministry's Aquatic Environment Working Group (AEWG) and Biodiversity Research Advisory Group (BRAG) and the Department of Conservation's Conservation Services Technical Working Group (DOC-CSTWG). 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 the Ministry of Fisheries, 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 the environmental effects of fishing and other issues covered, as at 30 June 2011 for all chapters except sealions, with the sealion chapter being up to date as at 7 December 2011 when it was subjected to final review by the AEWG.

Pamela Mace
Chief Scientist, Ministry of Agriculture and Forestry

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 of Fisheries' annual report from the Fisheries Assessment Plenary (for example, Ministry of Fisheries 2011) and emulate that document's 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 Report from the Fisheries Assessment Plenary has a focus on individual fishstocks, this report has a focus on aquatic environment fisheries management issues that often cut across many fishstocks, fisheries, or activities, and sometimes across the responsibilities of multiple agencies.

This first version does not cover all issues and 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 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 hoki, scampi, squid, and some highly migratory species in the 2010 Report from the Fisheries Assessment Plenary (not updated in 2011), and others will follow.

The first part of this document describes the legislative and broad policy context for aquatic environment research, and the main 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 effects; and marine biodiversity. The third part 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 reviewed by the appropriate working group at least once but the specific wording has not been agreed to the extent that is common practice for working group reports from the fishery assessment working groups. As at June 2011, chapters have been developed for selected issues but others will follow in subsequent iterations of this document. The exception to this is the sea lion chapter which was revised in December 2011 to reflect important new research findings. Chapters for seabirds, Hector's and Maui's dolphins, and fish bycatch are high priorities for 2011/12.

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 Māori Fisheries Act 2004, the Māori 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 (e.g., 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, and 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). These Acts are administered by other agencies and this leads to a requirement for the Ministry of Fisheries to work with other government departments (especially the Department of Conservation) 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.

Table 1.2: International instruments and regional agreements to which New Zealand is a signatory, that influence the Ministry of Fisheries 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** (and other codes of conduct) 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. • **Environmental Performance Indicators EPI (MfE)** The purpose of the EPI programme is to "develop and use indicators to measure and report how well we are looking after our environment". Seamount communities have been identified within the EPI project as key habitats for which extent and condition should be measured as indicators.

1.3. *Policy setting*

1.3.1. 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 Ministry's 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; 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.

1.3.2. Ministry of Fisheries Statement of Intent 2011/14

The Ministry of Fisheries' Statement of Intent, SOI, is an important guiding document for the short to medium term. That for 2011–2014 is available on the Ministry's website at:

http://www.fish.govt.nz/en-nz/Publications/Statements+of+Intent/SOI-2011-2014/default.htm

The SOI sets out the Ministry's strategic direction, its priorities and detailed work areas for the next five years and the output plan for 2010/11. Aquatic Environment and Biodiversity research summarised in this document is most relevant to outcome 2 of the SOI, *Fishing is managed to support the health of the aquatic environment*. The SOI states, *inter alia*, that the Ministry will support a healthy aquatic environment by increasing understanding of relationships between fishing and the aquatic environment. To that end, the Ministry will contract 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;

- strategic biodiversity research to increase our understanding of the systems that support fisheries productivity;

1.3.3. Fisheries Plans

The 2011/14 Statement of Intent affirms that fisheries plans will encapsulate a planned approach to the long-term management of fisheries and associated environmental impacts, based on agreed objectives. The SOI sets out the purpose and function of fisheries plans as to:

- set management objectives for fisheries resources;
- prioritise the services that will most effectively and efficiently contribute to those objectives, and then;
- monitor performance.

The Ministry is developing five Fisheries Plans that will be the principal tool for achieving fisheries management objectives, including for aquatic environment issues. Plans for Deepwater and Highly Migratory species have been approved by the Minister and a suite of three plans for Inshore species (Finfish, Shellfish and Freshwater fisheries) have been developed to working drafts. These plans establish management objectives for each fishery, including those related to the environmental effects of fishing.

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 Biodiversity Strategy (2000); the Biosecurity Strategy (2003, followed by its science strategy 2007); the Strategy for Managing the Environmental Effects of Fishing (SMEEF, 2005[1]); the MPA Policy and Implementation Plan (2005); MfE's discussion paper on Management of Activities in the EEZ (2007); MRST's Roadmap for Environment Research (2007); and the Revised Coastal Policy Statement (2010). Links to these documents are provided in Appendix 10.6 because they provide some of the broad policy setting for aquatic environment issues and research across multiple organisations and agencies.

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 relevant legislation and government policy, the future directions and priorities for fisheries research. 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 will be identified in Annual Operational Plans that are currently being developed.

For deepwater fisheries and highly migratory stocks (HMS), the transition to the new research planning approach is reasonably 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 Operational 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-

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[1]The Strategy for Managing the Environmental Effects of Fishing, SMEEF is available at: http://www.fish.govt.nz/en-nz/Publications/State+of+our+fisheries/Fisheries+and+Their+Ecosystems/smeef.htm

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 given in Appendix 2. 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. 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, FRST, Universities, etc.)
- Stakeholder meetings as required to discuss relative priorities for particular projects

The process for aquatic environment research for 2011/12 (other than aspects driven by deepwater and HMS plans or the specific needs of inshore fishery managers) followed essentially these same steps and was completed in early 2011.

The Ministry runs a separate planning group to design and prioritise its research programme on marine biodiversity. This Biodiversity Research Advisory Group (BRAG) has both peer review and planning roles and therefore differs slightly in constitution (if not so much in practice) 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 meetings are periodically revised and updated (see Appendix 1 for the 2011 AEWG Terms of Reference).

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 2011 are listed in Appendix 1).

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 of the strategic goals in the New Zealand Biodiversity Strategy (2000) and the Strategy for New Zealand Science in Antarctica and the Southern Ocean (2004), but the focus of the programme is currently being reviewed to align it with more recent strategic documents.

Usually following consideration at one or more meetings of appropriate working groups, reports from individual projects are reviewed by the Ministry before they are finalised. Fisheries Assessment Reports, FARs, and Aquatic Environment and Biodiversity reports, AEBRs, are also subject to formal editorial review whereas Final Research Reports, FRRs, and Research Progress Reports, RPRs, have less formal processes. Finalised FARs and AEBRs can be found at:

http://fs.fish.govt.nz/Page.aspx?pk=61&tk=209

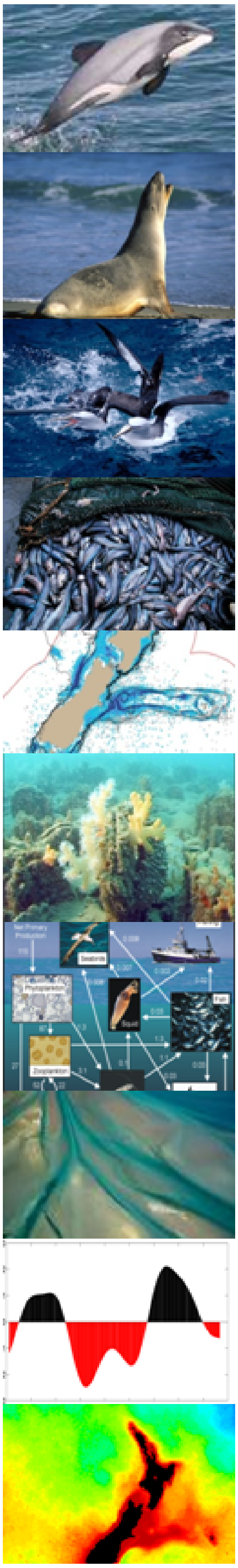
Increasingly, FRRs are also being made available at this site so the results of all projects commissioned by the Ministry can be more accessible.

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): bycatch 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). Other emerging issues (such as the genetic consequences of selective fishing and the impacts of aquaculture) are not dealt with in detail in this synopsis 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 strategic research on marine biodiversity. This research has been driven largely by the Biodiversity Strategy but has strategic importance for fisheries in that it provides for better understanding of the eocsystems 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 fish extraction, 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. 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 associated with the fishery. The Ministry has since included similar fishery-specific sections in other working group reports and the plenary, including many pelagic fisheries and the trawl fisheries for scampi and squid, but work on environmental issues has otherwise been more difficult to access for fisheries managers and stakeholders. The Ministry is, therefore, looking at better ways to document, review, publicise, and integrate information from environmental assessments with traditional fishery assessments. 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. The integration of all this work into a single source document analogous to the Report from the Fishery Assessment Plenary will take time and not all issues will be covered for some years.

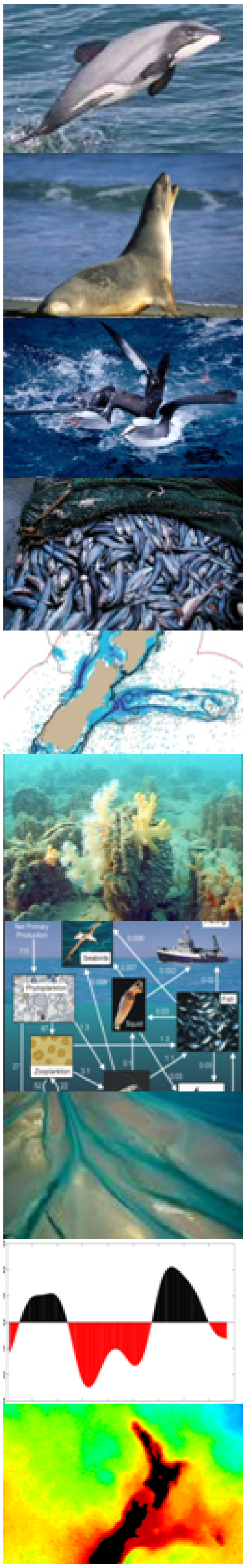
Figure 1.1: Summary of themes in the Aquatic Environment and Biodiversity Annual Review 2011.



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 to be made? • What mitigation approaches are most successful and in what circumstances? • What levels of bycatch would lead to different population outcomes?	• Estimation of annual bycatch 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 • Full quantitative risk assessment for selected seabird populations • Modelling to assess robust links between observed bycatch and population outcomes • Unobserved mortality of sea lions via biomechanical modelling
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 bycatch? • What do trends in bycatch show?	• Continued monitoring cycle for deepwater. • Productivity of some deepwater species is being assessed
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 what do we lose when each is disturbed? • What are the consequences of different management approaches?	• Testing of habitat classifications. • Assessment of recovery rate of some key inshore habitats • Assessment of relative sensitivity of habitats. • Mapping of sensitive biogenic habitats. • Multi-impact risk assessment
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?	• Assessing trends in the productivity of mesopelagic fishes on the Chatham Rise • Review of all fish diet studies • Habitat of significance: Kaipara Harbour fish habitats (SNA) • Habitat of significance: review of information for inshore finfish • Habitat of significance: coastal shark nursery areas (starting with rig)
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 • Shellhash habitat function • Experimental response of shellfish to warming and acidification • Monitoring surface plankton • Implications of ocean acidification for phytoplankton diversity • Analysis of IPY voyage data

Figure 1.1 *continued*: Summary of Themes in the Aquatic Environment and Biodiversity Review 2011

CURRENT STATE OF KNOWLEDGE
• Aggregate "on deck" bycatch 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 very 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. • Qualitative or semi-quantitative risk assessments have been completed for almost all seabirds and marine mammals. • Fullyquantitative risk assessments have been completed for two seabird populations, Hector's / Maui's dolphins, and sea lions. • Impact of fishing-related mortality on most protected species remains uncertain because of some key knowledge gaps. • Some methods of mitigating bycatch have been formally tested.
• Bycatch and discards are monitored using observer records for main deepwater fisheries. • Bycatch and discards for inshore vessels remain poorly known. • Some mitigation approaches have been assessed (e.g., for scampi trawl). • Trends in Chatham Rise bycatch mirror trawl survey trends for some species.
• 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 (but not in coastal waters, especially for most shellfish dredge fisheries). • Good understanding of the effects of trawling on some nearshore habitats. • General understanding of the effects of trawling on biogeochemical processes. • 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 as part of a wider biodiversity and MSI programme. • A preliminary trophic model of the Subantarctic 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 keyspecies (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. • This theme has links and synergies with MSI, DOC, universities and the MFish biodiversity programme.
• 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 has been developed. • Demersal fish trophic studies Chatham Rise have been completed. • A review of NZ data from deep-sea and abyssal habitats has been completed. • A multidisciplinary study of longterm (1000 years) changes to NZ marine ecosystem is complete. • Latitudinal gradient project, ICECUBE and 2 large scale surveys in the Ross Sea have been conducted.



THEME 1: PROTECTED SPECIES

3. New Zealand sea lions *(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 bycatch in some trawl fisheries, improving estimates of SLED post-exit survival, and improving understanding of the ability of the NZ sea lion population to sustain the present levels of bycatch.
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 ongoing declines in population size. Estimation of interactions given low numbers of observed captures.
MFish Research (current)	SRP2010-03, SRP2010-05, PRO2010-01, SRP2011-03, SRP2011-04, IPA2009-09.
Other Govt Research (current)	DOC Marine Conservation Services Programme (CSP): POP2010-01, POP2011-01.
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	See the New Zealand fur seal chapter.

3.1. Context

Management of fisheries impacts on New Zealand (NZ) sea lions are legislated under the Marine Mammals Protection Act 1978 and the Fisheries Act 1996. Under s 3E of the Marine Mammals Protection Act, the Minister of Conservation, with the concurrence of the Minister of Fisheries, may approve a population management plan (PMP) to establish a maximum allowable level of fishing-related mortality for the species. 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.

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 inmanagement measures."*

[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.

In the absence of a PMP, the Ministry of Fisheries (MFish) manages fishing-related mortality of NZ sea lions under s 15(2) of the Fisheries Act. 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 NZ sea lion bycatch 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 NZ sea lion bycatch 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 NZ sea lion bycatch will be outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ sea lions are most likely to interact. These fisheries include trawl fisheries for arrow squid (SQU 1T and 6T), 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 the Campbell Islands (SBW6I), do not impact the long term viability of the sea lion population and captures are minimised through good operational practices.* Chapters in the National Deepwater Plan for arrow squid and scampi are under development.

Currently, MFish limits the actual or estimated bycatch of sea lions in the SQU6T trawl fishery based on tests of the likely performance of candidate bycatch control rules (and, hence, bycatch limits) using an integrated population and fishery model (Breen *et al*. 2010)[3]. Candidate rules are assessed against the following two management criteria:

a. A rule should provide for an increase in the sea lion population to more than 90% of carrying capacity[4], 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] The Ministry is currently consulting on changes to this management approach. See the SQU6T Operational Plan: Initial Position Paper for further details (available online: http://www.fish.govt.nz/en-nz/Consultations/Squid+fishery+around+the+Auckland+Islands/default.htm).

[4] 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.

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 also 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. For example, 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; Childerhouse and Gales 1998). Subsistence hunting and subsequent commercial harvest of NZ sea lions for skins and oil resulted in population decline and contraction of the species' range (Gales 1995, Childerhouse and Gales 1998). 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[5] 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); Dundas Island; and Figure of Eight Island. On Campbell Island there is one breeding colony at Davis Point, another possible colony at Paradise Point, plus a small number of non-colonial breeders (Wilkinson *et al*. 2003, Chilvers 2008, Maloney *et al*. 2009). Breeding on the Auckland Islands represents 71–87% of the pup production for the species, with the remaining 13–29% occurring on Campbell Island (based on pup counts in 2003, 2008 and 2010; see section 3.2.5).

Although breeding is concentrated on the Auckland Islands and Campbell Island, occasional births have been reported from the Snares and Stewart Islands (Wilkinson *et al*. 2003). Breeding is also taking place on the New Zealand mainland at the Otago peninsula, 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 walk 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 2006). 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) appears more restricted (Marlow 1975, Robertson *et al*. 2006).

3.2.3. Foraging ecology

Most foraging studies have been conducted on lactating female NZ sea lions from Enderby Island (Chilvers *et al*. 2005a, 2006, Chilvers and Wilkinson 2009). These show that females 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

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[5] 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 as are defined as "terrestrial sites where NZ sea lions occur but where pups are not born, or where less than 35 pups are born per year over 5 consecutive years."

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; 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. 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). Caution must be exercised when drawing conclusions based on these comparisons given the small size of the Otago sub-population and the fact that all of its females are descended from a single individual that arrived from the Auckland Islands in 1992. Any observed differences may reflect differences in environment between the Auckland Islands and the Otago peninsula, differences in genetic makeup, 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 2011, Augé *et al*. 2011). 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 less 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) recently 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). Although 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, with 27% of all females that survive to age 3 never breeding.

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 for their harems (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 1977). 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 2007, 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). Auckland Islands pup production ranged between about 1500 and 3000 pups born each year from 1995 to 2010 (Robertson and Chilvers 2011; Table 3.2). The data show a decline of about 49% in pup production from a peak of 3021 in 1997/98 to 1550 ± 41 pups in 2010/11[6] (Chilvers and Wilkinson 2011), with the largest single-year decline (31%) occurring between the 2007/08 and 2008/09 counts.

Total NZ sea lion abundance 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 (95% 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.

Table 3.2: Pup production and population estimates of NZ sea lions from the Auckland Islands from 1995 to 2010. Pup production data are direct counts or mark-recapture estimates from Robertson and Chilvers (2011). Standard errors only apply to the portion of pup production estimated using mark-recapture methods. Population estimates from P. 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	2 504		15 675	14 732–16 757
1996	2 685		16 226	15 238–17 318
1997	2 974		16 693	15 656–17 829
1998	3 021		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[7]	41		

[6] 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).
[7] Ibid.

For the Campbell Island population, pup production was estimated at 726 pups in 2010 (Robertson and Chilvers 2011). Pup production estimates at Campbell Island are increasing over time, although this trend may, to some extent, also reflect differences in methodology (Maloney *et al*. 2009). 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 sub-population, annual pup production has ranged from 0 to 7 pups since the 1994/95 breeding season, with five pups recorded in 2010/11 (McConkey *et al*. 2002, Augé 2011). A recent modelling exercise suggested that this population can expand to 9–22 adult females by 2018 (Lalas and Bradshaw 2003). The sub-population at Otago is of special interest because it highlights the potential for establishing new breeding colonies, in this case from a single pregnant female (McConkey *et al*. 2002).

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 fisheries bycatch (see below).

In addition to the established effects, there are a number of other anthropogenic effects that may also 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); 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* which 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* which killed 33% and 21% of pups on the Auckland Islands in 2001/02 and 2002/03 respectively (Wilkinson *et al*. 2006). Epizootic events may also affect 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), and male aggression towards females and pups (Wilkinson *et al*. 2000, Chilvers *et al*. 2005b).

Despite a historic reduction in population size as a result of subsistence hunting and commercial harvest, the NZ sea lion population does not display low genetic diversity at microsatellite loci and thus does not appear to have suffered effects of genetic drift and inbreeding depression (Robertson 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[8] on the basis of a marked (30%) decline in pup production in the last 10 years, at some of the major rookeries (Gales 2008). The IUCN further recommended that the species should be reviewed within a decade in light of what they considered to be the current status of NZ sea lions (i.e., declining pup production, reducing population size, severe disease outbreaks).

In 2010, DOC updated the New Zealand Threat Classification status of all NZ marine mammals (Baker *et al*. 2010). In the revised list, NZ sea lions had their threat classification increased from At Risk, Range Restricted[9] to Nationally Critical under criterion C[10] with a Range Restricted qualifier based on the recent rate of decline (Baker *et al*. 2010).

3.3. Global understanding

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 trawl fisheries resulting in incidental bycatch, specifically from animals being caught and drowned in the trawl nets. These interactions are largely confined to trawl fisheries in Sub-Antarctic waters (Figure 3.1); particularly the Auckland Islands arrow squid fishery (SQU6T), but also the Auckland Islands non-squid fisheries targeting mainly scampi (SCI6A), 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).[11]

NZ sea lions forage to depths of up to 600 m (Table 3.1), within the habitat where depth ranges for prey species range from 0–500 m for arrow squid, 250–600 m for spawning southern blue whiting and 200–500 m for scampi (Ministry of Fisheries 2011). There is seasonal variation in the distribution overlap between NZ sea lions and the target species fisheries, with breeding male and female NZ sea lions likely to be ashore for prolonged periods between late November and January (Table 3.3). 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.

[8] 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).

[9] 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).

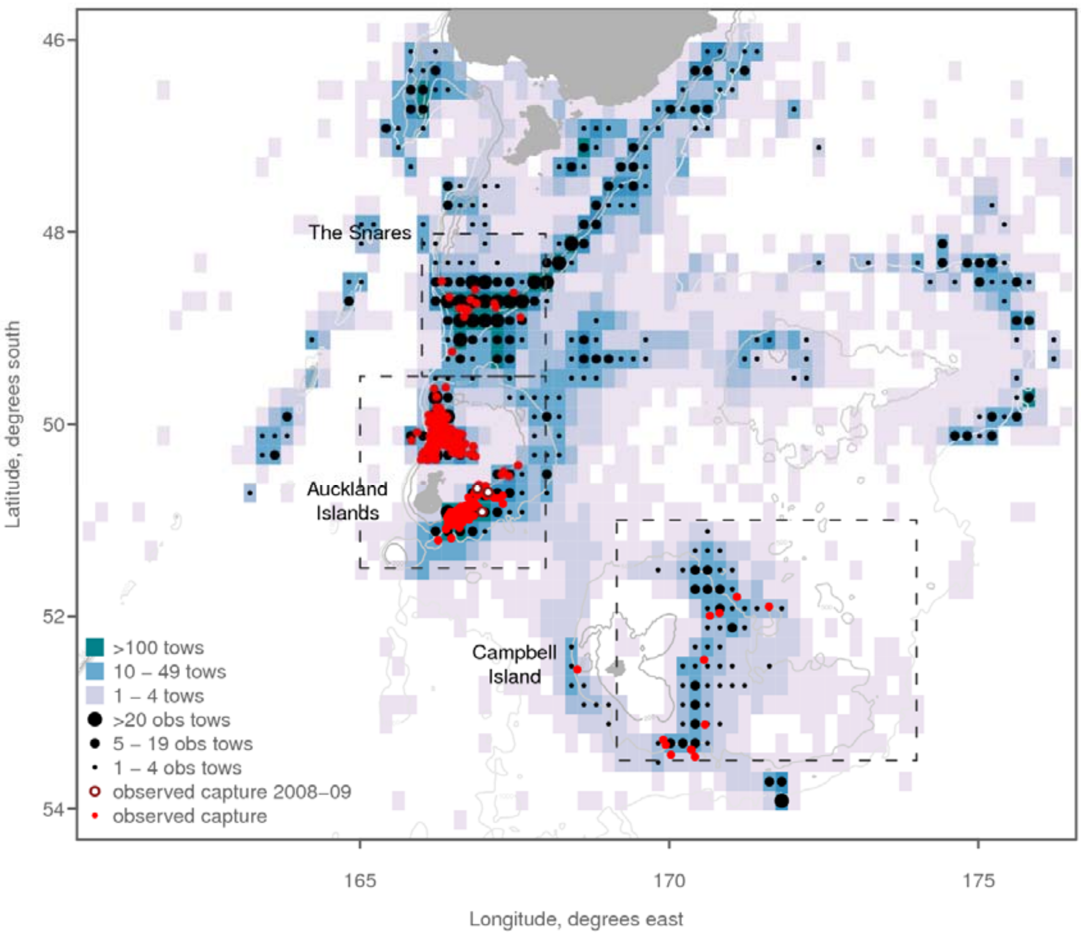
[10] A taxon is listed as 'Nationally Critical' under criterion C if the population (irrespective of size or number of sub-populations) has a very high (rate of) ongoing or predicted decline; greater than 70% over 10 years or three generations, whichever is longer (Townsend *et al*. 2008).

[11] 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.

3.4.1. Quantifying fisheries interactions

Since 1988, the level of NZ sea lion bycatch has been monitored by government observers aboard a proportion of the fishing fleet in the SQU6T fishery (Wilkinson *et al*. 2003), generally amounting to around 20–40% observer coverage between 1995 and 2010 but reaching almost 100% during the 2001/02 season (Table 3.4). Over the same period, there has also been 1–15% observer coverage around the Auckland Islands for non-squid trawl fisheries (primarily targeting scampi, but also jack mackerel, orange roughy and hoki), 20–60% observer coverage in the Campbell Island southern blue whiting fishery, and 8–43% observer coverage for the Stewart-Snares shelf trawl fisheries (primarily targeting squid, but also hoki, jack mackerel and barracouta; Table 3.4). Fishers have tended to report NZ sea lion bycatch at a lower rate than observers. 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). Observers observed an overall average of 4.7–11.2% of trawl tows each year over this time period, but fisheries where most sea lions are caught had higher observer coverage.

Figure 3.1: Annual average trawl effort, annual average observer coverage, and observed NZ sea lion captures in the Sub-Antarctic region of New Zealand's EEZ. Data includes all trawl effort, excluding tows targeting inshore species, for the 14 years from 1 October 1995 to 30 September 2009. Dashed lines indicate the areas containing fishing effort that were used for estimating total captures and interactions in Table 3.4. Reproduced from Thompson and Abraham (2010).



The number of NZ sea lion captures reported by observers has been incorporated 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, Thompson *et al*. 2011). Estimates in Table 3.4 for the SQU6T and Campbell Island fisheries were generated using Bayesian models, whereas those for the Stewart-Snares and the non-squid Auckland Islands fisheries were generated using ratio estimates (Thompson *et al*. 2011). 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 that were decomposed upon capture or that climbed aboard vessels (Smith and Baird 2007b, Thompson and Abraham 2010 Thompson *et al*. 2011). Only 8 of the 248 captures from 1995/96 to 2008/09 were released alive (Thompson and Abraham 2010). Interactions are defined as the number of sea lion that would have been caught if no SLEDs were used (Thompson *et al*. 2011).

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

<table>
<tr><th>NZ sea lions</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th></tr>
<tr><td>Breeding males</td><td colspan="3">Dispersed at sea or at haulouts</td><td colspan="3">Breeding colony</td><td colspan="6">Dispersed at sea or at haulouts</td></tr>
<tr><td>Breeding females</td><td colspan="4">Breeding colony and at sea</td><td colspan="2">Breeding colony</td><td colspan="6">Breeding colony and at sea</td></tr>
<tr><td>Pups</td><td colspan="12">Breeding colony</td></tr>
<tr><td>Non-breeders</td><td colspan="12">Dispersed at sea, at haulouts or breeding colony periphery</td></tr>
<tr><th>Major fisheries</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th></tr>
<tr><td>Squid</td><td colspan="4"></td><td colspan="2">Stewart-Snares Shelf</td><td colspan="4">Auckland Islands and Stewart-Snares Shelf</td><td colspan="2">Auckland Islands</td></tr>
<tr><td>Southern blue whiting</td><td>Bounty Islands</td><td colspan="2">Pukaki Rise and Campbell Rise</td><td colspan="9"></td></tr>
<tr><td>Scampi</td><td colspan="12">Auckland Islands</td></tr>
</table>

In the years since SLEDs were introduced in the SQU6T fishery, both the observed and estimated numbers of NZ sea lion captures have declined overall, except for a slight increase in 2009/10 (Table 3.4). Conversely, for those other fisheries where SLEDs are 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 (Table 3.4). For the Stewart-Snares and the Auckland Islands non-squid 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 indicate that the interaction rate of female NZ sea lions (synonymous with capture rate in the absence of SLEDs) is influenced by a number of factors including year, distance from 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).

Table 3.4: Annual trawl effort, observer coverage, observed numbers of sea lions captured, observed capture rate (sea lions per 100 trawls), estimated sea lion captures, interactions, and the estimated strike or capture rate (with 95% confidence intervals) for the trawl fisheries operating around the Auckland and Campbell Islands and the Stewart-Snares shelf, and for all trawl fisheries combined (see Fig. 1). Data from Thompson *et al*. (2011).

All trawl fisheries (excluding inshore)		Observer coverage	Observed captures		Estimated captures		Estimated interactions	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995/96	9466	11	16	1.6	158	91–264	158	90–265
1996/97	10954	15	28	1.7	160	107–234	160	106–234
1997/98	9968	14	14	1	82	53–124	82	51–126
1998/99	10557	16	6	0.4	36	25–51	36	23–53
1999/00	9046	23	28	1.4	91	66–129	91	62–130
2000/01	8910	39	46	1.3	66	59–74	85	63–111
2001/02	9947	19	23	1.2	69	52–92	98	66–142
2002/03	8304	19	11	0.7	38	28–52	67	41–102
2003/04	10044	23	21	0.9	66	48–89	200	114–339
2004/05	11091	23	14	0.5	58	41–81	172	92–295
2005/06	9313	21	14	0.7	56	39–79	161	88–276
2006/07	6724	24	15	0.9	49	36–67	109	63–179
2007/08	6545	33	8	0.4	31	22–42	102	47–204
2008/09	6676	27	3	0.2	24	15–35	92	35–188
2009/10	5513	34	15	0.8	48	34–66	120	62–224

Auckland Islands squid (SQU6T)		Observer coverage	Observed captures		Estimated captures		Estimated interactions		Estimaetd strike rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995/96	4467	12	13	2.4	141	73–245	141	73–244	3.2	1.7–5.4
1996/97	3717	19	28	3.9	144	91–218	144	90–217	3.9	2.6–5.7
1997/98	1441	22	13	4.2	61	34–103	61	32–104	4.2	2.5–6.9
1998/99	402	38	5	3.2	15	7–27	15	5–29	3.7	2.2–5.9
1999/00	1206	36	25	5.7	68	44–104	67	41–106	5.6	3.9–8.3
2000/01	583	99	39	6.7	39	39–40	58	37–82	10.0	8.4–12.4
2001/02*	1647	34	21	3.7	44	30–65	73	42–113	4.4	2.9–6.5
2002/03	1466	28	11	2.6	20	13–32	49	24–83	3.3	2.0–5.4
2003/04	2594	30	16	2	42	27–65	176	90–312	6.8	3.6–11.8
2004/05^	2693	30	9	1.1	34	18–56	147	69–274	5.4	2.6–9.9
2005/06	2459	28	9	1.3	30	17–51	135	62–249	5.5	2.6–10.0
2006/07	1317	41	7	1.3	17	10–28	77	33–144	5.8	2.7–10.7
2007/08	1265	46	5	0.9	12	6–21	82	28–183	6.5	2.4–14.3
2008/09	1925	40	2	0.3	9	3–18	77	19–175	4.0	1.1–9.0
2009/10	1188	26	3	1	13	5–27	85	28–191	7.2	2.5–15.8

Auckland Islands non-squid (scampi)		Observer coverage	Observed captures		Estimated captures		Estimated capture rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995/96	1471	6	3	3.49	13	8–19	0.69	0.37–1.06
1996/97	1539	13	0	0	11	6–16	0.69	0.37–1.06
1997/98	1823	13	1	0.42	14	8–20	0.69	0.37–1.06
1998/99	1801	4	1	1.3	13	8–20	0.69	0.37–1.06
1999/00	2157	8	0	0	15	8–23	0.69	0.37–1.06
2000/01	2012	6	4	3.15	18	11–25	0.69	0.37–1.06
2001/02	2214	8	0	0	15	8–23	0.69	0.37–1.06
2002/03	1907	11	0	0	13	7–20	0.69	0.37–1.06
2003/04	1667	13	3	1.38	15	9–21	0.69	0.37–1.06
2004/05	1457	1	0	0	10	5–15	0.69	0.37–1.06
2005/06	1370	9	1	0.82	10	6–15	0.69	0.37–1.06
2006/07	1369	7	1	1.03	10	6–15	0.69	0.37–1.06
2007/08	1480	11	0	0	10	5–16	0.69	0.37–1.06
2008/09	1580	8	1	0.81	12	7–18	0.69	0.37–1.06
2009/10	1021	14	0	0	7	4–11	0.69	0.37–1.06

Table 3.4: continued.

Campbell Island SBW		Observer coverage	Observed captures		Estimated captures		Estimated capture rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.
1996	474	26	0	-	1	0–4	0.18	0–1.15
1997	641	34	0	-	1	0–4	0.12	0–0.67
1998	963	28	0	-	1	0–5	0.11	0–0.62
1999	788	28	0	-	1	0–4	0.12	0–0.7
2000	447	52	0	-	0	0–2	0.11	0–0.6
2001	672	60	0	-	0	0–2	0.08	0–0.43
2002	980	28	1	0.37	3	1–11	0.35	0.02–1.26
2003	599	43	0	-	0	0–3	0.11	0–0.58
2004	690	33	1	0.43	3	1–9	0.39	0.02–1.38
2005	726	37	2	0.74	5	2–12	0.65	0.09–1.87
2006	521	28	3	2.07	10	3–21	1.76	0.32–4.31
2007	544	32	6	3.47	18	9–32	3.15	1.12–6.32
2008	557	41	2	0.88	5	2–11	0.77	0.1–2.14
2009	627	20	0	-	1	0–6	0.18	0–1.03
2010	527	43	11	4.87	25	16–38	4.58	2.27–7.74

Stewart-Snares (mainly squid)		Observer coverage	Observed captures		Estimated captures		Estimated capture rate	
Year	Tows	%	No.	Rate	Mean	95% c.i.	Mean	95% c.i.
1995/96	3056	9	0	0	3	2–5	0.1	0.05–0.15
1996/97	5066	10	0	0	5	3–8	0.1	0.05–0.15
1997/98	5769	10	0	0	6	3–9	0.1	0.05–0.15
1998/99	7581	16	0	0	7	4–11	0.1	0.05–0.15
1999/00	5257	23	3	0.25	8	6–11	0.1	0.05–0.15
2000/01	5660	43	3	0.12	9	6–12	0.1	0.05–0.15
2001/02	5124	18	1	0.11	6	4–9	0.1	0.05–0.15
2002/03	4343	16	0	0	4	2–7	0.1	0.05–0.15
2003/04	5097	21	1	0.09	6	4–9	0.1	0.05–0.15
2004/05	6226	24	3	0.2	9	6–12	0.1	0.05–0.15
2005/06	4963	19	1	0.1	6	4–8	0.1	0.05–0.15
2006/07	3497	24	1	0.12	4	3–6	0.1	0.05–0.15
2007/08	3247	36	1	0.09	4	3–6	0.1	0.05–0.15
2008/09	2546	31	0	0	3	1–4	0.1	0.05–0.15
2009/10	2781	43	1	0.08	4	2–5	0.1	0.05–0.15

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

3.4.2. Managing fisheries interactions

For NZ sea lions, efforts to mitigate fisheries bycatch 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 1993, the exclusion zone was replaced with a Marine Mammal Sanctuary with the same controls on fishing (Chilvers 2008). The area was also 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 is required by the current industry body (the Deepwater Group), fleet wide in application and monitored by MFish observers. In 1992, the Ministry of Fisheries 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. This has happened seven times (1996 to1998, 2000, and 2002 to 2004) since this plan was first adopted in 1993 (Table 3.5; Robertson and Chilvers 2011).

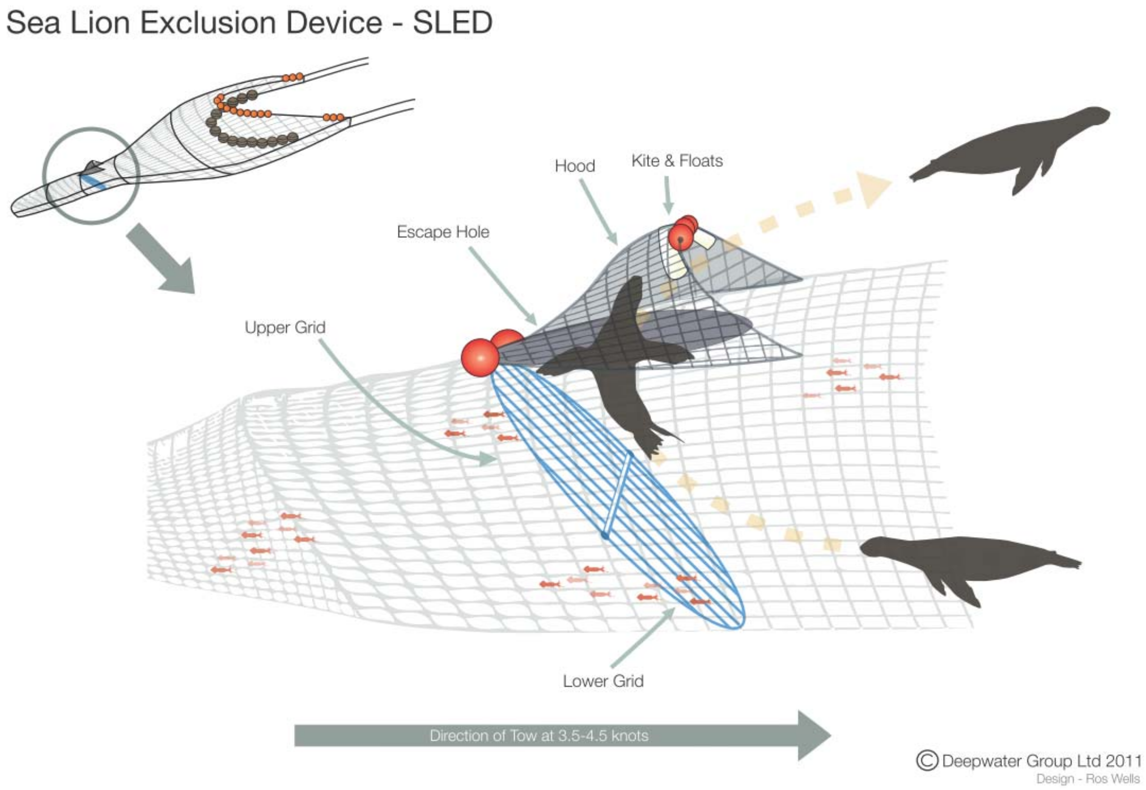


Figure 3.2: Diagram of a NZ sea lion exclusion device (SLED) inside a trawl net. Image courtesy of the Deepwater Group.

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 relatively simple estimation of the total number of NZ sea lions killed. However, following the introduction of SLEDs, the number of NZ sea lions interacting with SLEDs and the proportion of those surviving are much more difficult to estimate. Since the introduction of SLEDs, therefore, it has become necessary to estimate the number of NZ sea lions interacting with trawls using a predetermined strike rate to monitor performance against any bycatch limits set. Using a predetermined strike rate enables the FRML to be converted into a number of tows. The rate of 5.65% assumed by MFish 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). The most recent strike rate modelling suggested rates of 5.8%, 6.5%, 4.0%, and 7.2% for the 2006/07 to 2009/10 fishing years, respectively (Table 3.4; Thompson *et al*. 2011) but the estimated rate has ranged between 3.3 and 10% in the past.

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 35% means that the strike rate is reduced from 5.65% to 3.67%, so that, for every 100 tows using an approved SLED, 3.67 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 escape such an encounter via 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 2011. 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 (females 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), overturned by the High Court
2002/03	70		Fishery closed by MFish (29 March), overturned by the High Court
2003/04	62 (124)	20%	Fishery closed by MFish (22 March), overturned by the High Court and 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%	

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 across the fleet (Clement and Associates Ltd. 2007) and the establishment of an underwater video monitoring programme to help understand what happens when a NZ sea lion encounters a SLED. The footage was not useful because very few sea lion interactions were observed, but one fur seal and one NZ sea lion have been observed exiting a net equipped with a SLED when white light illumination was used. Given the very small number of observed interactions and that the footage was obtained under conditions that differ from those encountered in typical commercial squid tows, this information is of limited value in assessing the average survival rate of NZ sea lions exiting SLEDs. The SLED Working Group was disbanded by group member consensus 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). The PBR approach was developed by the United States National Marine Fisheries Service to calculate the maximum number of animals that may be removed from a marine mammal stock, not including natural mortalities, while allowing that stock to reach or maintain its Optimum Sustainable Population size, defined as being at or above the Maximum Net Productivity Level (Wade 1998). PBR is calculated by the following formula:

$$PBR = N_{MIN} \tfrac{1}{2} R_{MAX} F_R$$

Where: N_{MIN} = the minimum population estimate of the stock;
R_{MAX} = the maximum theoretical or estimated net productivity rate of the stock at a small population size; and
F_R = a recovery factor between 0.1 and 1.0

Definitions for the various components of a PBR can be found in Wade (1998) and Wade and Angliss (1997). The PBR approach is appropriate for estimating whether a particular level of human-induced mortality is likely to compromise meeting the optimum sustainable population size objective in the absence of detailed biological data. The PBR approach was not designed to provide for in-season management of fisheries with marine mammal bycatch but rather to trigger longer term bycatch reduction efforts should the bycatch exceed PBR (Wade 1998).

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 fisheries interactions

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 bycatch 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 was constructed 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 NZ sea lion bycatch that occurs 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 bycatch counts 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 Context (two MFish criteria and two DOC criteria). For each set of runs the population indicators were summarised and the rules compared in tables.

3.4.4. Sources of uncertainty

There are several outstanding sources of uncertainty in modelling the effects of fisheries interactions on NZ sea lions; some are likely to make the results of the BFG model conservative while others may make it optimistic. In particular, the 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 the 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, potentially as a consequence of attempting to estimate λ for a declining population. 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.

The estimated abundance of NZ sea lions relative to the carrying capacity of mature individuals (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 also unknown. 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 density dependent response was assumed to occur entirely in the mortality rate of pups. The strength of this response is unknown, and an assumed "shape parameter" (z) was fixed into the model with a value of $z = 3$. In sensitivity runs, the model was fitted using values of $z = 2$ (relatively weak density dependence) and $z = 4$ (relatively strong density dependence), but there is currently no information to support a strong preference for any of the assumed values. 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 strike rates for recent years are very imprecise (Thompson *et al*. 2011, 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 MFish databases.

			Percentage of tows		
Year	No. of tows	Mean tow duration (hours)	Less than 4 hours	Between 4 and 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

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). However, the low number of captures filmed and the inability to assess longer term survival means that this approach could not be used to determine likely survival rates (e.g., Roe 2010, p.4).

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 and not as a direct result of physical trauma resulting from interactions with the trawl gear (including the SLED; 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 were 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 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 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). Head trauma, however, could not be ruled out as a potential contributing factor, possibly due to impacts with the SLED grid (Roe and Meynier 2010, Roe 2010). In order to quantify the likelihood of a NZ sea lion impacting head first on the grid of the SLED and experiencing trauma sufficient to render the animal insensible, 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 derived from a number of sources, including necropsies (for head mass), video footage of NZ sea lions interacting with SLEDs (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 a Seal Exclusion Device (SED) in the Tasmanian small pelagic mid-water trawl fishery has been used (Lyle 2011). The SEDs are not identical to the New Zealand SLEDs, but both have steel grids (to separate the catch from the pinniped) located to the rear of an escape hole in the trawl. 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). In an initial trial, the head form (weighing 4.8 kg) was launched at three locations on the SLED grid at maximum speed of 10 $m.s^{-1}$. 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 (Ponte *et al*. 2010, 2011). 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. This provides an upper bound for the assessment of risk but Ponte *et al*. (2010) also imputed risk at speeds below the maximum.

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.

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. 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 involving changes in 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, some additional assumptions were made based on the Australian observations. Using these data, 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.

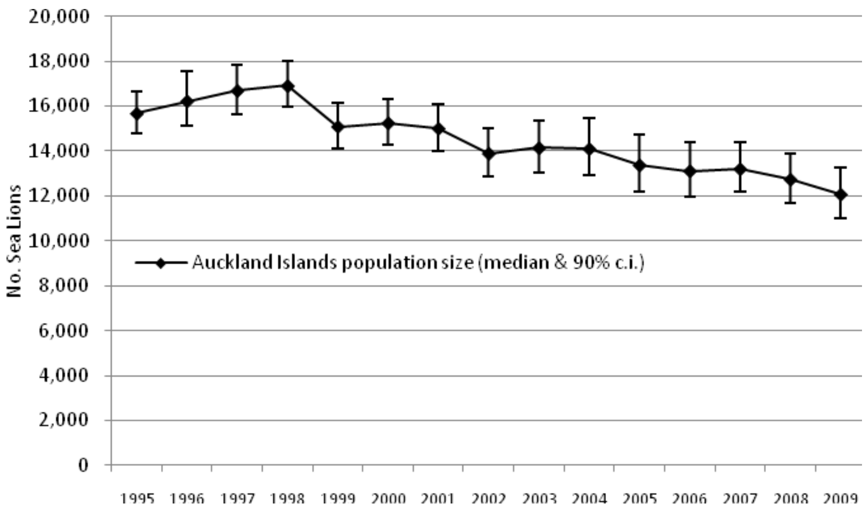
These results indicate that the risk of mortality for NZ sea lions interacting with the SLED grid is probably low, although some remaining areas of uncertainty were identified. The use of linear acceleration, as opposed to rotational acceleration, in the biomechanical modelling may underestimate the 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 are considered to be a reasonable proxy. 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.

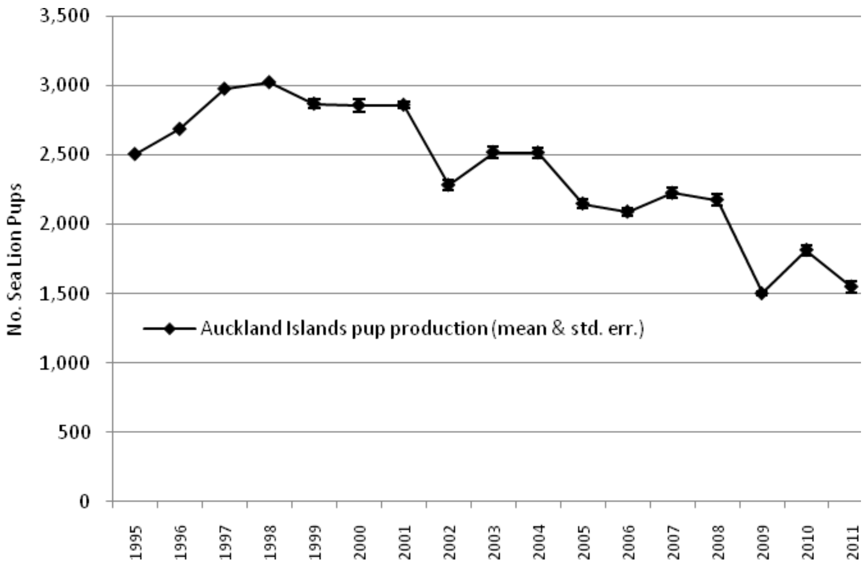
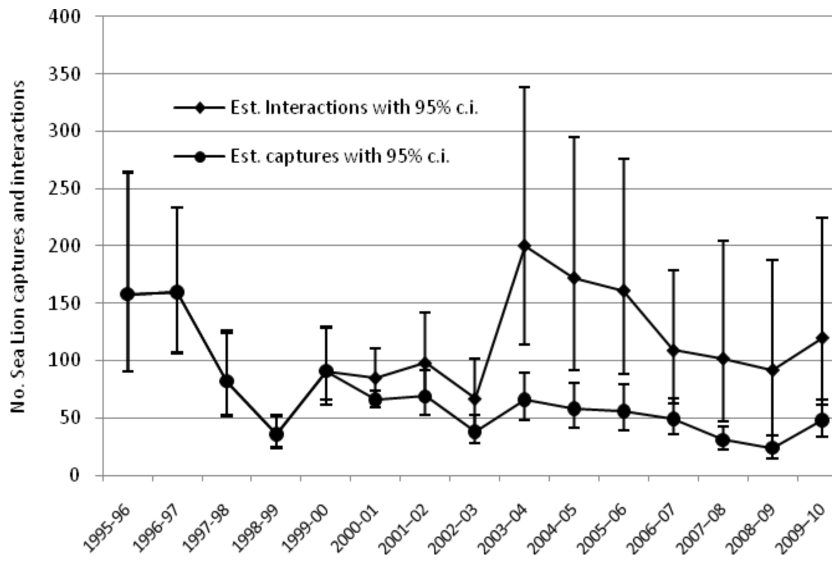
3.4.5. Potential indirect threats

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). The extent to which this may result in resource competition has not been assessed but certainly requires more sophisticated trophic or ecosystem modelling.

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 1 550 pups at the Auckland Islands (SE = 41) in 2010/11 726 pups at Campbell Island in 2010 5 pups at the Otago Peninsula in 2010/11
Population trend	Decreasing at the Auckland Islands, where there was a net decline in overall abundance of 23% between 1995 and 2009 or 29% between the peak in 1998 and 2009. There was concomitant decline in pup production of 38% or 49% over these periods.



	 Probably increasing at Campbell Island based on substantial increases in pup counts (although methodology has changed over time). Increasing at the Otago Peninsula through a combination of reproduction and immigration.
Threat status[12]	NZ: Nationally Critical, C, RR, in 2010 IUCN: Vulnerable, A3b, in 2008
Number of interactions	120 estimated interactions (95% CI: 62–224) in trawl fisheries in 2009/10 48 estimated captures (95% CI: 34–66) in trawl fisheries in 2009/10 15 observed captures in trawl fisheries in 2009/10
Trend in interactions	Decreasing trend in estimated captures and interactions since 2003-04, but with a slight increase in 2009-10. 

[12] See the Conservation biology and threat classification section for definitions of NZ and IUCN threat status terms.

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4. New Zealand fur seal (*Arctocephalus forsteri*)

Scope of chapter	This chapter outlines the biology New Zealand fur seals (*Arctocephalus forsteri*), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	Areas with significant fisheries interactions include waters over or close to the continental shelf surrounding the South Island and southern offshore islands, notably Cook Strait, West Coast South Island, Banks Peninsula 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 population to sustain the present levels of bycatch.
Emerging issues	Improving data and information sources for future ecological risk assessments.
MFish Research (current)	PRO2006-05, PRO2006-07, PRO2007-01, PRO2007-02, PRO2008-03.
NZ Research (current)	DOC Marine Conservation Services Programme (CSP): POP2011-05.
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	See the New Zealand sea lion chapter.

4.1. Context

Management of fisheries impacts on New Zealand (NZ) fur seals are 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 of Fisheries, may approve a population management plan (PMP) to establish a maximum allowable level of fishing-related mortality for the species. There is no PMP in place for NZ fur seals.

In the absence of a PMP, the Ministry of Fisheries (MFish) 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."*

In 2004, DOC approved the *Department of Conservation Marine Mammal Action Plan for 2005–2010* (Suisted and Neale 2009). 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 bycatch 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 most relevant National Fisheries Plan for the management of NZ fur seals bycatch 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 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 to be 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 is complete and includes Operational Objective 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 is nearing completion while the timeframes for the HAK and JMA chapters are yet to be confirmed.

4.2. Biology

4.2.1. Taxonomy

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

4.2.2. Distribution

Pre-European archaeological evidence suggests that NZ fur seals were present along much of the east coasts of the North Island (except the less rocky coastline of Bay of Plenty and Hawke Bay) and the South Island, and, to a lesser extent, on the west coasts, where in comparison fewer areas of suitable terrestrial habitat were available (Smith 1989, 2005). 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, Ling 2002, Lalas 2008).

Currently, NZ fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º 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 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, 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).

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 (rookeries) 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 smallest densities in September–October (Crawley and Wilson 1976). Females arrive at the breeding colony from November and lactating females remain at the rookery (apart from short foraging trips) for about 10 months until the pups are weaned, usually during August–September (Crawley and Wilson 1976).

4.2.3. Foraging ecology

Most foraging research in New Zealand has focused on lactating NZ fur seals at Open Bay Islands off the South Island west coast (Mattlin *et al.* 1998), Otago Peninsula (Harcourt *et al.* 2002), and Ohau Point, Kaikoura (Boren 2005), using time-depth-recorders, satellite-tracking, or very-high-frequency transmitters. Individual females show distinct dive pattern behaviour and may be shallow or deep divers, but generally forage at night and in depths shallower than 200 m. For animals from Open Bay Islands, dives were generally deeper and longer during autumn and winter. Females can dive to at least 274 m (for a 5.67 min dive in autumn) and remain on bottom for a maximum of 11.17 min at over 237 m 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 hours 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 rookery 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.

Data collection methods to analyse NZ fur seal diets have included investigation of freshly killed animals (Sorensen 1969), scats, and regurgitates. Fish prey items predominate in scats and can be recognised by the presence of otoliths, bones, scales, and lenses, and cephalopods predominate in regurgitated samples as 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, particularly if one collection method is used, and thus limit attempts at quantitative analysis of the species composition.

Dietary studies of NZ fur seals have been conducted at rookeries 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 rookeries 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 (*Octopus 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).

4.2.4. 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 1978).

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 these are rare events. Breeding animals come ashore to mate after a period of sustained feeding at sea. Breeding males arrive at the breeding colonies (rookeries) to establish territories during October–November. Breeding females arrive at the colony from late November. Pregnant animals 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. Pups remain at the breeding colony from their birth date until they are weaned (at between 8 and 12 months of age).

The 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 rookery 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 may represent variation in the ability of mothers to provision their pups from year to year.

The sex ratio of pups at a colony may vary by season (Bradshaw *et al.* 2003a, 2003b, Boren 2005), and in years of high food resource availability, more mothers may produce males or more males may survive (Bradshaw *et al.* 2003a, 2003b).

4.2.5. Population biology

Population estimates available for NZ fur seals in New Zealand are 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 number of 100,000 animals as approximating the New

Zealand population (Taylor 1990, see Harcourt 2001). However, this estimate is very much an approximation, and its accuracy is difficult to assess in the absence of wide-scale population surveys.

Fur seal rookeries 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 rookery 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 rookeries (Cape Foulwind, Wekekura Point, and Open Bay Islands) and data are held by Hugh Best and Department of Conservation, but are unpublished. 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 at least 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 rookeries 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). Recent Department of Conservation information exists for continuing increases in colony sizes in many coastal areas (for example Nelson-Marlborough, Kaikoura, Banks Peninsula, and Stewart Island).

A 2009 aerial survey of the South Island west coast from Farewell Spit to Puysegur Point and Solander Island was unable to obtain similar counts to corresponding ground counts collected at a similar time at the main colonies, primarily because of the survey design and the nature of the terrain (Baker *et al.* 2010a). However, this work 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 are not well known, especially for more isolated areas. For example, the most recent available counts for the Chatham Islands group were collected in the 1970s (Wilson 1981), and in 1993–94 for the Bounty Islands where Taylor (1996) reported an increase in pup production since 1980 and estimated a total population of at least 21,500 NZ fur seals, with over 50% of the available area occupied by the NZ fur seals. 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 potential sources of mortality related to its habitat, location, food availability, environment, and year, as well as the ability of observers to see and count all the dead pups (may be limited by terrain, weather, or time of day).

Mean 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, with additional numbers of mortalities due to stillbirth, suffocation, trampling, drowning, predation, and human disturbance. 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 known predators, such as various sharks, New Zealand 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 bacterial diseases and parasites and environmental contaminants, though it is not clear how threatening these are to an animal's survival. These include tuberculosis infections, *Salmonella*, hookworm enteritis, phocine distemper, and septicaemia (which is 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.

4.2.6. Conservation biology and threat classification

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

In 2008, the IUCN updated the Red List status of NZ fur seals, listing them as Least Concern on the basis of their large and apparently increasing population size (Goldsworthy 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).

Research investigating any genetic differentiation between NZ fur seals by colony and region has been on-going 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, while 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. Their work aims, if possible, to determine the provenance of animals caught during fishing activities, through the identification and isolation of any colony genetic differences.

4.3. Global understanding

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 approximately half of the population residing in Australian waters (Goldsworthy and Gales 2008). However, similar to the overall population estimate for New Zealand, this figure is very much an approximation, and its accuracy is difficult to assess in the absence of wide-scale population surveys.

Pinnipeds are caught incidentally in a variety of fisheries worldwide (Read *et al.* 2006), including NZ fur seals, Australian fur seals, and Australian sea lions in Australian trawl and inshore fisheries (for example, Shaughnessy 1999, Norman 2000); Cape fur seals in South African fisheries (Shaughessy and Payne 1979), South Amercian sea lions in trawl fisheries of Patagonia (Dans *et al.* 2003); seals and sea lions in United States waters (Moore *et al.* 2009).

4.4. State of knowledge in New Zealand

NZ fur seals are attracted to various fishing gears and anecdotal evidence suggests that the sound of the winches as trawlers haul their gear acts as a 'dinner gong'. The attraction of fish in a trawl net, on longline hooks, or caught in a setnet provide opportunities for NZ fur seals to fatally interact with fishing gear.

Most mortalities 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 in the time limited by their breath-hold abilities (Shaughnessy and Davenport 1996). The operational aspects that relate to 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). 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 up close to the surface. At the haul, NZ fur seals readily attempt to feed from the codend as it is hauled on deck and dive after fish that come loose and escape from the net. Some NZ fur seal captures were associated with a gear event, particularly during shooting and hauling the net, when gear failure, breakages, or turns executed by vessels resulted in the net being near, or at, the surface (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 a certain fleet nationality), 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. Other influences on NZ fur seal capture rate (of Australian and NZ fur seals) may include inclement weather and sea state, vessel 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 study found similar mortality rates between those with and without Seal Exclusion Devices (see also Hooper *et al.* 2005).

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, which around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts (Figure 4.1 and 4.2).

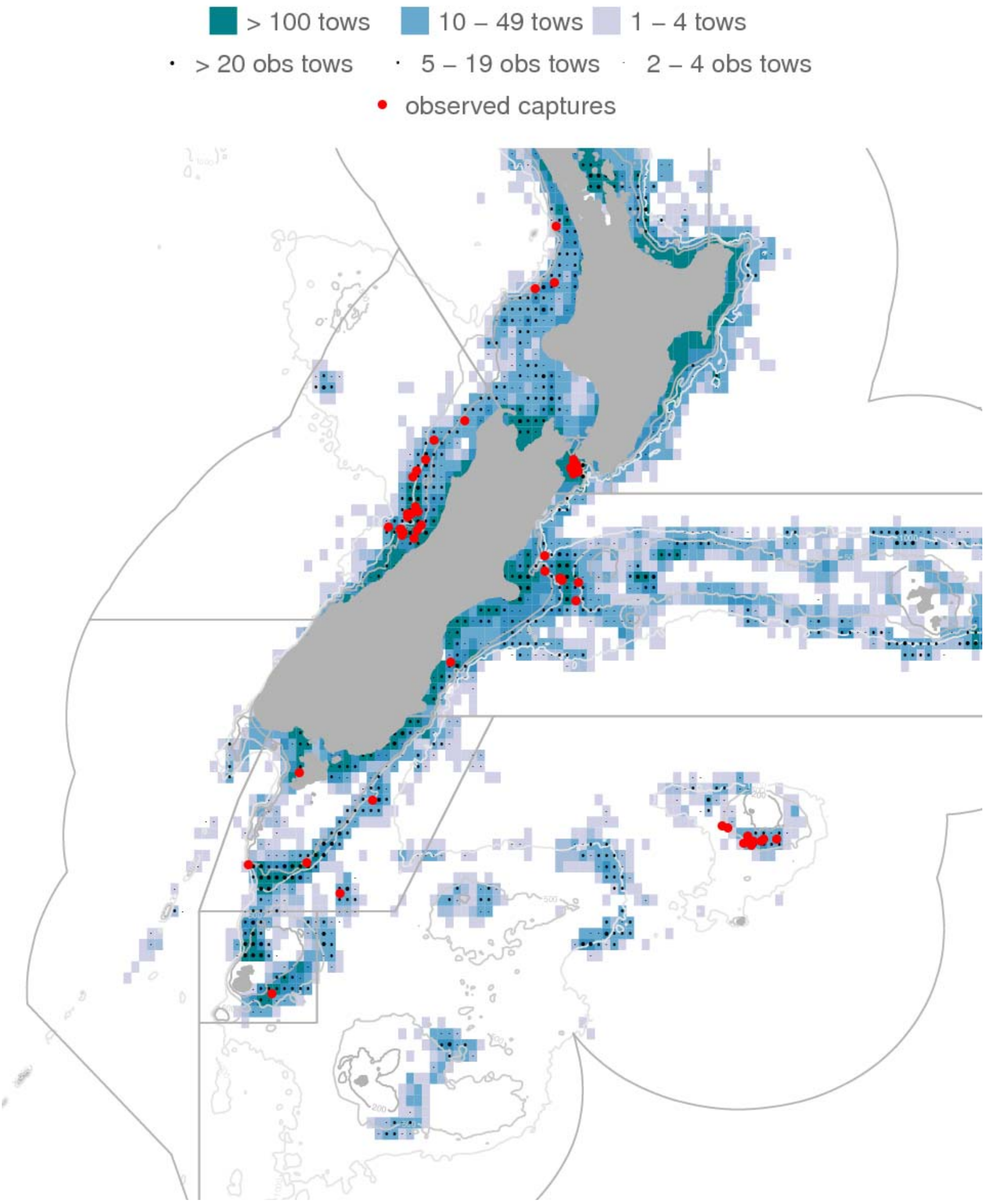


Figure 4.1: NZ fur seal captures and trawl fishing effort from October 2008 to September 2009. Reproduced from Abraham and Thompson 2011.

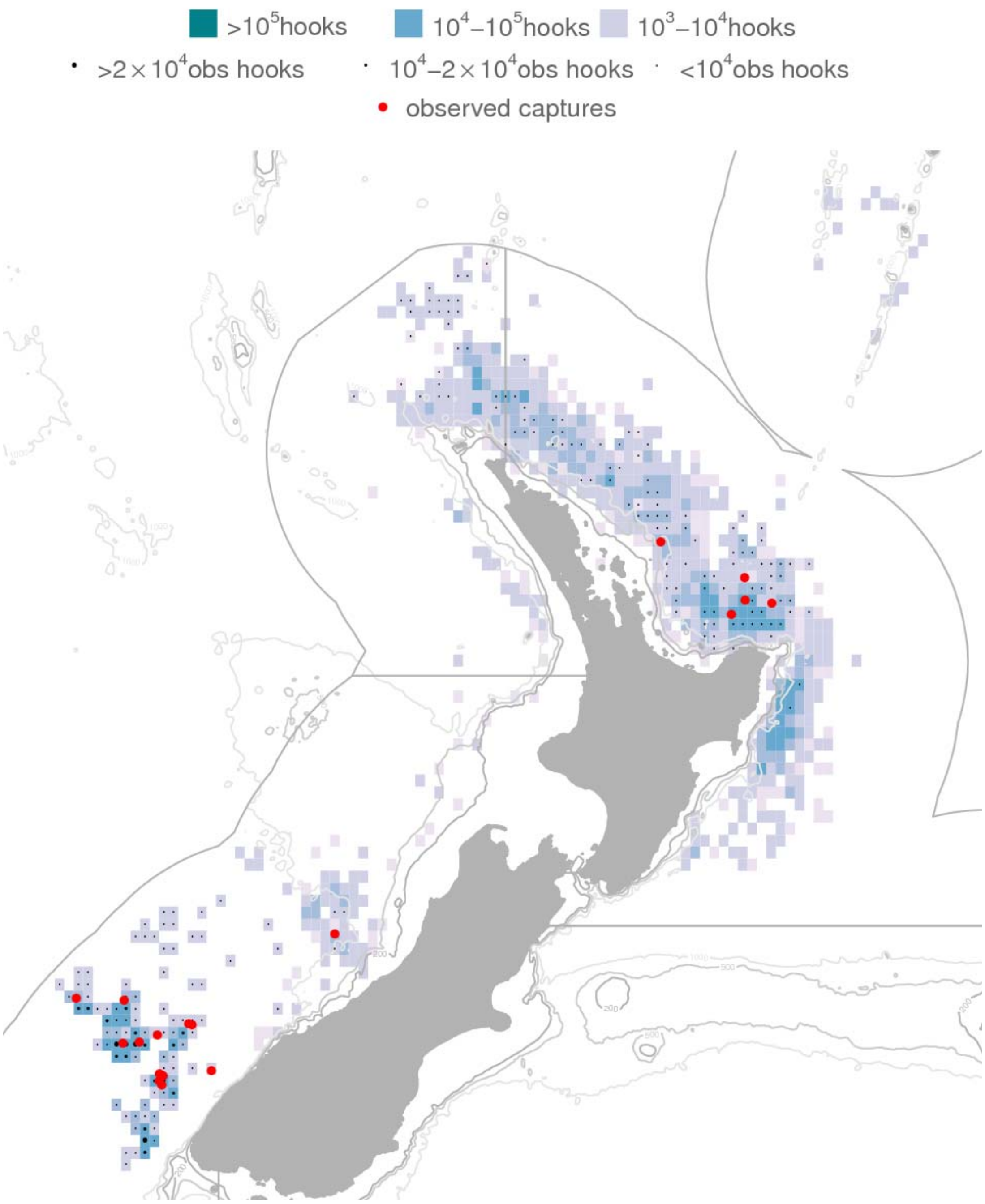


Figure 4.2: NZ fur seal captures and surface longline fishing effort from October 2008 to September 2009. Reproduced from Abraham and Thompson 2011.

Observed NZ fur seal captures are mainly from trawl effort in defined seasons in areas where fishing occurs relatively close to land (where NZ fur seal rookeries or haulouts exist). 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 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 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.

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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Breeding males	at breeding colony				dispersed at sea or at haulouts							
Breeding females		at breeding colony		at breeding colony and at-sea foraging and suckling								at sea
Pups			at breeding colony									at sea
Non-breeders	dispersed at sea, at haulouts, or breeding colony periphery											
Major fisheries	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Hoki trawl	Puysegur		Chatham Rise						Cook Strait, west coast South Island			
Squid trawl			Stewart-Snares shelf, Auckland Is. Shelf, east coast South Island									
Southern blue whiting trawl	Campbell Rise										Bounty Is., Pukaki Rise	
Southern bluefin tuna longline						Southern bluefin tuna longline						

4.4.1. Quantifying fisheries interactions

Observer data and commercial effort data are used to characterise the incidental captures and estimate the total numbers caught. The main emphasis of the Ministry of Fisheries (in relation to NZ fur seal incidental deaths) has been to estimate or predict the total annual captures during trawl fishing, and the data stratification (for example, by target species, area, gear type, vessel nationality) has varied over the last 15 years reflecting the requirements of the Ministry of Fisheries at the time.

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 observed captured and the representativeness of the observer coverage. Initially stratified ratio estimates were provided for the main trawl fisheries. NZ fur seal captures have been estimated since 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 predictions 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). 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. Thus, NZ fur seal capture rates are almost unknown for the smaller vessels (28 metres or less in length) that target inshore species and because the effort of these vessels contributes to about half of the annual tows made in the EEZ, this is a source of potential error in the prediction of total numbers (Smith and Baird 2009). The operation of these 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 logbook requirements means that data is now improving.

Since 2005, there has been a small downward trend in the predicted capture rates, and the annual predictions of NZ fur seal captures appeared to show a downward trend (Smith and Baird 2009, Thompson and Abraham 2010, Abraham and Thompson 2011). This probably reflects efforts to reduce bycatch combined with a reduction in the amount of fishing effort since the late 1990s. The most marked decrease of total captures was predicted for the west coast South Island area where most effort targeted hoki during winter months and on Stewart-Snares shelf where squid and hoki were main targets.

Similar modelling methods were used to produce the most recent set of predicted NZ fur seal captures in trawl fisheries, though tow data in this analysis were grouped (as consecutive tows targeting the same species in an area by a vessel) to reduce the computational load (Thompson and Abraham 2010, Abraham and Thompson 2011). The overall downward trend in estimated annual captures for trawl fisheries has continued (see Table 4.2), as a result of the continued decrease in total tows made each year and a concurrent decrease in capture rate. Note these capture rates include animals that are released alive (7% of observed trawl capture in 2008-09; Thompson and Abraham 2010).

Ratio estimation is 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-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. Estimated numbers range from 127 (95% CI 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 capture in 2008-09; Thompson and Abraham 2010)

Captures of NZ fur seals in other fishing gears including setnets and recreational fishing activities are not generally documented, though in a study of recreational fishers' interactions with protected species, no data were collected for NZ fur seals (Abraham *et al.* 2010b). Little information is available about NZ fur seal interactions with setnets other than that they occur with some related mortality (in setnets off the eastern and southern coast of the South Island; Rowe 2009).

Table 4.2: Percent observer coverage, observed and estimated total number of NZ fur seal captures, and estimated capture rates (per 100 tows or per 1000 hooks) by fishing year for trawl and surface longline fisheries in the New Zealand EEZ. Numbers in parentheses are 95% confidence intervals. Data from Abraham and Thompson (2011).

Year	% observer coverage	Observed captures (no.)	Estimated captures (no.)	Estimated capture rate
Trawl fisheries				
1998-99	5	190	1591 (1454-1744)	2.62
1999-00	6	203	1539 (1400-1693)	2.65
2000-01	7	170	1490 (1348-1649)	1.87
2001-02	6	157	1273 (1164-1394)	2.03
2002-03	5	67	807 (494-1238)	0.98
2003-04	5	84	971 (611-1578)	1.28
2004-05	6	200	1273 (829-1974)	2.59
2005-06	6	144	881 (591-1320)	2.20
2006-07	8	72	501 (304-764)	0.91
2007-08	10	141	710 (489-996)	1.56
2008-09	11	72	550 (338-826)	0.74
Surface longline fisheries				
1998-99	18	102	129 (121-140)	0.082
1999-00	10	42	81 (69-97)	0.053
2000-01	11	43	82 (65-104)	0.042
2001-02	8	44	110 (90-134)	0.048
2002-03	17	56	125 (99-156)	0.030
2003-04	20	40	100 (85-119)	0.027
2004-05	19	20	51 (40-64)	0.028
2005-06	17	12	43 (32-56)	0.019
2006-07	26	10	54 (45-65)	0.010
2007-08	18	10	40 (35-46)	0.026
2008-09	26	22	49 (43-56)	0.027

4.4.2. Managing fisheries interactions

The impact of incidental fishing related captures on the NZ fur seal population is presently unknown. However, despite this uncertainty, fishing interactions are probably 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 the NZ and IUCN threat status of the species (although the consequences for individual colonies may differ).

In the absence of further information, management has focused on encouraging vessel operators to alter fishing practices to reduce risk to the NZ fur seal population from fishing activity by managing the risk of impacts on individuals, 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 and hauling the gear when NZ fur seals are congregating around the vessel. Its major focus is reducing the time gear is at or near the surface when it poses the greatest risk. MFish monitors and audits vessel performance against this procedure (see the Ministry of Fisheries 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, that is, trawl fisheries. Finding ways to mitigate captures has proven difficult for a number of reasons; the animals are free swimming, can easily dive to the depths of the net when it is being deployed or hauled or brought to the surface during a turn, and are known to deliberately enter nets to feed. Further, any measures also need to ensure that the catch is not compromised, either in terms of the amount of fish or their condition. This is one potential drawback of using seal exclusion devices (see Rowe 2007). Adhering to current risk mitigation methods (e.g. MMOP) will help to minimise the level of impacts, however rates may fluctuate depending on fleet deployment, NZ fur seal abundance and local feeding conditions.

4.4.3. Modelling 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 (for example, the west coast South island population). 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 yet been reviewed by the Aquatic Environment Working Group.

4.4.4. Sources of uncertainty

Any measure of the effect of NZ fur seal mortality from commercial fisheries on NZ fur seal populations requires good 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 dynamics of these populations are generally not well understood. The location of a population (breeding colony) is important in the proximity to natural feeding areas as well as to risk of capture in fishing gear.

At present the main sources of uncertainty are the lack of consistent data for the estimation of total numbers, population parameters, and at-sea distribution — at the level of a colony or wider geographic area where several colonies are close together (Baird 2011). In particular, collation and analysis of existing data, such as that for the west coast South Island, should be completed and peer-reviewed. Data exist for certain strategically placed rookeries, in terms of fisheries interactions. There is a 20-year data set of pup production from three west coast South Island colonies, a reasonably long data series from the Otago Peninsula, and another from Kaikoura. Some of these colonies have also been used for foraging studies, and all these colonies are close to major fishing grounds. However, methods of survey design, data collection, and data analysis may also add to uncertainty around both the input data and the estimated total numbers.

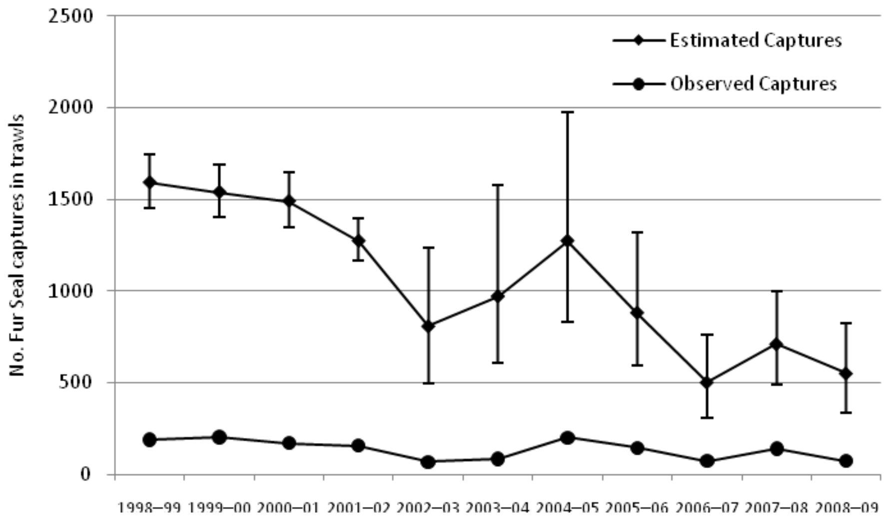
Maximum benefit could be gained through the use of all available data, as shown by the monitoring of certain colonies of NZ fur seals in Australia to provide a measure of overall population stability or otherwise (see Shaughnessy *et al.* 1994, Goldsworthy *et al.* 2003).

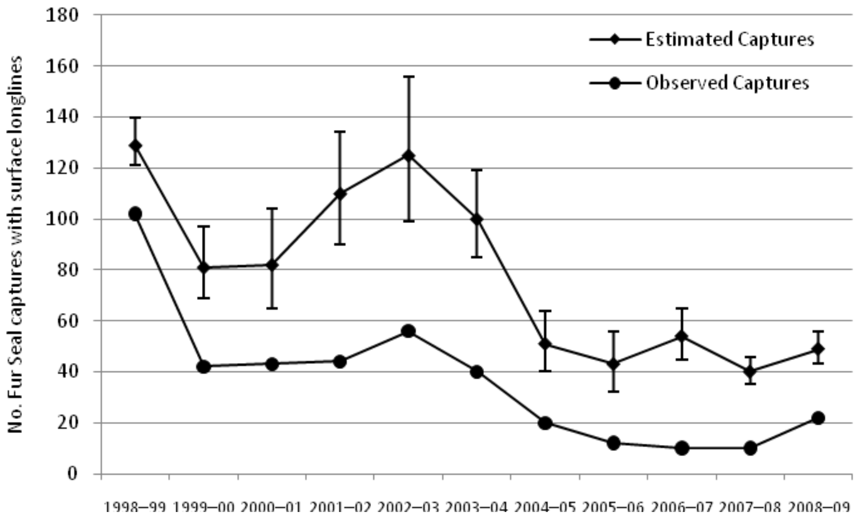
Fur seals may forage in waters nearby a colony or haulout, or may range widely, depending on the sex, age, and individual preferences of the animal (see Baird 2011). It is not known whether the NZ fur seals around a fishing vessel are from colonies nearby. Some genetic work is proposed to test the potential 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 adds uncertainty to the prediction of total captures. However, the main source of uncertainty in the level of bycatch is the lack of information from the inshore fishing fleets that use a variety of fishing methods.

Some uncertainty in the estimation of total captures can be included in the models, but substantial improvements in observer coverage would provide accurate and informative data of the fishing operations as well as on the observed incidental catch (for example, life stage, sex, size, and samples for fatty acid/stable isotope analysis for use in foraging and diet research and for determination of the provenance, or at least provide a data source for testing when the genetic techniques have been refined).

4.5. Indicators and trends

Population size	Unknown, but maybe as high as 100,000 in the New Zealand EEZ
Population trend	Increasing at some mainland rookeries but unknown for offshore island colonies.
Threat status	NZ: Not Threatened, Increasing, Secure Overseas, in 2010 IUCN: Least Concern, in 2008
Number of interactions	550 estimated captures (95%CI: 338-826) in trawl fisheries in 2008-09 49 estimated captures (95%CI: 43-56) in surface longline fisheries in 2008-09 72 observed captures in trawl fisheries in 2008-09 22 observed captures in surface longline fisheries in 2008-09
Trends in interactions	Decreasing for both trawl and surface longline fisheries, with a net reduction in observed captures of 65% for trawl fisheries and 62% for surface longline fisheries between 1998-99 and 2008-09. 



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THEME 2: NON-PROTECTED BYCATCH

There are no chapters in this theme for this initial version.

THEME 3: BENTHIC IMPACTS

5. 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.
MFish Research (current)	BEN2007/01, BEN2009/02, DAE2010/04, DAE2010/01, DEE2010/05, DEE2010/06
NZ Research (current)	MSI (ex-FRST) programmes: *Coasts & Oceans OBI* (IO3) C01X0501, *Marine Biodiversity & Biosecurity OBI* (IO1) C01X0502, *Coastal Conservation Management* C01X0907, *Impacts of resource use on vulnerable deep-sea communities* C01X0906, *Deepsea mining of the Kermadec Ridge* C01X0808.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture
Related issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring, marine mining/sand extraction, land-based effects.

5.1. 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 5.1). 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 5.2 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 5.1). 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 5.3). 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.

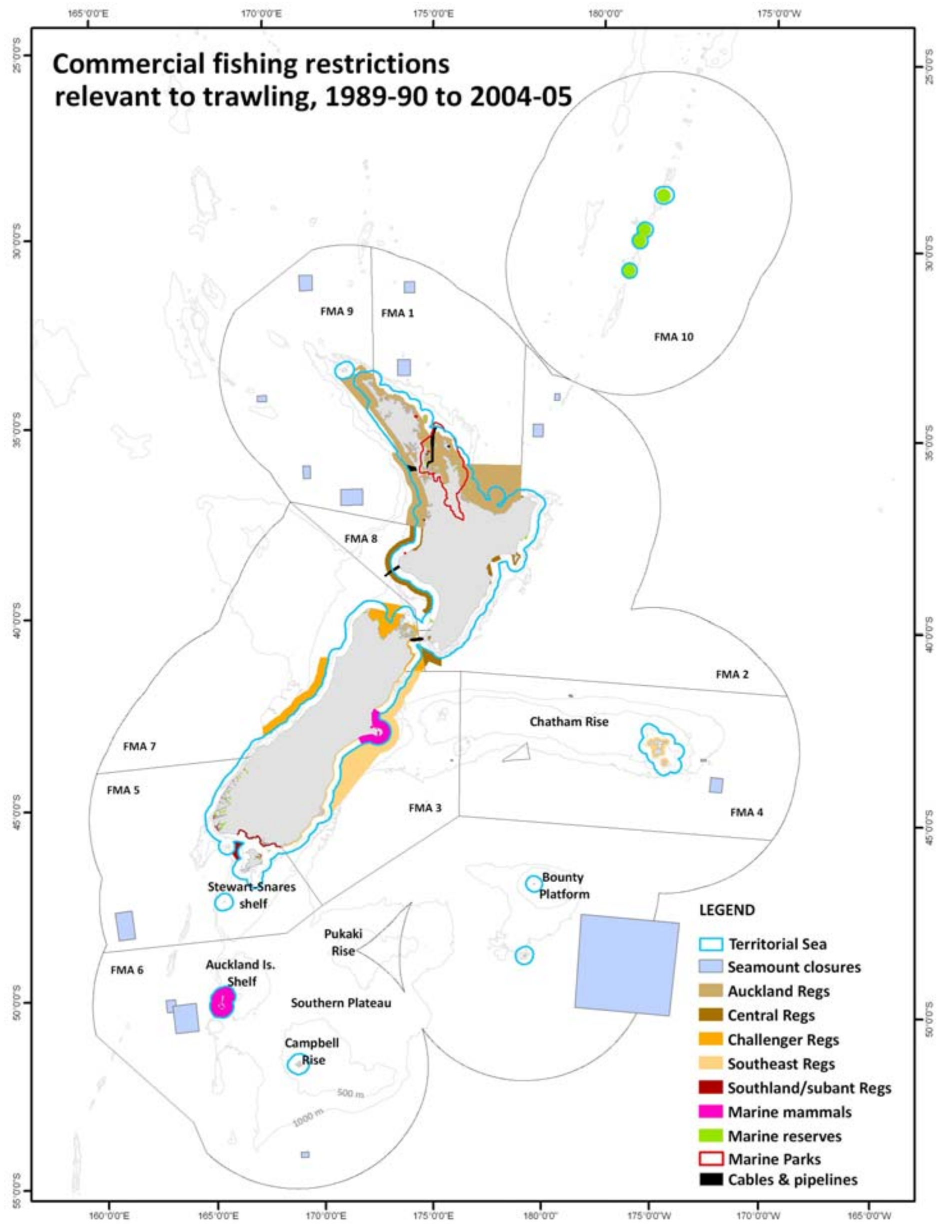


Figure 5.1: Map, from Baird and Wood 2010, of the major spatial restrictions to trawling present at some stage during 1989–90 to 2004–05 and the Ministry of Fisheries Fishery Management Areas (FMAs) within the outer boundary of the New Zealand EEZ. Vessels longer than 28 m may not trawl within the TS 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.

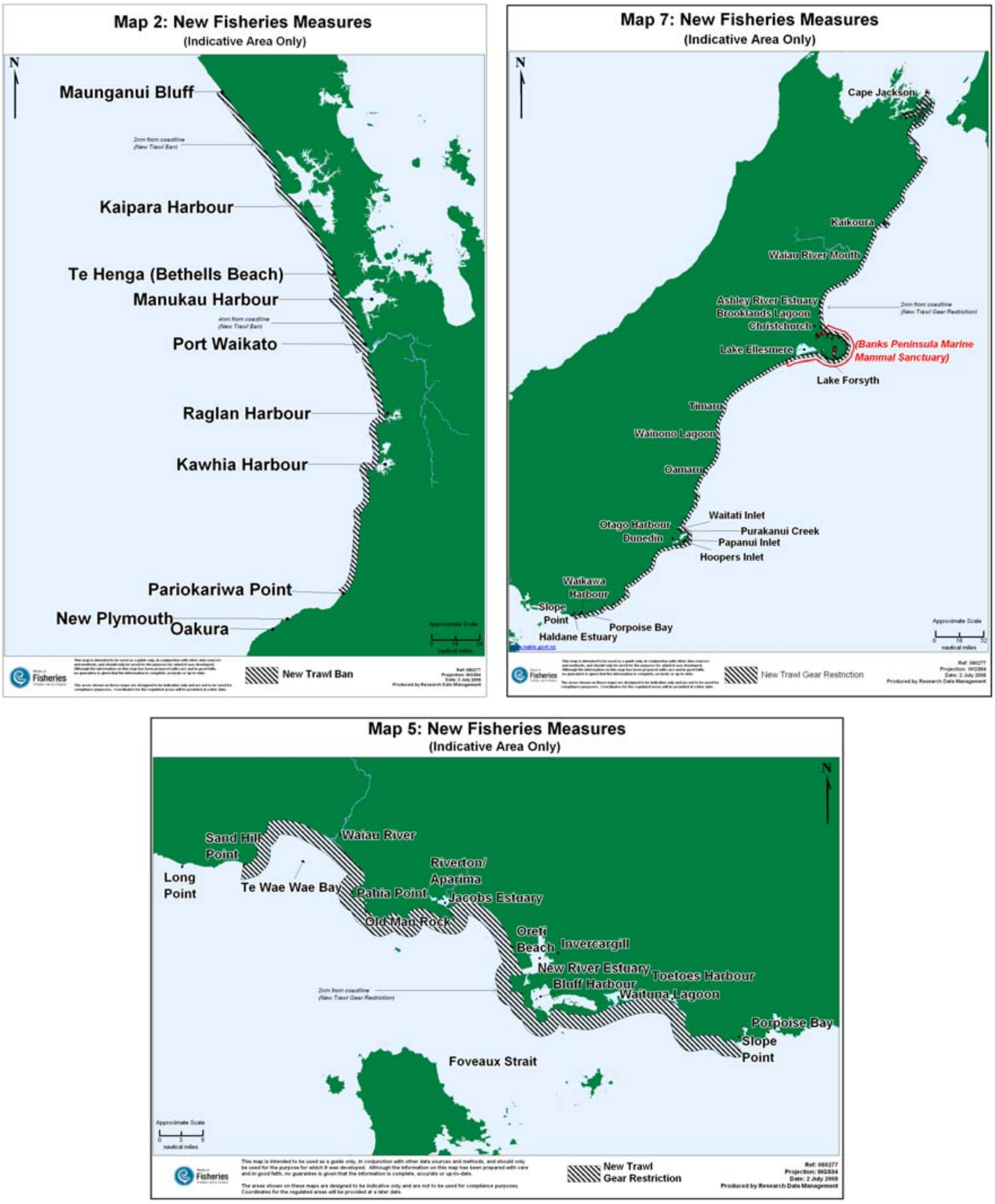


Figure 5.2: Maps from Ministry of Fisheries website showing the general locations of areas closed to trawling to protect Hector's and Maui's dolphins. Note scales differ. (http://www.fish.govt.nz/en-nz/Consultations/Archive/2008/Hectors+dolphins/Decisions.htm?wbc_purpose=Basic&WBCMODE=PresentationUnpublished%2525252525252cPresentationUnpublished**)**

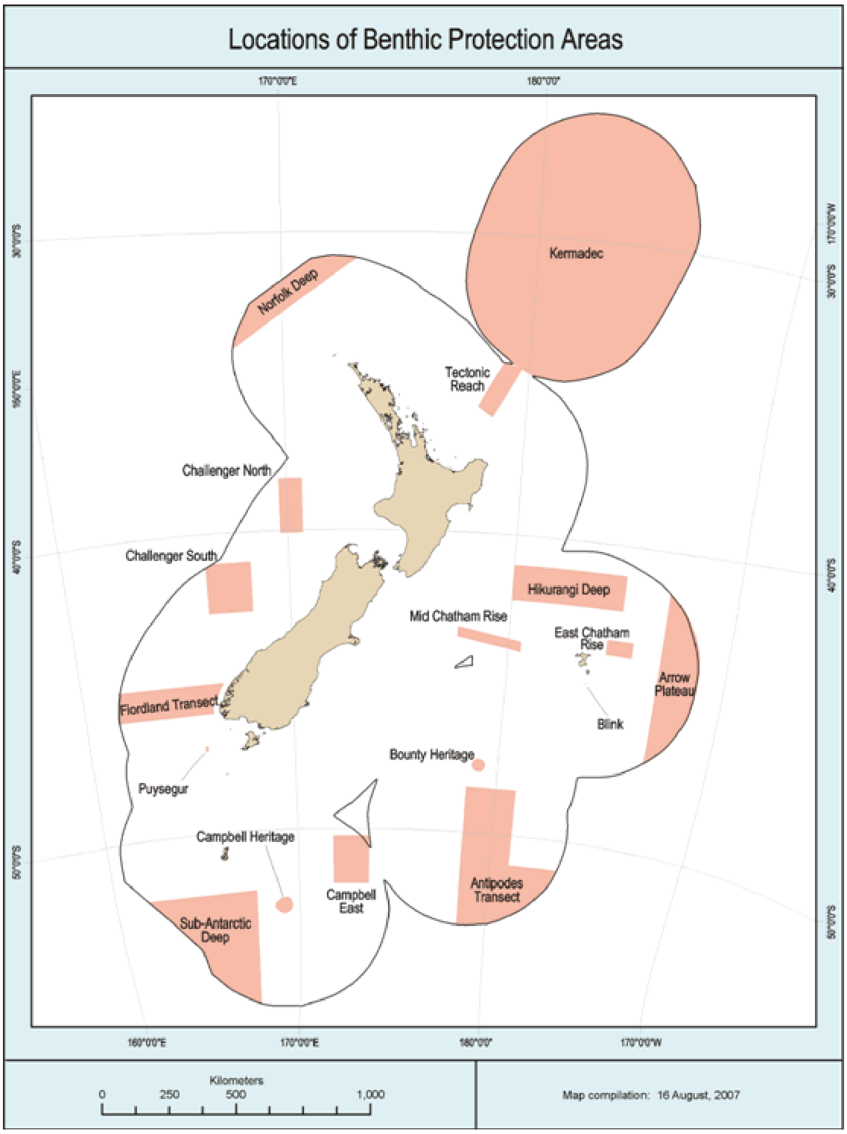


Figure 5.3: Map from Ministry of Fisheries website showing the general locations of Benthic Protection Areas (BPAs) (http://www.fish.govt.nz/en-nz/Environmental/Seabed+Protection+and+Research/Benthic+Protection+Areas.htm?wbc_purpose=basic&WBCMODE=presentationunpublished&MSHiC=65001&L=10&W=BPA%20&Pre=%3Cspan%20class%3d'SearchHighlight'%3E&Post=%3C/span%3E). See also Helson *et al.* 2009.

5.2. *Global understanding*

Concerns about the use of towed fishing gear on benthic habitats were first raised by fishermen in the fourteenth century in the United Kingdom (Lokkeborg 2005). Fishermen 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 a degree of 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 the 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 charteristics 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 soft-sediment communities of the deep sea has developed only more 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 cause sediment resuspension and can, depending on sediment and local currents, alter surface sediment characteristics. The 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, local currents, and wave action (if any). Biologically, trawling can alter benthic communities, reduce total biomass of benthic species, and increase predation by scavengers. Sites subject to greater natural disturbance are often less susceptible to change.

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 5.4) 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).

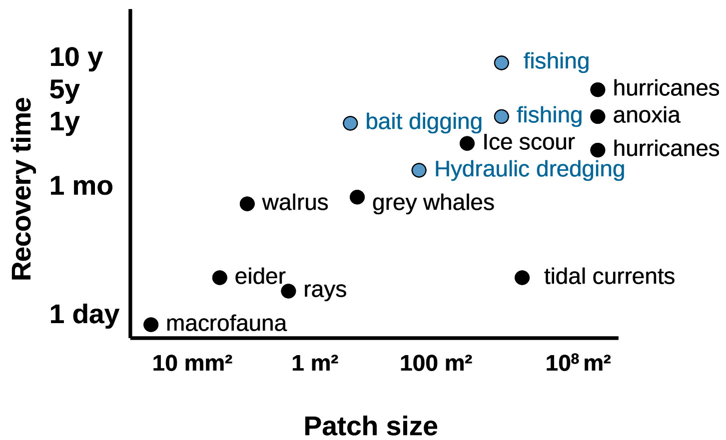


Figure 5.4: General relation between the spatial extent of disturbance events and the time taken to recover from such events in marine systems (after Kaiser *et al.* 2003).

Rice (2006) summarised the findings of five major reviews of the effects of mobile bottom-contacting fishing gears on benthic species, communities, and habitats conducted by international or independent science-based organizations between 2000 and 2005 (the International Council for Exploration of the Seas (ICES), the U.S. National Academy of Sciences, the U.S. National Marine Fisheries Service (NMFS), the United Nations Food and Agriculture Organization, and the American Fisheries Society, see 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. 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 al.*2009).

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, 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.

5.3. 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.

5.3.1. Distribution of Habitats

Mapping of benthic habitats at the large scales inherent in fisheries management is expensive and time-consuming. Because of this limitation, the Ministry for the Environment, the Ministry of Fisheries and the Department of Conservation jointly commissioned an environmental classification of New Zealand’s Exclusive Economic Zone to provide a spatial framework that subdivided the geographic domain into units having similar environmental and biological character (see also the marine biodiversty chapter in this document). Development of the Marine Environment Classification (MEC) occurred between 2000 and 2004, with a formal launch in 2005 (Snelder *et al.* 2004, 2005, 2006). The MEC was based on multivariate clustering of spatially explicit physical data layers to produce an hierarchal classification that enables users to delineate environmental variation at different levels of detail and a range of associated spatial scales. The MEC has a nominal spatial resolution of 1 km, a scale that is appropriate to predicting expansive habitats at the level of the EEZ.

A physically based classification was chosen because data were available or could be modelled, and because environmental pattern was thought a reasonable surrogate for biological pattern, particularly at larger spatial scales. Selected biological datasets were used to tune the classification so that the physically based classes maximised discrimination of variation in biological composition at various levels of classification detail. Statistical tests showed that the classes were biologically distinctive. The authors suggested that the MEC provided managers with a useful spatial framework for broad scale environmental and conservation management, but cautioned that the full utility and limitations would become clear only as the MEC was applied to management issues. They further stated that a spatial framework is a tool to organise data, analyses and ideas and is only a component of the information that would be employed in any analysis. The 20-class version (Figure 5.5, see also Table 5.1 for the average attributes of each of the classes defined at this level) has been the most widely cited and used, 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 sought to provide a general classification that had relevance to a broad range of biological groups. It was tuned against biological data sets for demersal fish, phytoplankton (as chlorophyll a), and benthic invertebrates, but performed least well as a classification of benthic invertebrates. At the 20-class level, the MEC 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 species (Leathwick *et al.* 2006) commissioned by the Department of Conservation. Variants of this classification based on 2, 6, and 10 physical variables all out-performed the original MEC for demersal fish, particularly at lower levels of classification detail. This indicated that classifications optimised for particular ecosystem components were likely to be better at predicting the distribution of those components than the general purpose MEC. At higher levels of classification (~100 classes) the classification based on 10 physical variables performed almost as well as a classification based on biological data (from the Ministry of Fisheries *trawl* database). The demersal fish optimised MEC was adopted by the Ministry for the Environment for their indicators related to bottom trawling and their March 2010 Environmental Snapshot where the location of trawling 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).

Based partly on this experience, the Ministry of Fisheries commissioned, as part of project BEN2006/01, a further classification optimised for benthic habitat and community classes (the Benthic-Optimised Marine Environment Classification, BOMEC). As was the case for the demersal fish optimised classification, many more physical, chemical, and biological data layers were available for the development and tuning of this classification. Especially relevant for benthic invertebrates was the inclusion of a single layer for sediment grain size (which was notably absent from the MEC). The recently-developed Generalised Dissimilarity Modelling (GDM, Ferrier *et al.* 2002, 2006, Leathwick *et al.* 2011) was selected to define the classification because this approach is well suited to the sparse and unevenly distributed biological data available for marine classifications. The BOMEC classes (Figure 5.6) 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 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 fine scales. This, in conjunction with the findings of Leathwick *et al.* (2006), reinforces the role of environmental classifications as broad-scale predictors of general patterns when more specific biological information is not available.

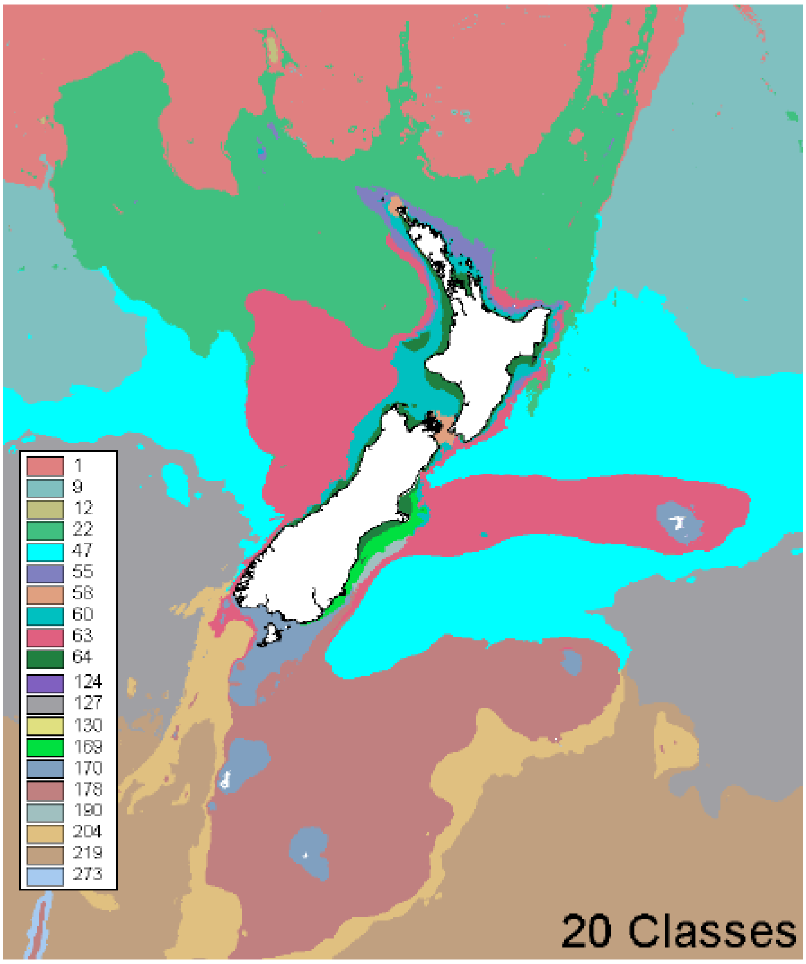


Figure 5.5: The 20-class version of the 2005 general purpose Marine Environment Classification (MEC, from Snelder *et al.* 2005). The class numbers are nominal; for attributes of each class at this level, see Table 5.1.

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.* (2010), 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. 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.

Table 5.1: 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

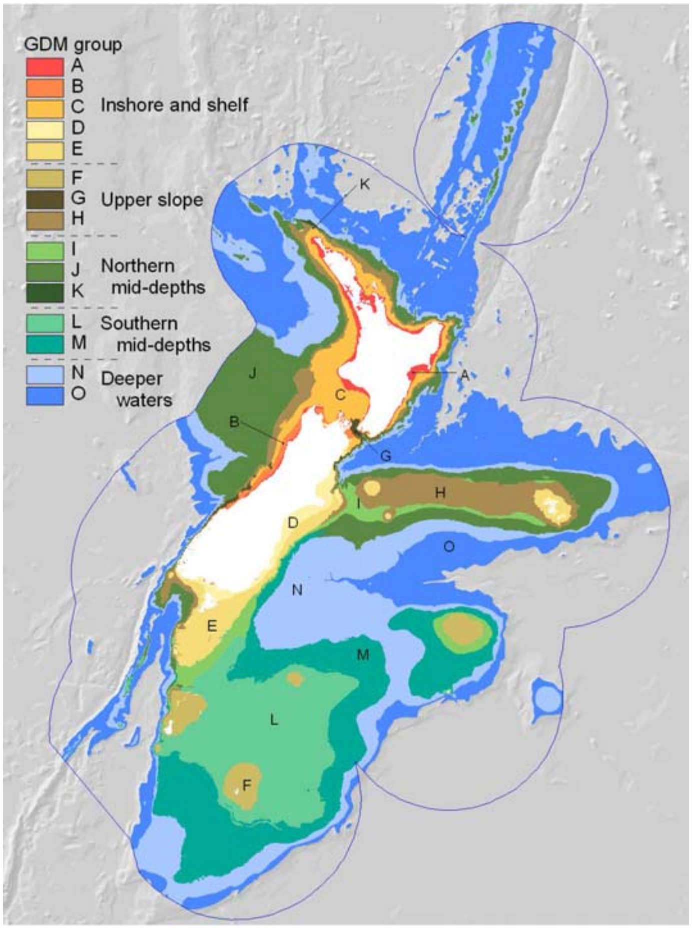


Figure 5.6: Map of the distribution of Benthic Optimised Marine Environment Classification (BOMEC) classes defined by multivariate classification of environmental data transformed using results from GDM analyses of relationships between environment and species turnover averaged across eight taxonomic groups of benthic species. From Leathwick *et al.* 2010.

5.3.2. Distribution of Fishing

Since 1989/90, mobile bottom fishing has been reported on one of three standardised reporting forms (Table 5.2). 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.

Baird *et al.* (2002, project ENV2000/05) 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. 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, project ENV2003/03) who found: interannual variability in both areas caused by the exploration of "new" fishery areas; that areas persistently fished were in depths of 100–200 m and 400–700 m; and areas that were fished only rarely tended to be on the edges of areas that were trawled regularly. The analysis was updated for all waters within the outer boundary of the EEZ (i.e., including the TS and the EEZ occlusions) by Baird *et al.* (2011, project BEN2006/01) for the 16 fishing years 1989–90 to 2004–05. Tows that were reported on TCEPRs as using bottom trawl gear or midwater gear within a metre of the seafloor were included in the main spatial analysis, but some additional analysis was possible using tows reported on CELRs. Until 2006/07, TCEPRs were typically used by vessels fishing in middle depth and deepwater fisheries whereas inshore vessels typically used CELRs. Despite this broad separation, bottom trawling reported on CELR forms comprised a substantial proportion of trawling in some areas, even for some "deepwater" species. For instance, Cryer and Hartill (2002) estimated that, in the Bay of Plenty (QMA 1), 78% of trawl tows for tarakihi, 75% for gemfish, and 39% for hoki were reported on CELR rather than TCEPR forms in the 1990s. Very little trawling on or near the bottom was reported in waters deeper than 1600 m and this depth was considered by Baird *et al.* (2011) to be the limit of "fishable" waters (more properly, trawlable waters).

Table 5.2: 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.* (2011) calculated three annual measures of fishing effort: the number of tows, the aggregate swept area, and the coverage ("footprint") of the total trawl contact. The area measures were based on estimates of swept area for each tow using a doorspread value to describe the width of the trawl and the tow length. Doorspread values were assigned to tows based on industry and scientist knowledge of the gear sizes used by different-sized vessels to target groups of species. This provided a relative swept area that represented the area of seabed likely to be contacted from the doors back to the net, and thus gave a better measure of seabed contact than the wingspread-based swept area estimated in earlier projects. However, the swept area measures are still limited, for example, by the resolution of the start and finish locations, the assumption that the tow is on the seabed between those locations (that actually define the vessel's position, not the net's position), and the lack of knowledge about the tow path and thus the assumption that the tow travels in a straight line between the start and finish positions. These, and other factors, are likely to result in an underestimate of the seabed area that has been trawled, especially since the late 1990s when a small proportion of the deepwater vessels operated twin trawl nets and the use of these nets was not clear in the data when the study was undertaken. The estimated swept areas also 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). To represent the trawl swept area spatially, tracklines were created between the reported tow start and finish positions and then buffered by the assigned doorspread value to generate trawl polygons. The aggregate swept area for each year is the sum of the areas in the polygons and the "footprint" is the estimated area of the seabed that is covered by the polygons overlaid and merged together. The trawl polygons were overlaid on a 5 x 5 km cell grid created in an Albers equal area projection to display and analyse the effort spatial and temporal distribution and the trends over the 16 years.

Baird *et al.* (2011, project BEN2006/01) produced maps of the aggregate swept area by year for each of the 22 main target species or species groups and summary tables and figures describing trends by target, gear type, depth zone, Fishery Management Area, and year. They used an Albers equal area projection for mapping and a cell size of 5 x 5 km throughout the EEZ. In contrast, Baird *et al.* 2002 used a cell size of 0.05 x 0.05 degrees of arc which resulted in cell sizes varying with latitude, complicating the interpretation of the impact statistics. The annual number of trawls peaked in 1997–98 at 78 610 tows (equivalent to an estimated swept area of about 180 450 km^2). In 2007/08, fewer than 55 000 tows (about 130 800 km^2) were reported on TCEPRs. Only a summary of Baird *et al.*'s most recent (2011) analysis is presented here; Figure 5.7 shows the aggregate swept area by cell for all qualifying trawl tows reported on TCEPR forms over the 16 years. A version of this map developed for the Ministry for the Environment up to an including the 2007/08 fishing year (e.g., Ministry for the Environment 2010) is not qualitatively different.

Baird *et al.* (2011) also attempted to utilise information on geographically small topographic features that can be a focus for some deepwater trawl fisheries (e.g., for orange roughy and cardinal fish). Tows on seamounts are often short (less than 20-30 minutes on the seabed) and the reported start and finish locations are commonly the same (because the reporting precision of TCEPRs is to the nearest minute of latitude or longitude). Baird *et al.* defined polygons for these tows as radii around the reported start position with the size of the polygon (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 5.7, yet can represent intense fishing effort on particular, small seamount features (e.g. Rowden *et al.* 2005, O'Driscoll and Clark 2005).

Overall, between 1989/90 and 2004/05, only about 25% of all mobile bottom fishing events were reported on TCEPRs. These were all trawl tows, mostly by relatively large vessels. Another 25% of events were bottom trawls reported on CELRs, and the remaining 50% were dredge tows for shellfish reported on CELRs. In the early to mid 1990s, many of the smaller vessels that had previously used CELRs changed to TCEPRs and their effort data were, therefore, included in Baird *et al.*'s (2011) analyses for those years. However, the adoption of TCEPRs was not uniform throughout the EEZ or in time. For example, much inshore trawling around the South Island and off the east coast of the North Island continued to be reported on CELRs and this effort cannot be included in the spatial analysis by cell. Not surprisingly, the distribution of trawling reported on CELRs is not the same as that reported on TCEPRs (Figure 5.8); 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). Thus, changes by these fishers between CELR and TCEPR forms will complicate the interpretation of any changes in the amount and distribution of bottom trawling reported on TCEPRs.

The proportion of effort reported on CELR forms is much lower for offshore fisheries and decreasing to negligible levels in all trawl fisheries once TCER forms were introduced in 2007/08 (Figure 5.9). The introduction of these forms was after the analyses presented by Baird *et al.* (2011) but data on these forms were included in the update commissioned by the Ministry for the Environment in 2010 and will affect all subsequent analyses.

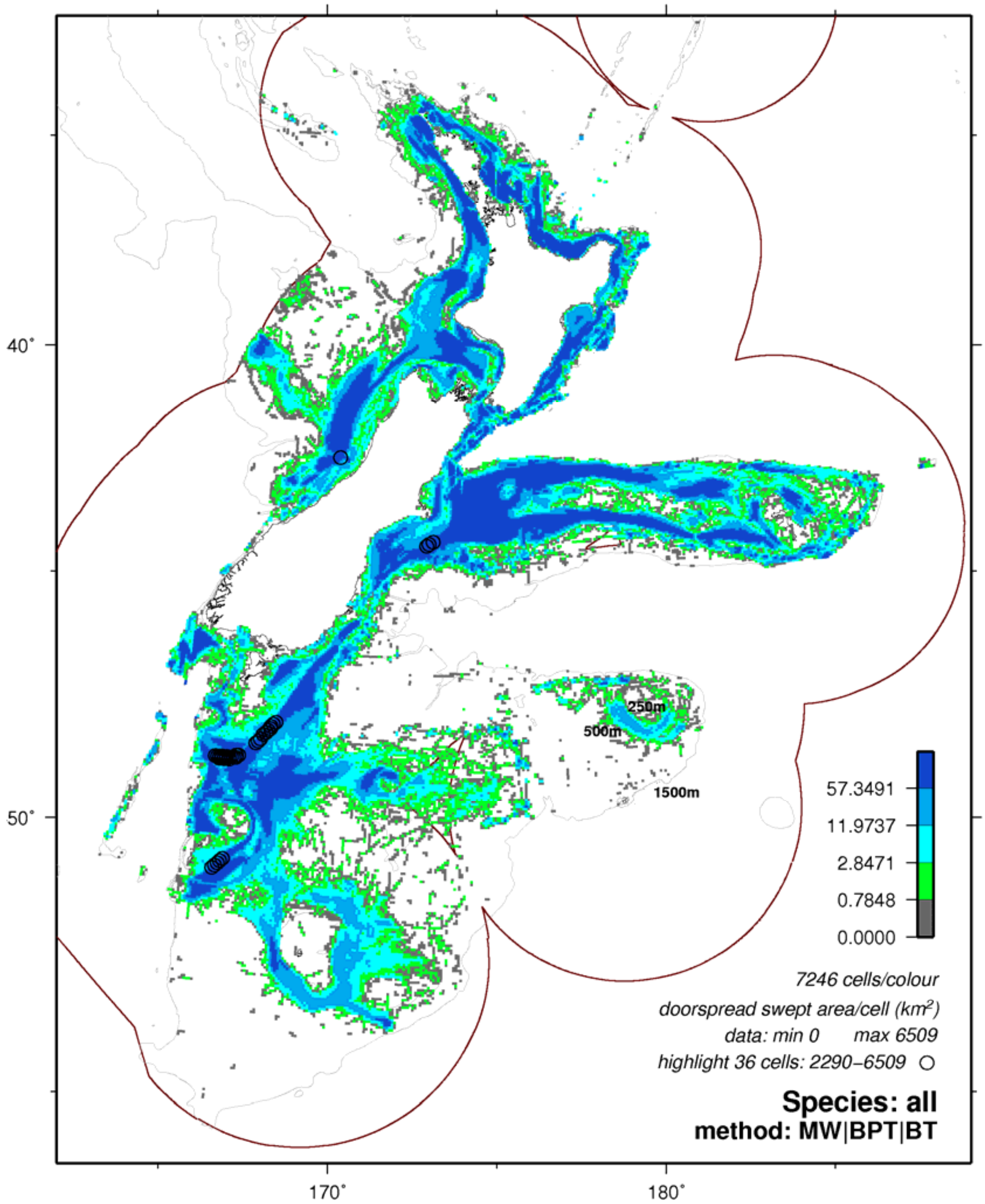


Figure 5.7: Map from Baird *et al.* 2011 showing the intensity of bottom-contacting trawling effort reported on TCEPR forms 1989–90 to 2004–05. The colour scale indicates the aggregate swept area estimated by Baird *et al.* for each 5 x 5 km cell, all target species combined (e.g., the 36 most intensively 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).

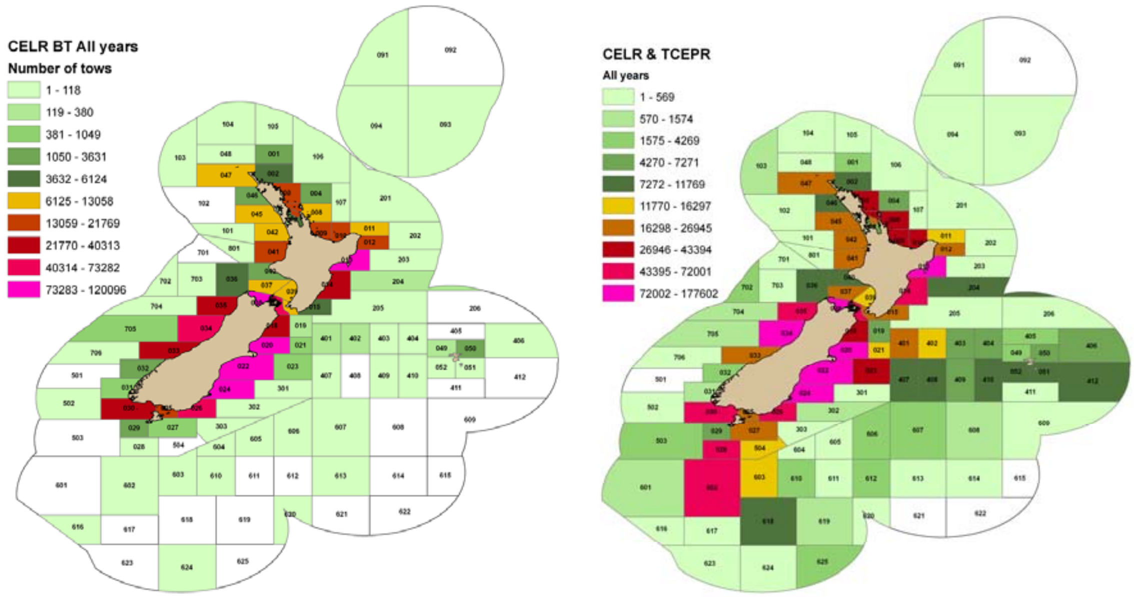


Figure 5.8: Broad-scale distribution from Baird *et al.* 2011 of bottom trawl effort reported on CELRs (left) and on CELRs and TCEPRs combined (right), for all fishing years 1989–90 to 2004–05.

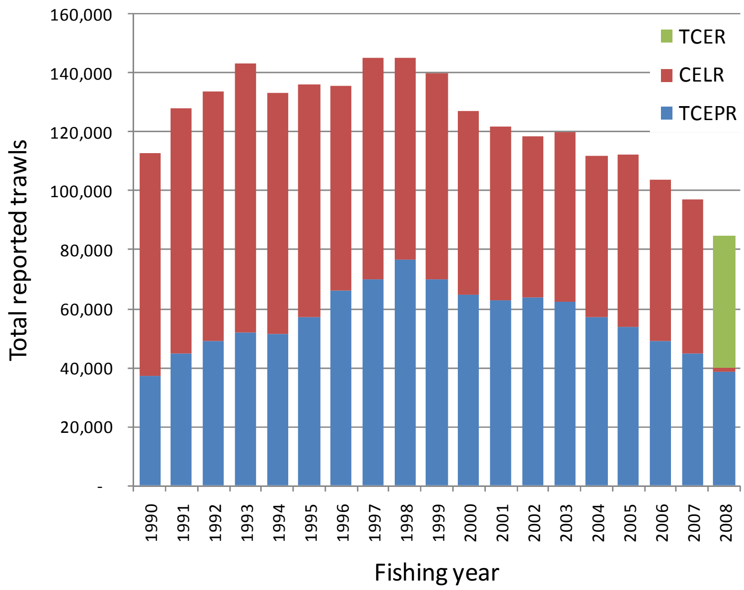


Figure 5.9: The number of trawl tows reported on Trawl Catch Effort and Processing Returns (TCEPR), Catch Effort and Landing Returns (CELR) and Trawl Catch and Effort Return (TCER) between the 1989/90 and 2007/08 fishing years.

Dredging for shellfish (oysters and scallops) is conducted in a number of specific areas that have separate, smaller statistical reporting areas (Figure 5.10). 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 5.11).

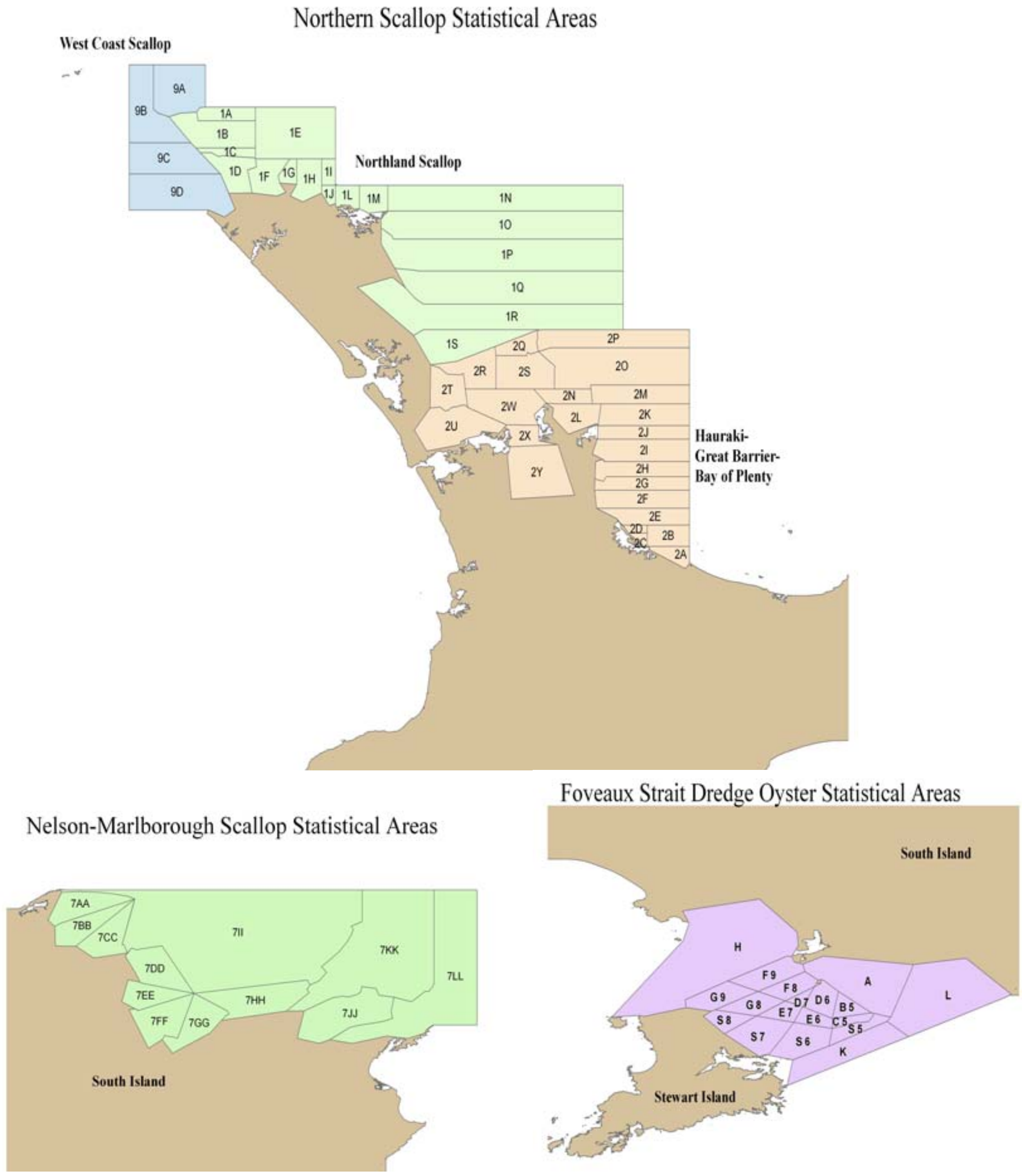


Figure 5.10: Maps taken from Baird *et al.* 2011 of statistical reporting areas for the main oyster and scallop dredge fisheries (scales differ). Note that these reporting areas are generally much smaller than the standard statistical reporting areas used for most finfish reporting.

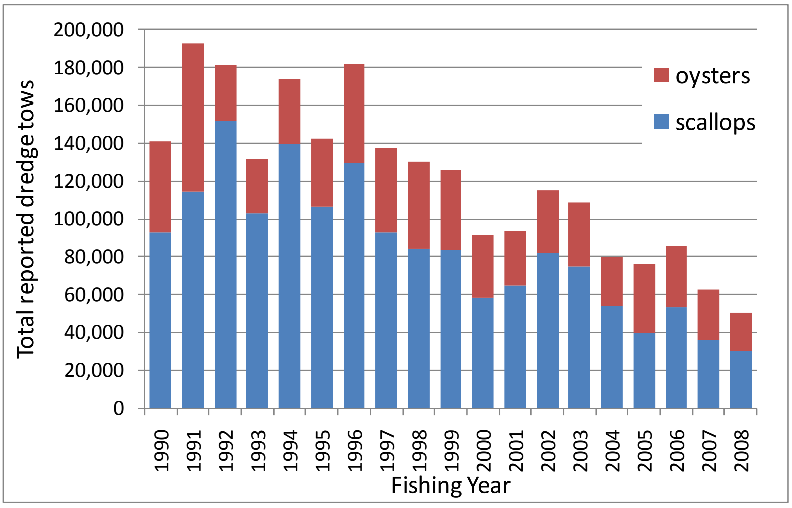


Figure 5.11: The number of dredge tows for scallop or oysters reported on Catch Effort and Landing Returns (CELR) between the 1989/90 and 2007/08 fishing years (data from Baird *et al.* 2011 and Ministry of Fisheries databases).

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 of Fisheries' 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.

5.3.3. Overlap of Fishing and Predicted Habitat Classes

Baird and Wood (2010, project BEN200601) overlaid the 16-year trawl footprint 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 5.12). 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 5.13. 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.

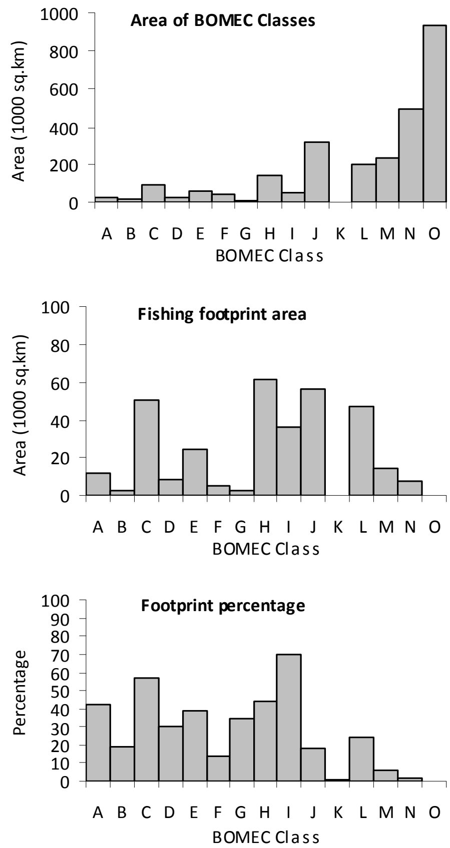


Figure 5.12: Plots from Baird and Wood (2010) of the areas of each BOMEC Class (top), the fishing footprint shown in Figure 5.8 (centre), and percentage of each BOMEC Class area covered by the fishing footprint (bottom).

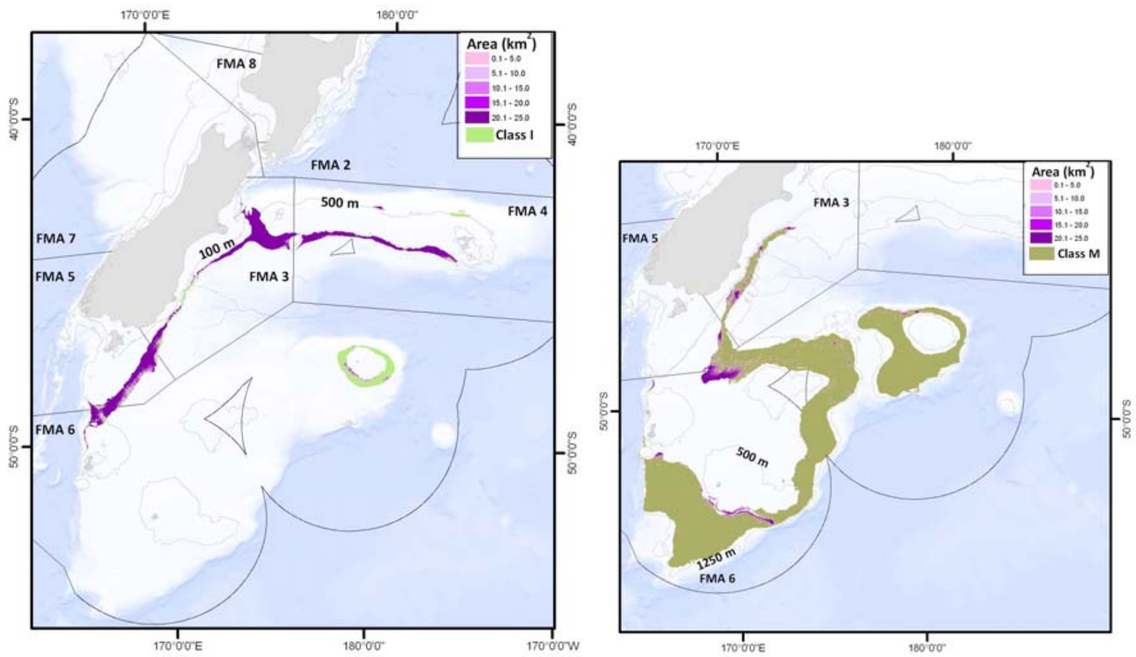


Figure 5.13: Maps from Baird and Wood (2010) showing BOMEC classes I (left) and M (right) overlaid with the footprint of trawls on or near the seafloor reported on TCEPR forms to 2004–05 for each 25-km^2 cell.

5.3.4. 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 be 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 5.3). 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 *et al.* 2010, Williams *et al.* 2011). Even though such impressive 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.

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 5.3: 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 & biogenic areas. Scallop dredge.	Observational, gradient analysis	In 1999, depth was found to be the most important explanatory variable for benthic community composition but a coarse index of dredge fishing intensity was more important than substrate type for many taxonomic groups. Sponges seemed most affected by scallop dredging, and samples taken in an area once rich in sponges had few species in 1999. This area had probably been intensively dredged for scallops. Analysis of historical samples of scallop survey bycatch showed a marked decline in sponge species richness between 1996 and 1998. In 2006, significant differences were identified 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.	Cryer *et al.* 2000 Tuck *et al.* 2009
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.* 2010 Williams *et al.* 2011

5.3.5. 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 BEN2009/02 provides for the implementation of a monitoring programme (designed in project ENV2005/23) for benthic invertebrate communities in Spirits Bay and Tom Bowling Bay. Changes in benthic communities since 1997 will be assessed at sites inside and outside the area closed to scallop dredging and trawling. The focus of this study is on the rate of recovery of benthic invertebrate communities known to be sensitive to disturbance by mobile bottom fishing methods.

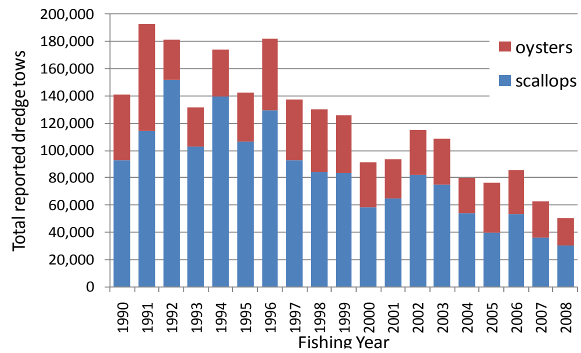
Project DAE2010/04 provides for an annual assessment of the “footprint” of middle depth and deepwater trawl fisheries, including the overlap of the footprint with various depth ranges and habitat classes. Inshore fisheries, including shellfish dredge fisheries, are not covered under this project, so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

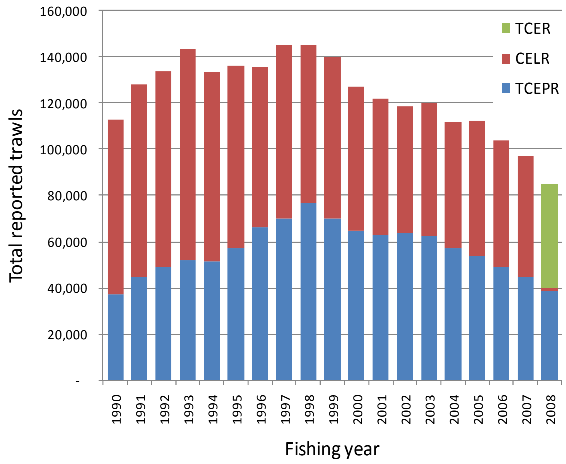
Project DEE2010/05 provides for the development of a suite of ecosystem and environmental indicators for deepwater trawl fisheries. The focus of this study is on developing a cost-effective approach to monitoring ecosystem status (e.g., providing a mechanism to detect ocean climatic changes or regime 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.

An expert based assessment of 65 threats to 62 marine habitats from saltmarsh to the abyss (BEN200705) 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.

5.4. Indicators and trends

Annual number of tows	2007/08 fishing year: 84 800 trawls that contacted the seabed 50 440 shellfish dredge tows
Trend in number of tows	Decreasing:





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

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.

5.5. References

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THEME 4: ECOSYSTEM EFFECTS

6. New Zealand Regional Climate and Oceanic Setting

Scope of chapter	Overview of primary productivity, oceanography, hydrology, bathymetry, and oceanic climate trends in the region.
Area covered	New Zealand regional setting
Focal localities	Plateaus, underwater topography, relative primary productivity
Key issues	• Climate trends of relevance to fisheries • Allows for correlative studies with fisheries statistics and demographics
Emerging issues	• Causal mechanisms that link the dynamics of a variable marine environment to variation in biological productivity, particularly of fisheries are not well understood in New Zealand • 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 • New Zealand's oceanic climate is changing
MFish Research (current)	ENV2007-04 Climate and oceanographic trends relevant to New Zealand fisheries; other related 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; SAM2005-02 Effects of climate on commercial fish abundance; ENV2009-04. Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys
NZ Research (current)	C01X502 Coasts & Oceans OBI IO 1. plankton productivity and natural variability; University of Otago-NIWA shelf carbonate geochemistry and bryozoans; Munida time-series transect; Geomarine Services-foraminiferal record of human impact; Regional Council monitoring programmes
Links to 2030	Environmental Outcome Objective 1; environmental principles of Fisheries 2030
Related issues	Ocean climate variability and change are predicted to have major implications for fishstock distributions and abundance, reproductive success, ecosystem goods and services

6.1. Context

Climate and oceanographic conditions play an important role in driving the productivity of our oceans and the abundance and distribution of our fishstocks, and hence fisheries. A full analysis of trends in climate and oceanographic variables in New Zealand is given in Hurst *et al.* (in press), the key output from MFish project ENV2007-04.

New Zealand is essentially part of a large submerged continent. Our territorial seas (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 6.1). 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 28 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).

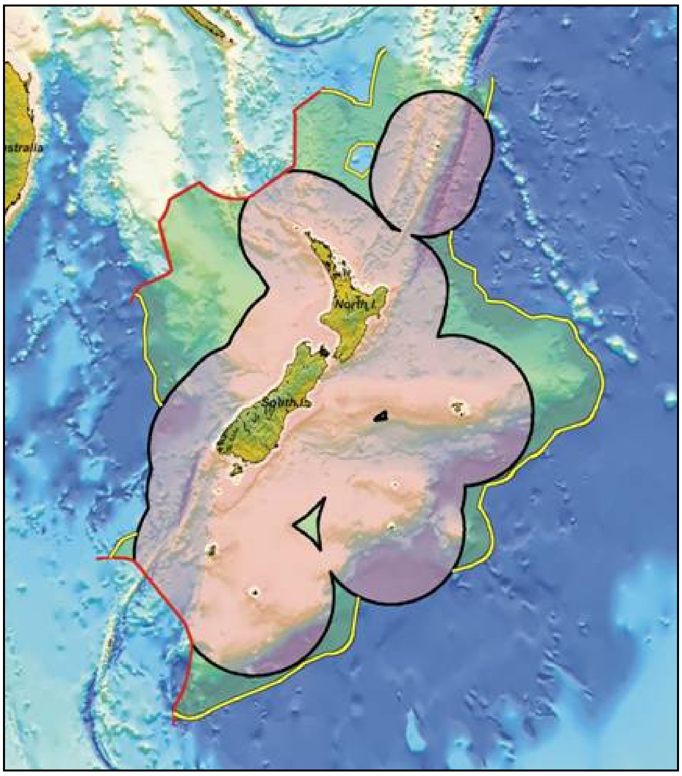

Figure 6.1: New Zealand land mass area 250,000 km^2; EEZ & territorial sea area (pink) 4,200,000 km^2; extended continental shelf extension area (light green) 1,700,000 km^2; Total area of marine jurisdiction 5,900,000 km^2. The black line shows the boundary of the New Zealand EEZ, the yellow line indicates 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.

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, 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 6.2).

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 a generally oligotrophic western Pacific Ocean (Figure 6.3) . Higher ocean colour reflecting higher levels of productivity is typically found around the coast and to the east across the Chatham Rise (Figure 6.3; 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 underwater topographic features in suitable depths provide additional localized areas of upwelling and increased productivity sometimes associated with commercial fisheries.

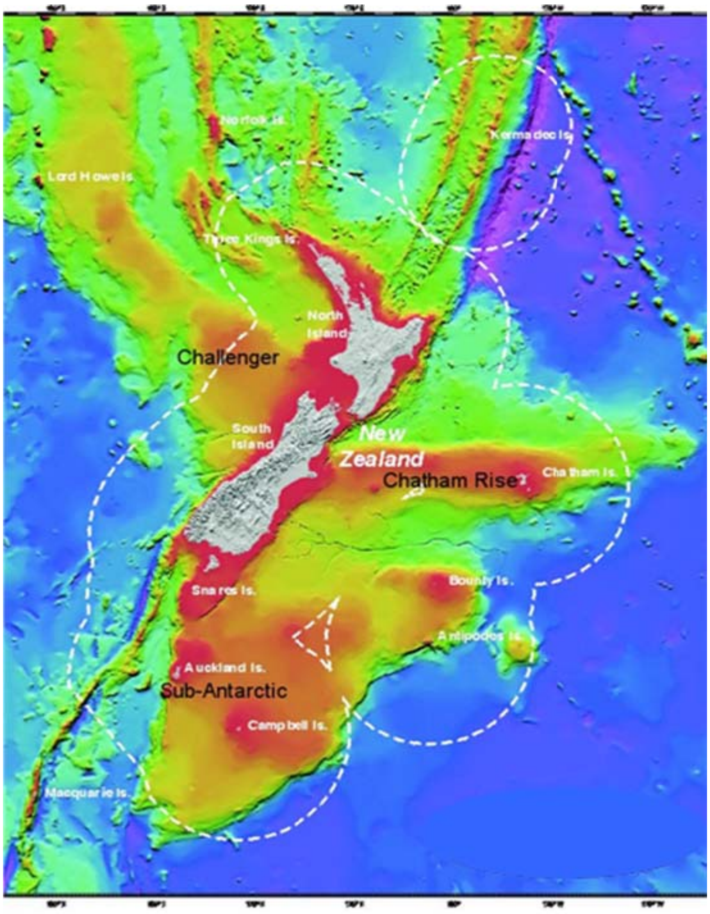

Figure 6.2: Undersea topography of New Zealand (red shallow to blue deep). White dash line shows the EEZ boundary. Image courtesy of NIWA.

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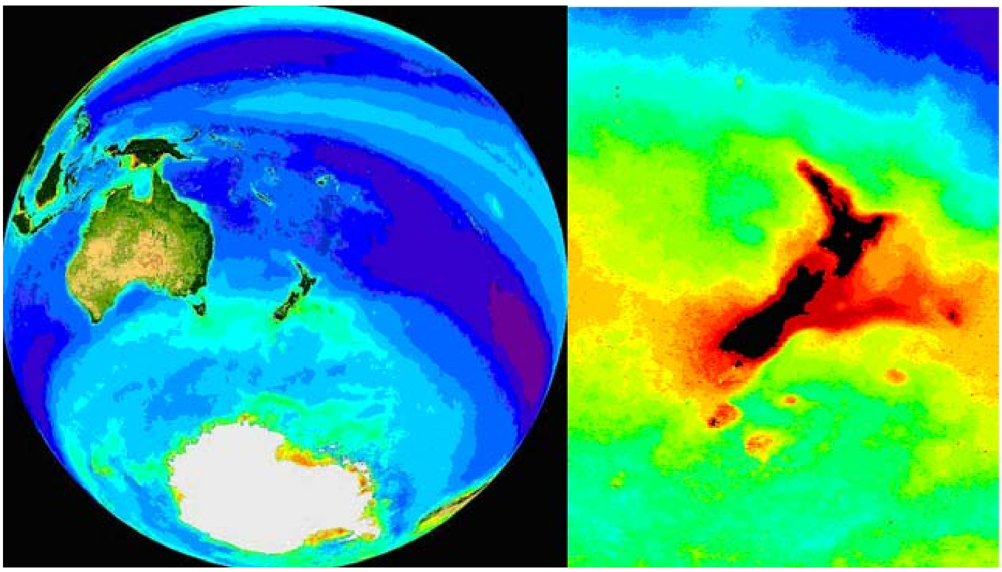

Figure 6.3: SeaWIFS image showing elevated chorophyll *a* (green) near New Zealand (left panel). Ocean colour in the New Zealand region from satellite imagery. Red shows the highest intensity of ocean colour typically associated with higher primary productivity (right panel). Images courtesy of NOAA and NIWA.

Both Figures 6.2 and 6.3 show that the strongest chorophyll *a* and ocean colour are associated with the coastal shelf around New Zealand and the Chatham Rise. 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).

The Tasman Sea (west of New Zealand) is separated from the South Pacific Gyre by the New Zealand landmass (Figure 6.4).

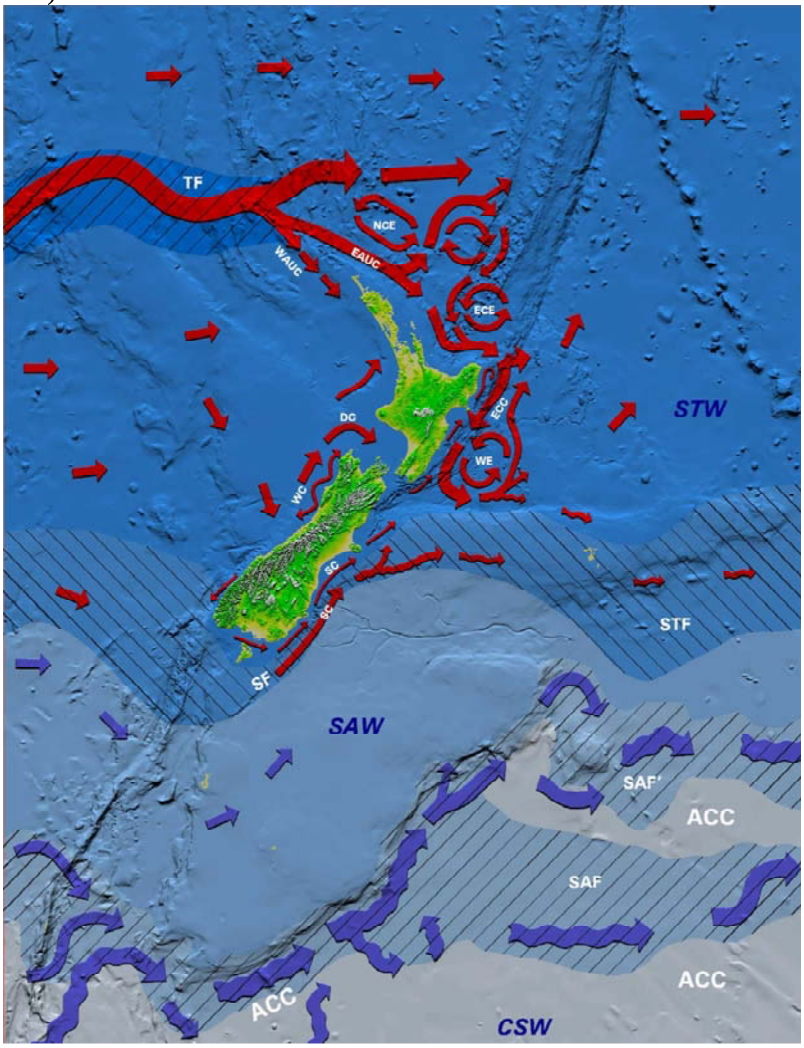

Figure 6.4: Circulation around New Zealand. TF Tasman Front (large red arrows), WAUC West Auckland Current, EAUC East Auckland Current, NCE North Cape Eddy, ECE East Cape Eddy, ECC East Cape Current, WE Wairarapa Eddy, DC D'Urville Current, WC Westland Current, SC Southland Current, SF Southland Front, 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 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 and Dunn 2003). The bulk of the separated flow crosses the Tasman Sea as the Tasman Front (Stanton 1981; Ridgway and 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 1988), before diverting southward around New Zealand, and then northward up the southeast coast of New Zealand where it is locally called the Southland Front (Heath 1985; Chiswell 1996; Sutton 2003).

The water in the eastern central Tasman Sea south of the Tasman Front, east of the influence of the EAC and north of the Subtropical Front is thought to be relatively quiescent. Ridgway and Dunne (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 though 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.

6.2. *Indicators and trends*

6.2.1. Sea temperature

Sea surface temperature (SST), sea surface height (SSH), air temperature, ocean temperature to 800m depth, SST and SSH all exhibit some correlation with each other over seasonal and interannual time scales (Hurst *et al.* in press). Air temperatures have increased by about 1°C since 1900 (Figure 6.5).

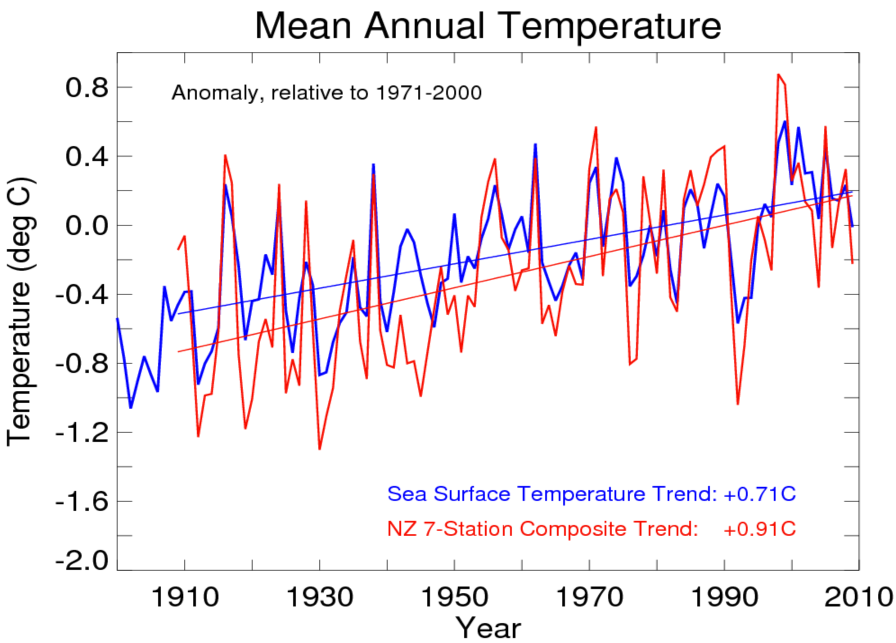

Figure 6.5: Annual time series in New Zealand. NOAA annual mean sea surface temperatures (blue line) [13] **and NIWA's seven-station annual mean air temperature composite series (red line), expressed as anomalies relative to the 1971-2000 climatological average. Linear trends over the period 1909-2009, in °C/century, are noted under the graph. (Image Source Mullan *et al.* 2010)**

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

Although a linear trend has been fitted to the seven-station temperatures in Figure 6.5, 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. These higher frequency variations can be related to fluctuations in the prevailing north-south airflow across New Zealand (Mullan *et al.* 2010). Temperatures are higher in years with stronger northerly flow, and are lower in years with stronger southerly flow. One would expect this, since southerly flow transports cool air from the Southern Oceans up over New Zealand

The unusually steep warming in the 1940-1960 period is paralleled by an unusually large increase in northerly flow during this same period Mullan *et al.* (2010). On a longer timeframe, there has been a trend towards less northerly flow (more southerly) since about 1960 Mullan *et al.* (2010). However, New Zealand temperatures have continued to increase over this time, albeit at a reduced rate compared with earlier in the 20th 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) down the Australian coast and to the east of the North Island, and much lower rates of warming south and east of the South Island (Figure 6.6).

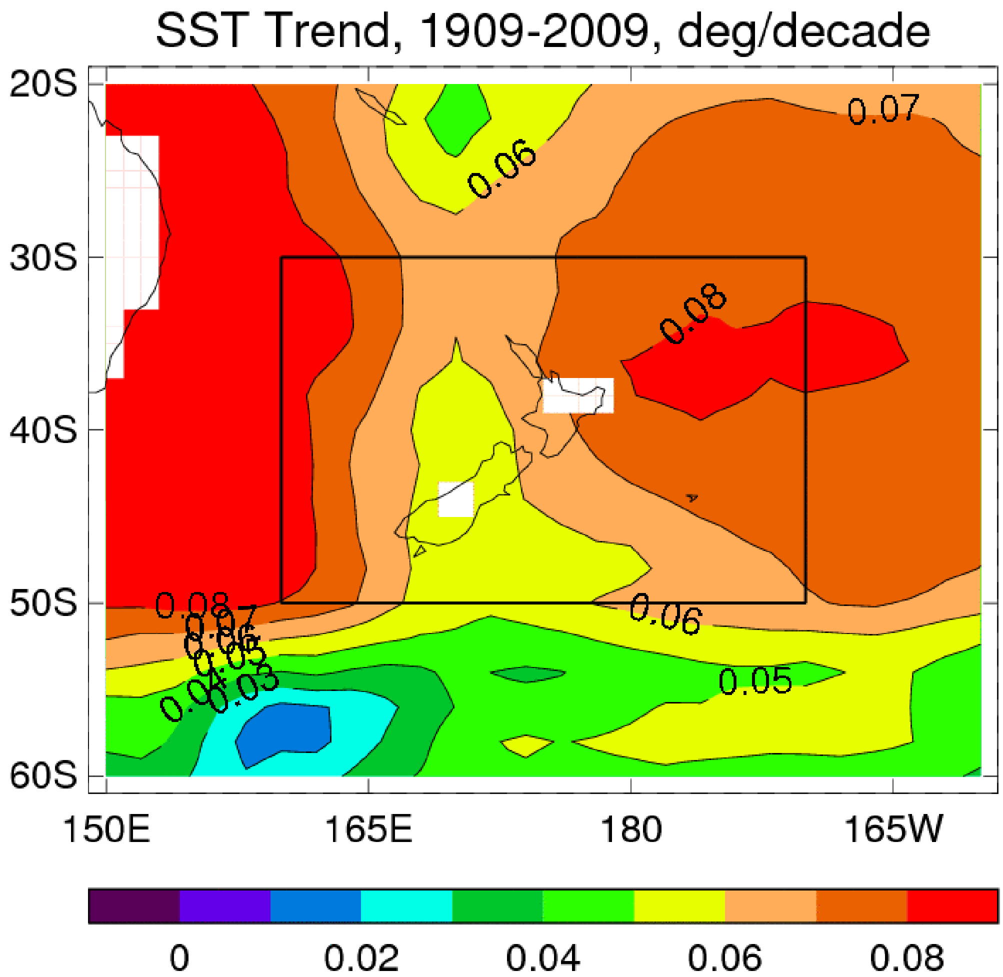

Figure 6.6: Trends in sea surface temperature, in °C/decade over the period 1909-2009, calculated from the NOAA_ERSST_v3 data-set (provided by NOAA's ESRL Physical Sciences Division, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/). The data values are on a 2° latitude-longitude grid. The box around New Zealand denotes the region used to produce the area-averaged sea temperatures plotted in Figure 2. (Image Source Mullan *et al.* 2010.)

Figure 6.7 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 and 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.

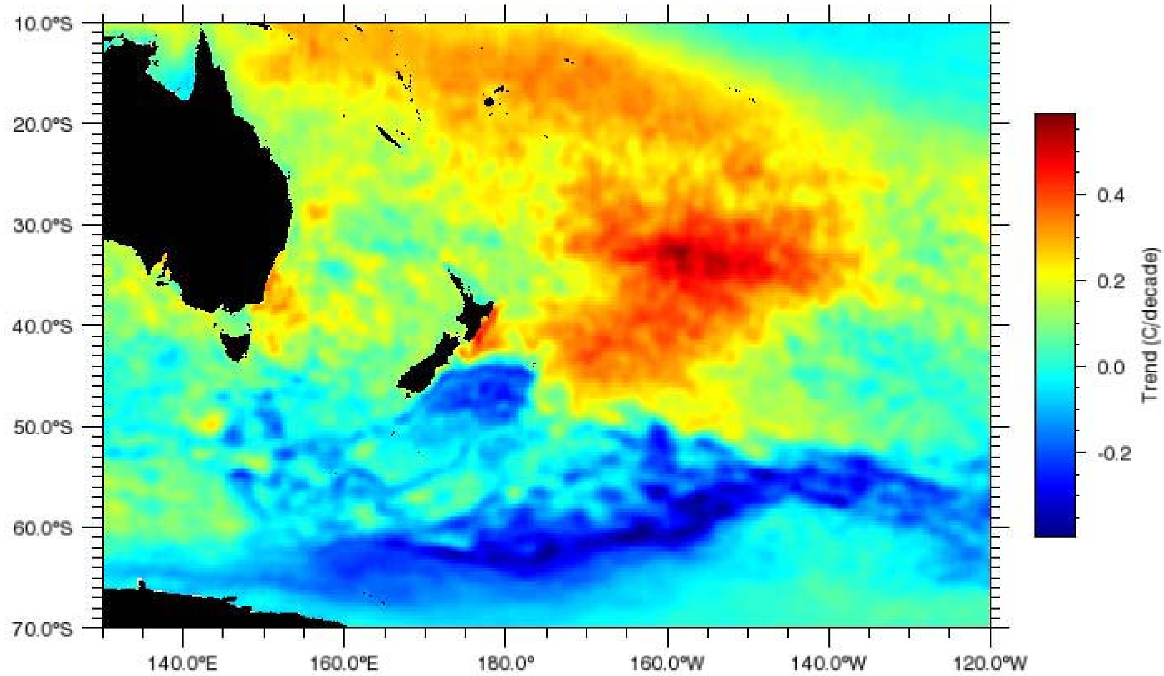

Figure 6.7: Trends in sea surface temperature, in °C/decade over the period 1982-2009. The data are again taken from NOAA, but are based on daily interpolated satellite measurements over a much finer 0.25° grid. See http://www.ncdc.noaa.gov/oa/climate/research/sst/oi-daily.php. This product is the result of an objective analysis, an optimum interpolation rather than a pure satellite retrieval, so as to correct for issues like the effect of the Mt Pinatubo eruption aerosols on satellite detected radiances. It is described in Reynolds *et al.* (2007)

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 6.8). The clearest fisheries example of a link between coastal SST and fish recruitment and growth is for northern stocks of snapper (*Pagrus auratus*), where relatively high recruitment and faster growth rates have been correlated with warmer conditions from the Leigh SST series (Francis 1993, 1994a).

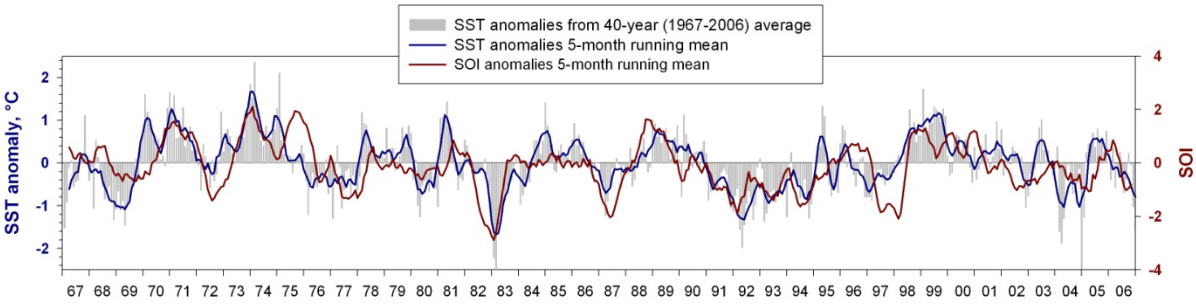

Figure 6.8: Sea surface temperature (SST) anomolies from SST measurements at Leigh (Auckland University Marine Laboratory) and Southern Oscillation Index (SOI) anomalies. (Image from Hurst *et al*. in press.)

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 6.9).

The ocean 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 and Roemmich (2001) and Sutton *et al*. (2005). The index presented for this transect (Figure 6.9) is for the most eastern section closest to New Zealand (161.5°E and 172°E). The eastern Tasman is chosen because it is closer to New Zealand, and because it has less oceanographic variability which can mask subtle interannual changes. The section of the transect shown is along fairly constant latitude is therefore unaffected by latitudinal temperature and seasonal cycle variation. The upper panel shows the temperature averaged along the transect between the surface and 800m and from 1991 to the most recent sampling.

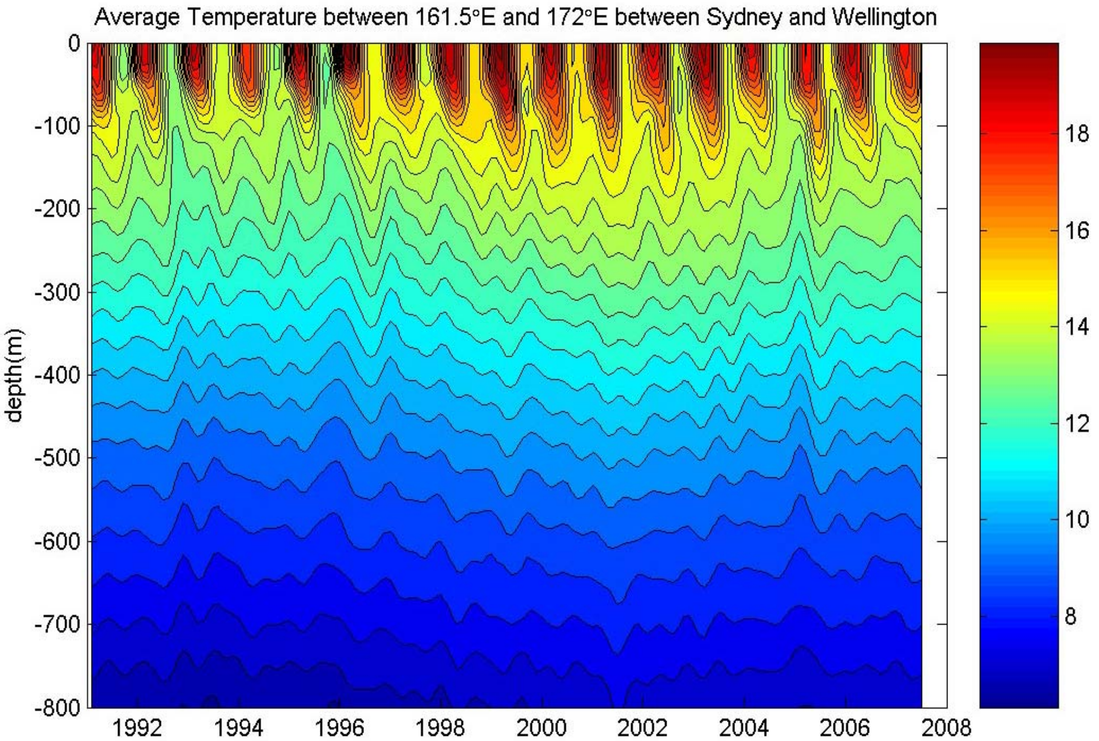

Figure 6.9: Eastern Tasman ocean temperature: Wellington to Sydney 1991–2008. Coloured scale to the right is temperature°C. (Image from Hurst *et al.* in press, after Sutton *et al.* 2005)

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 apparent by the isotherms increasing in depth through that time period. This warming was significant in that it extended to the full 800m 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 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.

6.2.2. Climate variables

The Interdecadal Pacific Oscillation (IPO) is a Pacific-wide reorganisation of the heat content of the upper ocean and represents large-scale, decadal temperature variability, with changes in phase (or "regime shifts") over 10–30 year time scales. In the past 100 years, regime shifts occurred in 1925, 1947, 1977 and around 2000 (Figure 6.10). 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.* in *press*).

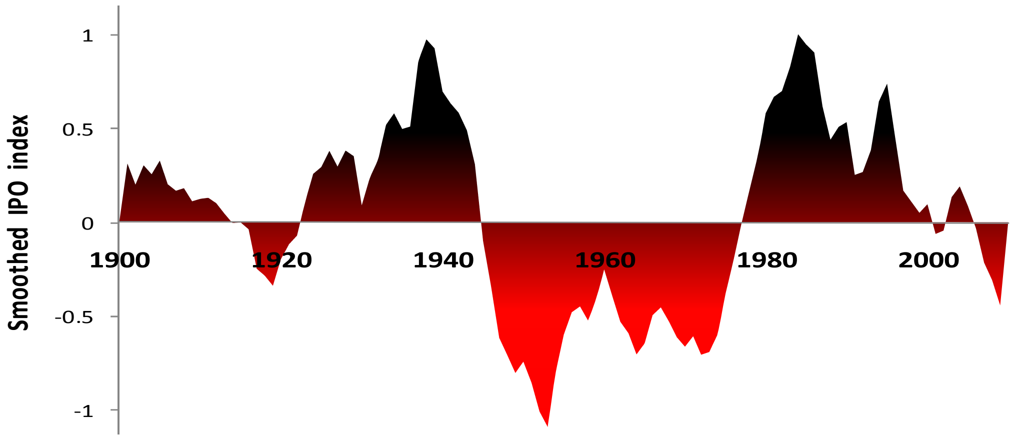

Figure 6.10: Smoothed index of the Interdecadal Pacific Oscillation (IPO) since 1900. (Image source NIWA based on data from the United Kingdom Meteorological Office, UKMO).

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.* in press). 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 1990, Zeldis *et al.* 2004, Chang and Mullan 2003). The SOI is available monthly from 1876 (Mullan 1995) (Figure 6.11).

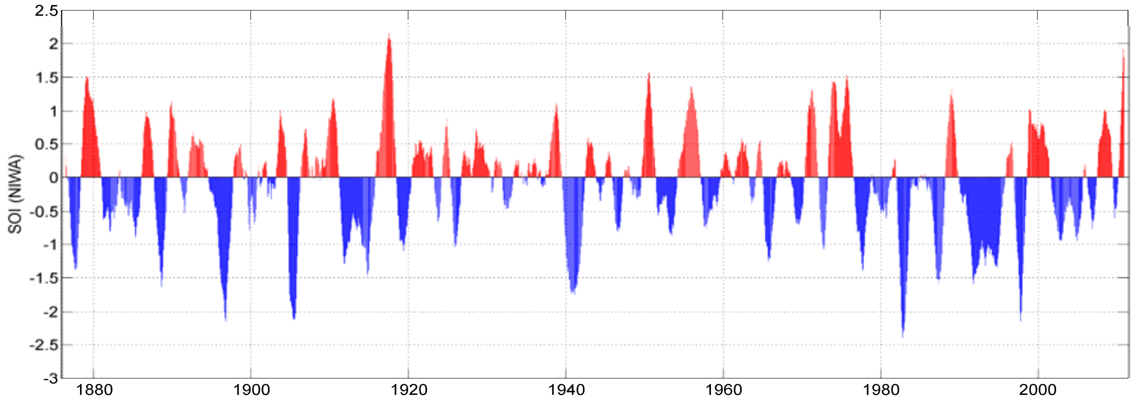

Figure 6.11: Southern Oscillation Index (SOI) 13-month running mean 1876-2010. Red indicates warmer temperatures, blue indicates cooler conditions for New Zealand. (Image courtesy of J. Renwick, NIWA.)

6.2.3. 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 ithe n the order of 2 gigatonnes (Gt) per annum (~30% of global anthropogenic emissions, IPCC, 2001a). The anthropogenic CO_2 signal is apparent to an average depth of ~1000m. 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 pH of seawater.

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 ocean is becoming more acidic. Since the industrial revolution, 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 300% increase in hydrogen ion concentration. Both the predicted pH in 2100 and the current rate of change in pH are outside the range experienced by the oceans for at least half a million years. Furthermore this trend is proposed by Caldeira and Wickett, (2003) to continue.

In New Zealand, the projected change in surface water pH between the 1990s and 2070 is a decrease of 0.15-0.18 pH units (Hobday *et al.* 2006). The only available time series of 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 R.V. *Munida* Otago Shelf Time Series). The time series is short and Hurst *et al.* (in press) describe the series as showing "no evidence of change in either pCO_2 or pH at present ([Fig.12 below]; K. Currie pers. comm.), despite a current local atmospheric CO_2 growth rate of 2.1 ppm/year (A. Gomez pers. comm.), although this may reflect that the sampling period is too short to distinguish long-term changes from seasonal and interannual variability."

The oscillations in Figure 6.12 are primarily due to seasonal changes in water temperature and seasonal effects of biological removal of dissolved carbon in the seawater. However, as more points have been added to the series (Figure 6.13), the downward trend is becoming clearer and a regression fitted to the sine wave is statistically significant (Keith Hunter, pers. comm.).

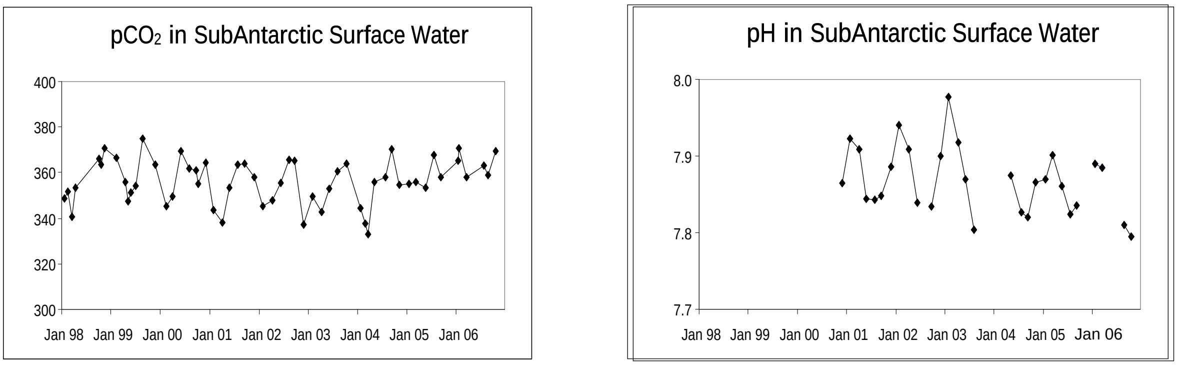

Figure 6.12: pCO_2 (partial pressure of CO_2) and pH in subantarctic surface seawater from the *R.V. Munida* transect, 1998–2006. (Image sourced from Hurst *et al.* in press.)

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 and biological activity in the plankton and sediment. Surface pH in the open ocean has been determined on a monthly basis at time series stations near Bermuda since 1983 (Bates 2001, 2007), and near Hawaii since 1988 (Brix *et al.* 2004, Dore *et al.* 2009).

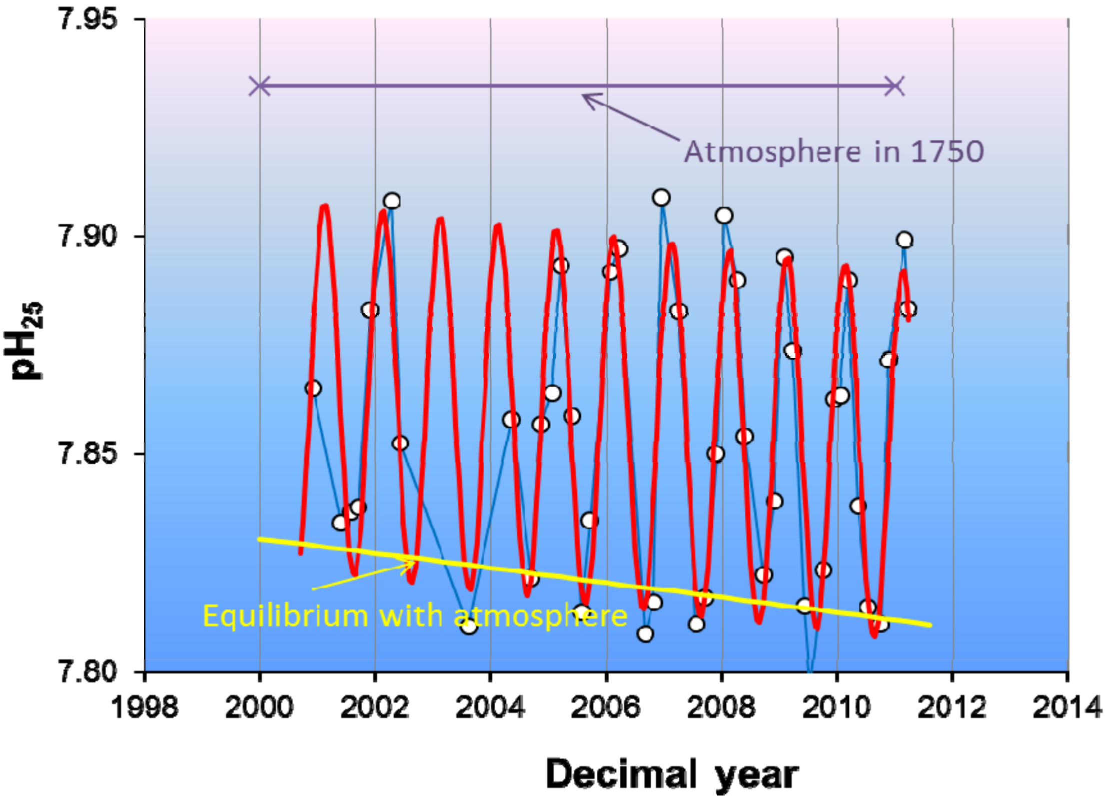

Figure 6.13: Ocean pH at 25°C pH in subantarctic surface seawater from the *R.V. Munida* transect, 2001–2011. The blue points and joining lines are the actual measurements, and the red line is a best fit to the points using a sine wave function (to represent seasonal change) and a constant slope to represent pH decreasing. The black line represents what the pH would have been in 1750 assuming equilibrium with the atmosphere at that time. The yellow line is what the pH would be assuming equilibrium with actual CO_2 concentrations as measured at Bering Head. pH^{25} is the pH measured at 25°C (Image Source: A Southern Hemisphere Time Series for CO_2 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.)

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. Placed in the context of the much longer time series of atmospheric CO_2 measurements, the short time series of pCO_2 and pH in seawater are tracking the atmospheric CO_2 in close parallel and inversely, respectively (Figure 6.14). Note that pH measurement is complicated by the chemical properties of seawater, and that several distinct pH scales exist in chemical oceanography. In addition, the regional means of seawater pH differ significantly with temperature, with the South Pacific at the lower end (Feely *et al*. 2009). The measurements of pH given in Figure 6.13 are derived in different ways from those in Figure 6.14 and are not therefore directly comparable.

The concern about ocean acidification is that the resulting reduction in carbonate availability for metabolic processing will impact organisms that produce shells or body structures of calcium carbonate, plankton productivity will be stimulated, and physiological stress increased. Organisms most likely to be affected are those at the base of the food chain (bacteria, protozoa, plankton), coralline algae, 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.* 2007).

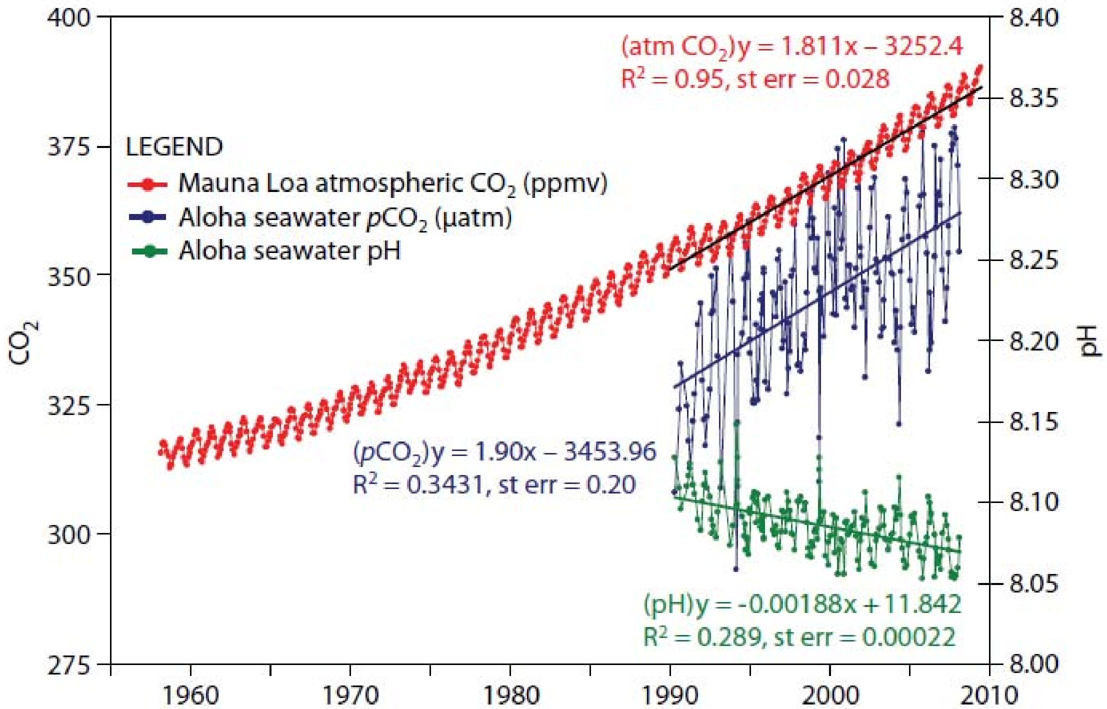

Figure 6.14: Time series of atmospheric carbon dioxide at Moana Loa, seawater carbon dioxide and surface ocean pH at Ocean station ALOHA in the subtropical North Pacific Ocean near Hawaii. pH is plotted from a combination of in situ pH, based on direct measurements and calculated from from dissolved inorganic carbon and alkalinity in the surface layer (after Dore *et al.* 2009). (Image directly sourced from Feely *et al.* 2009 with permission.)

6.3. *Ocean climate trends and New Zealand fisheries*

This section has been quoted almost directly from the summary in Hurst *et al.* (in press). 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 since the late 1970’s, 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 6.13). 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 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 fisheries indices for southern gemfish (Renwick *et al.* 1998), hake, red cod and red gurnard (Dunn *et al.* 2008), rock lobster (Booth *et al.* 2000), and southern blue whiting (Willis *et al.* 2007, Hanchet and 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 800m, 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 fisheries indices for elephantfish, southern gemfish, hoki, red cod, red gurnard, school shark, snapper, stargazer and tarakihi (Francis 1994a,b, Renwick *et al.* 1998, Beentjes and Renwick 2001, Gilbert and 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 800m) 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 fisheries indices. Of note are the increased Chl 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.* in press).

- 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 and 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 program for pH and pCO_2, and development of new programs 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.* (in press), although indices described are an integral part of monitoring the speed and impacts of global warming. 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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7. 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
MFish Research (current)	BEN2007/05, HAB2007/01, TOH2007/03, ZBD2008/01, ZBD2008/07, ENV2009/07, GMU2009-01, ENV2010/03, ENV2010/05, SEA2101/15
NZ Research (current)	Ministry of Science and Innovation (MSI) funded programme (Coastal Conservation management) and the biogenic habitat survey (2011) funded by Oceans Survey 2020, MFish, NIWA and MSI.
Links to 2030 objectives	Under the Environment Outcome habitats of special significance to fisheries need to be protected.
Related issues	Land-based impacts on fisheries and supporting biodiversity, bycatch composition, marine environmental monitoring.

7.1. 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 of Fisheries 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).

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 both the highly migratory and deepwater and middle-depths (deepwater) national fish plans (the inshore national fish plans are yet to be released). 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”. Work is underway on a policy definition of HPSFM that will assist implementing these outcomes and objectives.

7.2. 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.

7.2.1. 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, coral reefs, shell beds and shallow bays or inlets (Kamenos *et al.* 2004; Caddy 2008). 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. The Edgecumbe Pinnacle off south-eastern Alaska, which has a prohibition on certain bottom-fishing gears to protect the complex benthic ecosystem (North Pacific Fisheries Management Council 1998).
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)

Freshwater examples of habitats protected for their 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.

7.2.2. 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. Such behaviour is best known for North American salmon species. 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. This habitat divergence occurs predominantly during the juvenile phase after transition from the larval stage (Kerr *et al.* 2010). The divergence appears to be a response to early life history experiences which influence individuals' growth (Kerr 2008). Prior to dispersal, larval growth rates of (subsequently) dispersive fish are significantly slower than those that will remain as residents. Conversely, growth rates of dispersive fish are faster than resident fish during the later juvenile and adult stages (Kerr *et al*. 2010). 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).

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.

7.3. State of knowledge in New Zealand

7.3.1. 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. Recent extensive fish-habitat sampling within the harbour in 2010 as part of the FRST Coastal Conservation 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, but their precise role as HPSFM remains to be quantified. Examples include open coast bryozoan fields, 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.

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.

7.3.2. Habitat classification

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, in press). 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).

7.3.3. 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).

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 is being completed in 2011 in collaboration with Oceans Survey 2020, NIWA and Ministry of Science and Innovation (MSI) funding.

A number of other national scale projects are also underway. A risk assessment framework is being developed to assess the effects of fishing and other anthropogenic effects upon coastal fisheries (BEN2007/05). 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). Projects to survey the relative importance of known rig nursery areas and identify threats to these areas are also underway (project ENV2010/05 and SEA 2010/15). These will provide information on the relative importance of harbour nursery areas for this species and aid in the identification of threats to fisheries production that might be mediated through impacts on recruitment. It will also help implement New Zealand's National Plan of Action (NPOA) – Sharks, to strengthen research on shark species.

Two Ministry of Fisheries Biodiversity projects are also underway which will provide baseline information on carbonate sediments and rhodolith beds (ZBD2008/07 and ZBD2009/03). Rhodolith beds have been identified as important nursery areas for commercially harvested species (e.g.

scallops, crabs and atlantic cod) and bivalve broodstock overseas (Kamenos *et al.* 2004, Hall-Spencer *et al.* 2008). The ZBD2009/03 project will characterise the distribution, diversity, growth rates and vulnerability of two rhodolith beds in New Zealand. Carbonate dominated sediments can enhance biodiversity at both the local (Hewitt *et al.* 2005) and regional scales (Ellingsen *et al.* 2007) and appear to contain a high proportion of habitat-dependent species (Thrush *et al.* 2006) The ZBD2008/07 project will quantify shifts in community structure and functional diversity in mollusc dominated habitats along gradients associated with an estuary-coast interface in two locations.

The Ministry of Science and Innovation (MSI) 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. MFish 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.

7.4. Indicators and trends

As no HPSFM are defined this section cannot be completed.

7.5. References

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8. Land-based effects

Scope of chapter	This chapter outlines the main known threats from land-based activities to fisheries and supporting biodiversity. It also describes the present status and trends in land-based impacts.
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	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 heavy metals and nutrients, respectively.
Key issues	Habitat modification, sedimentation, aquaculture, shellfish, sediment runoff, land-use, pollution, nutrients, water quality, contamination, consequences to fisheries 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.
MFish Research (current)	ENV2009/07, TOH2007/03, BEN2007/05, HAB2007/01, ZBD2008/01, ZBD2008/07
NZ Research (current)	Ministry of science and Innovation (MSI) funded programs - Coasts and Oceans OBI (IO3) C01X0501, C01X0305, CO1X0307, CO1X0504, UOCX0902 and C09X0305.
Links to 2030 objectives	Objective 8: Improve RMA fisheries interface.
Related issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring.

8.1. Context

It has been acknowledged for some time now that land-based activities can have important effects on marine and freshwater fisheries. The three main threats to the world's oceans are land-based impacts, fishing and climate change (GESAMP 2001). 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).

Impacts on fisheries from land-based activities, such as sediment runoff or effluent, are controlled by Regional Councils under the Resource Management Act 1991. Fisheries are controlled under the Fisheries Act 1996. Fisheries 2030 is a long-term policy strategy and direction paper of the Ministry of Fisheries. 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' (lead by MfE and MAF) is addressing a range of issues (including water quality) through the development of standards. The ongoing revision of the Coastal Policy Statement (2008) also has relevance to matters of fisheries interest. The Ministry

of Fisheries works with other agencies, principally DOC, MfE and regional councils and through the Natural Resource management Network – to influence these processes to ensure consideration of land-based impacts upon fisheries.
Land-based effects on fisheries and supporting biodiversity in this context are defined as resulting either from the inputs of contaminants from terrestrial sources (e.g., heavy metals, nutrients, sediments) 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., land slides) 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.

The risk from land-based impacts for fisheries 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 Ministry of Fisheries mainly manage marine fisheries, therefore this topic area will be dealt with first. The Ministry of fisheries also manages the freshwater eel fishery; this will be dealt with latterly within relevant sections.

8.2. Global understanding

The two main classes of land-based threats are physical alterations and pollutants. The coastal zone is increasingly affected by physical alterations of habitats and/or the hydrodynamic environment, such as reclamation, flood gates, seawalls, dredging and dredge spoil disposal. Anthropogenic contaminants and hydrodynamic alterations affect some of the most productive areas of the marine environment, including estuaries and near-shore coastal waters.

8.2.1. Stressors

The importance of different land-based stressors differs 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). A stressor is defined (after (Thrush *et al.* 2008)) as:

> *"a factor that impacts on the fitness of individuals; species abundance distributions across natural landscapes may be affected simultaneously by a number of anthropogenic and natural stressors. These stressors may not simply act in additive ways; rather multiplicative interactions occur either increasing (synergistic) or dampening (antagonistic) the effects of stressors. "*

Stressors, including land-based stressors, 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 stressors 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 stressors (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 stressors are rare.

Sediment deposition can be an important stressor, 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, Glibert *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[14], 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[15]. 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 stressors 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 stressors 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.

8.2.2. 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, Hanson *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).

[14] Accessible on the www.os2020.org.nz website.
[15] 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

8.3. 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 stressor. 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). 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, Hobday *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). 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.

8.3.1. Completed research

A Ministry of Fisheries funded project (IPA2007/07) has reviewed the impacts of land based stressors 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. Eutrophication was also identified as a potential threat from experience overseas. The negative impacts of sediment include decreasing efficiency of filter-feeding shellfish (such as cockles, pipi, and scallops), reduced settlement success and survival of larval and juvenile phases (e.g., paua, kina), and reductions in the foraging abilities of finfish (e.g., juvenile snapper). Indirect effects include the modification or loss of important nursery habitats, particularly biogenic habitats (green-lipped and horse mussel beds, seagrass meadows, bryozoan and tubeworm mounds, sponge gardens, kelps/seaweeds, and a range of other structurally complex species). Inshore filter-feeding bivalves and biogenic habitats were identified as the most likely to be adversely affected by sedimentation.

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 stressors in areas relevant to fisheries in New Zealand have been addressed by two 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).

Toheroa populations do not sustain any recreational or commercial harvesting but have failed to recover 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.

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, 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 stressors:

- 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 stressors 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 stressors on coastal marine ecosystems.

In addition there are a number of other areas of uncertainty. The locations where addressing land-based impacts is likely to result in a lowering in risk to the fishery or increased fisheries production, excluding those already mentioned, are unsure. A national view of the impacts of land-based stressors upon fisheries does not exist, this could be facilitated by better coordination and planning of the many disparate marine monitoring programs running around the country. This improved coordination and planning of marine monitoring has already been achieved in some places, e.g., the United Kingdom[16]. Possible national scale proxies for coastal faecal contamination may exist from either coastal bathing beach quality or shellfish harvesting closure information, but the utility of these for fisheries purposes is presently unclear.

8.3.2. Current research

A number of ongoing research projects exist that will improve the knowledge of land-based impacts upon fisheries. 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 stressors 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. Two Ministry of Fisheries biodiversity projects also have components that address land-based effects. The threats to biogenic habitats are addressed in project ZBD2008/01 and changes to the growth rates of key carbonate producing species in response to land-derived sediments are investigated in project ZBD2008/07.

Research is also ongoing on land-use effects at a national scale. Information on threats is being collated and a framework developed to allow for all anthropogenic threats to coastal areas to be considered together (project BEN2007/05). A semi-quantitative expert knowledge approach is being used to assess the relative impacts of threats, and their interactions, on specific habitats based on Halpern, Selkoe *et al.* (2007). A national scale threat analysis is also being carried out for biogenic habitats, given their likely importance for fisheries management (project HAB2007/01).
A number of Ministry of Science and Innovation (MSI) funded projects[17] of particular relevance are (project number and lead agencies in brackets):

- Ecosystem-based management of New Zealand's coastal and oceanic waters (C01X0501, NIWA). This research aims to provide knowledge of marine ecosystem function, dynamics and resilience as the basis of an ecosystem-based approach to management of resources within New Zealand’s coastal and oceanic waters

- Restoration of aquatic ecosystems (C01X0305, NIWA). This research aims to increase the knowledge base and tools for restoration of degraded streams, rivers, lakes and estuaries

- Effects-based protection and management of aquatic ecosystems (C01X0307, NIWA). This research aims to develop tools for managing effects of contaminants (sediments, nutrients, chemical pollutants, faecal microbes) in freshwater and estuarine ecosystems associated with landuse intensification and change

[16] http://www.cefas.co.uk/data/marine-monitoring/national-marine-monitoring-programme-(nmmp).aspx
[17] www.frst.govt.nz

- Estuarine ecodiagnostics (C01X0504, NIWA). This research aims to establish the resilience of estuarine environments to contamination, and decision points for management options to prevent further decline in ecosystem integrity and/or restoration.

- 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"). This will be achieved by monitoring the effects of diverting all of Christchurch's treated wastewater discharge from the eutrophied Avon-Heathcote (Ihutai) Estuary.

- Integrated catchment management (C09X0305, Landcare). The research aims to conduct multi-disciplinary, multi-stakeholder research to provide information and knowledge that will improve the management of land, freshwater, and near-coastal environments in catchments with multiple, interacting, and potentially conflicting land uses.

8.4. *Indicators and trends*

A national view of water quality, and its application to fisheries, is difficult to extract from the diverse data sources available. 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. The quality, availability and comparability of this data is likely to be variable, although some national protocols do exist (Robertson *et al.* 2002) and have been adopted for more than 40 estuaries (P. Gillespie pers. comm.). 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[18],or summary reports such as the Hauraki Gulf state of the Environment 2004 report[19]. 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.

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[20]. 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

[18] http://maps.auckland.govt.nz/aucklandregionviewer/?widgets=HYDROTEL
[19] http://www.arc.govt.nz/environment/coastal-and-marine/hauraki-gulf-forum/hauraki-gulf-state-of-the-environment-report.cfm
[20] 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). This is an underestimate because streams with catchments less than $10km^2$ were excluded from this calculation. The main sources of Nitrogen and Phosphorous were from pastoralism (70%) and erosion (53%). The dairy herd in New Zealand has doubled since 1979 (whilst other grazer numbers have been stable or declining)[21]. The amount of Urea and Superphosphate (New Zealand's most common nitrogen and phosphorous fertiliser) have increased more than twenty fold and two fold over the same period[22]. Dairying is the single largest user of Urea (65% of the total) and Superphosphate (35% of the total) in the country[23]. 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 (from mammalian 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 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)[24]. 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[25]. Certain fisheries now are in practice limited not by the TACC but 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 and 96 days for the 2006-7, 2007-8, 2008-9 and 2009-10 fishing years, respectively due to sewage spills[26].

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[21] www.stats.govt.nz
[22] http://www.maf.govt.nz/statistics/fertiliser/
[23] www.stats.govt.nz
[24] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.
[25] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.
[26] Statistics supplied by New Zealand Food Safety Authority in Whangarei.

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THEME 5: MARINE BIODIVERSITY

9. Biodiversity

Scope of chapter	Provide an overview of the MFish Biodiversity Programme and address: National and global context of NZ marine biodiversity research; Research findings and progress of the Ministry of Fisheries Biodiversity Research Programme from 2000–2010; 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 2007)
Area covered	New Zealand Territorial Seas, EEZ and Continental shelf extension (BioInfo); Antarctic Ross Sea region (BioRoss)
Focal localities	New Zealand waters have globally significant levels of marine biodiversity, particularly coastal habitats, offshore island habitats and underwater topographical features such as seamounts. With the exception of shallow sea ice impacted coastal habitats, these features apply also to the Ross Sea region"
Key progress	• The estimated proportion of known marine biodiversity classified as endemic to New Zealand is high (44%). Approximately 17,000 marine taxa have been recorded in NZ waters and it is estimated that a similar number remain undiscovered • Significant progress has been made with mapping of biodiversity and habitats, and evaluation of risk from stressors has begun. • Biodiversity and its functional role is a component of an ecosystem approach to fisheries management
Emerging issues	• The cumulative effects of ocean climate change and other anthropogenic stressors on biodiversity and aquatic ecosystems (structure and function) are likely to be complex, large and negative. • The nature and role of marine microbial biodiversity in large scale biogeochemical and ecosystem processes. • Genetic and life-history stage connectivity between and within large scale habitats may be important to the size and placement of protection zones. • Long-term trends of change in the marine environment (including biodiversity) are not available at a national scale. • The effectiveness of current protection measures in safeguarding marine biodiversity and aquatic ecosystem health in NZ and Ross Sea region are unknown – metrics for assessing effectiveness are needed. • 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 to the CBD Aichi-Nagoya Agreement.
MFish Research (current)	53 biodiversity projects commissioned over the period 2000-10; 2 more in pipeline. Currently in 3rd 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. MFish biodiversity research has strong synergies with marine research funded by MFish Aquatic and Environment Working Group (AEWG), Ministry of Science and Innovation (MSI), Department of Conservation (DoC), Land Information New Zealand (LINZ), MAFBiosecurity

	(MAFBNZ), Ministry for the Environment (MfE)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, national Institute of water and Atmospheric Research (NIWA) and Cawthron Institute. MSI programmes include Coasts & Oceans OBI (IO3) C01X0501, Marine Biodiversity & Biosecurity OBI (IO1) C01X0502, Coastal Conservation Management C01X0907, Impacts of resource use on vulnerable deep-sea communities C01X0906; DoC, MFish, NIWA and Landcare Research - NZ Organisms Register.
Links to Fisheries 2030	Environmental Outcome Objective 1; environmental principles of Fisheries 2030 including listed principles: Ecosystem-based approach, Conserve biodiversity: Environmental bottom lines, Precautionary approach, Responsible international citizen, Inter-generational equity, Best available information, Respect rights and interests (MFish 2009).
Related issues	Land sea interface; marine monitoring, cumulative effects of extraction in the marine environment, protected areas.

9.1. Context

This chapter reviews the MFish Biodiversity Programme 2000-2010 in the context of global and national concerns about biodiversity, as identified by the New Zealand Biodiversity Strategy (NZBS, Anon 2000).

Biodiversity was defined by the NZBS 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; this includes diversity within species, between species and of ecosystems. 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."*

The biodiversity website http://www.biodiversity.govt.nz amplifies further on 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.*

Marine biodiversity decline is characterised not only by extinctions, but by invasions and hybridisations, populations of species reduced in number, habitats that have been diminished or removed, and ecosystem processes (e.g. biological cycling of water, nutrients and energy) that have been disrupted. When considering human impacts on marine biodiversity it should be kept in mind that we are often looking at marine biodiversity that is already altered. The 'shifting baseline syndrome' is a common obstacle to useful biodiversity assessment and monitoring[27]. Furthermore the organism size range we sample is often 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.

New Zealand's ocean territory (including territorial sea and the recent continental shelf extension[28]) is very large relative to the area of land[29] and includes some 15-18,000 kilometres of coastline extending from the sub-tropical north to the cool Subantarctic 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[30]).

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 regions size, the depth range, geomorphological and hydrological complexity as well as limited water column sampling and limited benthic sampling, especially below 1500 metres. If we also take into account recent indications of massive oceanic microbial diversity (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, such as fishing, aquaculture, shipping, petroleum and mineral extraction, renewable energy, tourism and recreation. Impacts from changing land use, including agricultural, urban run-off and coastal development also continue. The potential loss of marine biodiversity and possible functionality caused by climate change and ocean acidification are of increasing concern worldwide. The growing arrival of non-indigenous (sometimes invasive) marine species is also a threat to local biodiversity (e.g., Coutts and Dodgshun 2003, Cranfield *et al.* 2003, Gould *et al.* 2008 Russel *et al.* 2008, Williams *et al.* 2008).

Knowledge about New Zealand's coastal marine environment and its land-sea interactions has progressed although understanding about the state of the marine environment and marine biodiversity on a national scale remains limited. This is true also for the Ross Sea region. 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 come to the threats we face (Costello *et al.* 2010) and the nature of their impacts. There are significant concerns with decline in some key species (MfE 2007), localised impacts on habitats and conditions (Thrush and Dayton 2002, Cryer *et al.* 2002, Clark *et al.* 2010a. Gordon *et al.* 2010) and emerging threats to the marine environment (MacDiarmid in press) 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.

New Zealanders increasingly value environmental, economic and social aspects of marine biodiversity and the ecosystem services that a healthy marine environment provides, although public

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[27] 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

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

[29] NZ sea area is ~5.8 million km^2 including TS, EEZ and continental shelf extension; 4th largest in the world; www.linz.govt.**nz**

[30] MacDiarmid, A (ed) 2007. The Treasures of the Sea: Nga Taonga. A Summary of the Biodiversity of the New Zealand Marine Ecoregion. WWF-New Zealand, Wellington.

awareness appears to be low. 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.[31] [32] A broad range of legislation, regulations and policies are in place to manage and regulate uses of the marine environment, to protect marine biodiversity and to improve management of the marine environment. However, progress on an integrating oceans policy reform has been slow compared with Canada, the UK, the USA and Australia (Peart *et al.* 2011).

9.1.1. Halting the decline in biodiversity

In June 2000, the '*New Zealand Biodiversity Strategy– Our Chance to Turn the Tide'* (*NZBS*) with the over-arching objectives "to halt the decline of biodiversity in New Zealand and protect and enhance the environment" was launched as part of New Zealand's commitment to the international Convention on Biological Diversity 1993 (Anon 2000). To meet long-term goals of the NZBS, a comprehensive plan, with stated objectives and actions[33], 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."

Responsibility for addressing Theme 3 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 (MFish)[34].

9.1.2. Implementation of the NZBS

A number of initiatives are underway to meet the challenges of meeting the goals of the NZBS. Commitments by MFish include the creation of NABIS (the National Aquatic Biodiversity Information System)[35], the administration of the MFish Biodiversity Research Programme, convening and chairing the Biodiversity Research Advisory Group[36], and developing a Marine Protected Area policy with DOC. DOC also surveys and monitors aspects of marine biodiversity, particularly in marine reserves[37]. MfE has encouraged Regional Councils to develop coastal monitoring programmes

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[31] 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

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

[33] The New Zealand Biodiversity Strategy with its stated goals, objectives and actions can be viewed at http://www.biodiversity.govt.nz

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

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

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

37 www.doc.govt.nz

and with MFish and DOC, initiated an approach to Marine Environmental Classification[38]. Biodiversity related research has also been carried out through MAFBNZ's Biosecurity Science Strategy. One result includes mapping and valuation of marine biodiversity around New Zealand's coastline[39].

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 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 Wellington (Te Papa) also conduct biodiversity sampling expeditions and national collections of specimens have been set up within Museums and also at NIWA.

9.1.3. New challenges and demands

In July 2009, the Minister of Science set a new overarching goal for research science and technology[40]:

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

The biological economy of the sea (largely fisheries and aquaculture) 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 (MFish 2009[41]). 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[42]) 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, but 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, recreational fisheries, aquaculture, hydrocarbon and mineral extraction) remain. Scientific research has provided information about the 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. We know quite a lot about the structure and function of biodiversity of macro-organisms within some New Zealand and Ross Sea marine ecosystems but we do not yet know the areas at greatest risk and so far, are unable to determine how much of the marine ecosystem should be or can be protected to maintain a healthy aquatic environment. There is growing awareness of the likely importance of the huge diversity, biomass and species mix of micro-organisms, nanno- and picno-plankton, and is a fast developing field of research. The response and resilience of biodiversity of all size scales to the cumulative effect of multiple stressors across large spatial scales (e.g. acidification, temperature increase and oxygen depletion), particularly as utilisation of marine resources increases, remain largely unquantified.

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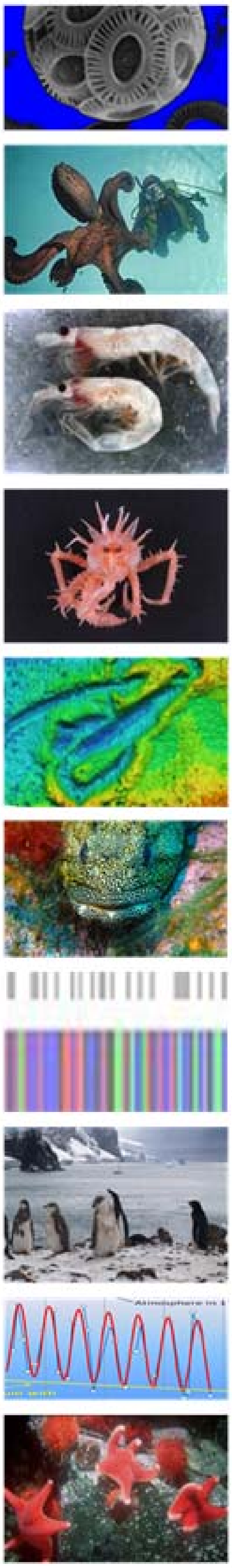
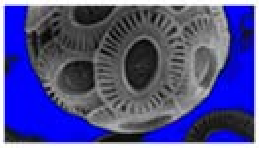
[38] www.mfe.govt.nz/issues/biodiversity/initiatives/marine.html#regional
[39] www.biosecurity.govt.nz/biosec/research
[40] MoRST feedback document on New Zealand's research science and technology: www.morst.govt.nz/Documents/publications/policy
[41] MFish (2009). Fisheries 2030 report. New Zealanders maximising benefits from the use of fisheries within environmental limits available from http://www.fish.govt.nz/en-nz/Fisheries+2030/default.htm
[42] Marine Stewardship Council www.msc.org



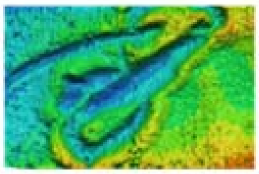
BIODIVERSITY THEMES	KEY QUESTIONS
BIODIVERSITY PATTERNS & DISTRIBUTION • Fauna and flora (taxonomy, biosystematics) • Distribution & abundance of major groups • Reviews of existing knowledge • Biogeography • Drivers of observed patterns	• What is the abundance and distribution of marine biodiversity 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	• 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	• 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?

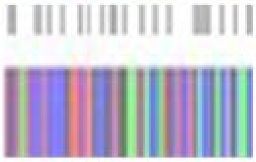
Figure 9.1: Summary of Ministry of Fisheries Biodiversity Research Programme 2000–2010.

ACHIEVEMENTS & KNOWLEDGE TO DATE	CURRENT WORK
• Taxonomy of coralline algae/ID Guide • Taxonomy of bryozoans (ID Guide) • New species from surveys added to 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	• Bryozoan ID Guide • Taxonomic ID from major surveys-all major phyla • New species catalogued in National Invertebrate Collection
• Ecological input to improve MEC (fish, benthic invertebrates) • Extensive new data sets and specimen collections obtained • Deep-sea habitats reviewed • Soft-sediment reviewed • Biogenic habitat 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	• Rhodolith beds as havens of biodiversity in NZ • Mapping biogenic structures • Testing of MEC with Chatham Challenger data
• Rocky reef ecosystem function studied • Functionality & connectivity of sea grass habitat 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	• Ocean acidification on shellfish • Response and recovery of seabed to disturbance-modelling project • Shellhash habitat function in the coastal zone
• Molecular ID of certain fish and plankton determined • EEZ and Ross Sea species 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	• Test of Chatham-Challenger results against MEC • Predictive modelling VMEs • Measuring risk and resilience (Chat-Chall objective) • Modelling benthic impacts
• 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









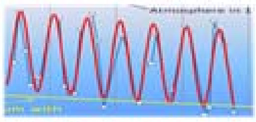



Figure 9.1 *Continued*: Summary of Ministry of Fisheries Biodiversity Research Programme 2000–2010.

9.1.4. Ministry of Fisheries response

The Ministry of Fisheries recognises the increasing societal expectation to use fisheries management measures that will achieve biodiversity conservation has signalled through Fisheries 2030[43] a 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 record 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 especially true of the need to better understand and mitigate the effects of fishing on the areas impacted by fishing.The effects of fishing on the aquatic environment and risks to biodiversity and marine ecosystems are recognised in Fisheries Plans. Research continues to be supported through the Deepwater Research Plan, as well as the Aquatic Environment and Biodiversity Research Programmes.

There are also a range of societal values beyond commercial, customary and recreational take from the sea that are recognised as part of "strengthening our society (see footnote 12). These include aesthetic and cultural values as well as other economic values such as tourism and marine recreation other than fishing[44]. To link socio-economic values of biodiversity to science supporting fisheries management will require a multi-disciplinary approach not yet taken in New Zealand.

MFish responded to the NZBS in 2000 with the establishment of the MFish Biodiversity Programme which has run successfully for more than 10 years with 53 research projects and a large number of published outputs, presentations and contributions to NZ and CAMLR management measures. Over this period, as other strategic MFish (and other departments) documents have been developed, the Biodiversity Programme has evolved new directions (MFish (2010) Part 2. Biodiversity Medium Term Research Plan). An overview of the Biodiversity Programme at a glance is given in Figure 9.1.

The Ministry of Fisheries also manages a *Biodiversity Strategy* research programme focused on the Ross Sea region of Antarctica. The importance of Antarctica and the Southern Ocean to New Zealand is widely acknowledged, and is clearly defined in New Zealand's Statement of Strategic Interest in Antarctica, last revised in 2002.

The Ministry is 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. MFish 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 MFish Antarctic 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 MFish Antarctic Working Group research and with other Ross Sea ecosystems research funded under the MSI Coasts and Oceans OBI C01X501 (e.g., Sharp *et al.* 2010).
As a result of more recent directives and policy initiatives, the MFish Biodiversity Programme is now undergoing realignment in response to the Government's economic directive for science, Fisheries 2030, Fish Plan objectives, the merger with the Ministry of Agriculture and Forestry (MAF), the NZ Coastal Policy Statement[45], the National Policy Statement on Indigenous Biodiversity[46], and emerging research initiatives across government and internationally. The Objectives of the programme will therefore be updated where necessary to reflect these changes.

[43] Fisheries 2030 The full document can be downloaded from www.fish.govt.nz/en-nz/Fisheries+2030
[44] MARBEF: The Valencia Declaration 2008 www.marbef.org/worldconference
[45] www.doc.govt.nz/publications/conservation/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/policy-11-indigenous-biological-diversity/
[46] www.mfe.govt.nz/publications/biodiversity/indigenous-biodiversity/index.html

9.2. *Global understanding*

This consideration of the MFish Biodiversity Programme includes the global responses to concerns about biodiversity and NZ's international obligations. 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[47].

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[48]. 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[49].

9.2.1. 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

[47] UNEP's work to promote environmental sustainability, the object of Millenium Development Goal 7, underpins global efforts to acheive all of the Goals agreed by world leaders at the Millennium Summit http://www.unep.org/MDGs/

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

[49] 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/

Targets 6-11 specifically refer to fisheries and marine ecosystems and are provided in Appendix 1 to 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."[50]

9.2.2. Global marine assessment

The biological diversity of the 72% of the planet covered by seawater is crucial to global resource security, ecosystem function and climate dynamics. The Marine Biodiversity Outlook Reports and Summaries prepared by UNEP's Regional Seas Programme for the 10th Conference of Parties of the Convention on Biological Diversity (CBD) held in 2010 provide the first systematic overview at a sub-global scale of the state of knowledge of marine biodiversity, the pressures it faces currently and the management frameworks in place for addressing those pressures[51].

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 impacts of fishing. These pressures are serious and 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.

9.2.3. Ocean climate change and 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 at 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

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

[51] UNEP (2003) Global Marine Assessments: a survey of global and regional marine environmental assessments and related scientific activities. UNEP-WCMC/UNEP/UNESCO-IOC. 132p available online at www.unep-wcmc.org/resources/publications/ss1/GMA_Review.pdf

Reef Marine Park Authority (2009) 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 adversely 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 [52]". 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[53]. The Working Group I and Working Group II Contributions to the Fifth Assessment Report include chapters on the ocean (WG I) and Climate Change 2014: Impacts, Adaptation, and Vulnerability including Chapters on Coastal and Oceans ecosystems, and sections on biodiversity(WGII). Working Group I 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 9.2). 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 [54].

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

[52] 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?’
[53] http://www.global-greenhouse-warming.com/IPCC-5th-Report.html
[54] www.marinehub.org/

available at the website[55]. 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[56].

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 9.2: 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.

In late June 2011, two newly released science-based reports heighten 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 and Pinnegar 2011) and the other assesses the critical state of the world's oceans in relation to climate change and other stressors (Rogers and Laffoley (2011).

[55] www.marinehub.org/
[56] arnmbr.org/content/index.php/site/aboutus/

9.2.4. Census of Marine Life 2000–2010

In 2010, the international initiative to conduct a Census of Marine Life[57] was concluded after ten years of accessing and databasing existing records, sampling and exploration around the globe. The Census is 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 2,700 scientists involved in the Census have mounted 540 expeditions, identified more than 6,000 potentially new species, catalogued upward of 31 million distribution records, and generated 2,600 scientific publications. New Zealand led CenSEAM[58], the seamount component of the Census of Marine Life, and played significant roles in a number of other programmes.

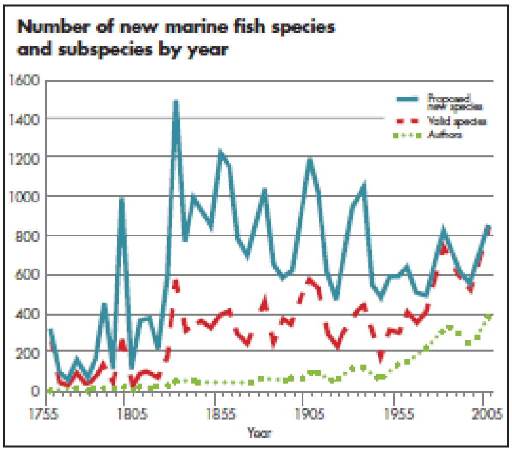


Figure 9.3: Number of new species officially recorded since 1755. Blue line number of proposed species, red dotted line number of valid species, green dotted line number of authors. (Image Source Ausubel *et al.* 2010.)

The Census upped the estimate of known marine species from about 800 in 2005(Figure 9.3) to nearly 250,000 by 2010. Among the millions of specimens collected in both familiar and seldom-explored waters, the Census found more than 6,000 potentially new species and completed formal descriptions of more than 1,200 of them. It found that some rare species are common. 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[59].

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, painting a new picture of the genetic structure of marine diversity. With the genetic analysis often called barcoding, the Census sometimes decreased diversity but generally its analyses expanded the number of species, especially the number of different microbes, including bacteria and archaea.

The Census has overwhelmingly demonstrated that the total number of species in the ocean remain largely unknown. The Census also demonstrated that evidence of human impacts on the oceans extends to all depths and habitats and that we still have much to learn to integrate use of resources with stewardship of a healthy marine ecosystem. The Census results could logically extrapolate to at least a million kinds of eukaryotic marine life that earn the rank of species and to tens or even hundreds of millions of kinds of microbes.

[57] www.coml.org/results-publications
[58] www.coml.org/global-census-marine-life-seamounts-censeam
[59] www.eol.org/

A summary of the overall state of knowledge about marine biodiversity by Costello *et al.* (2010) places New Zealand 6th out of 18 national regions (Figure 9.4).

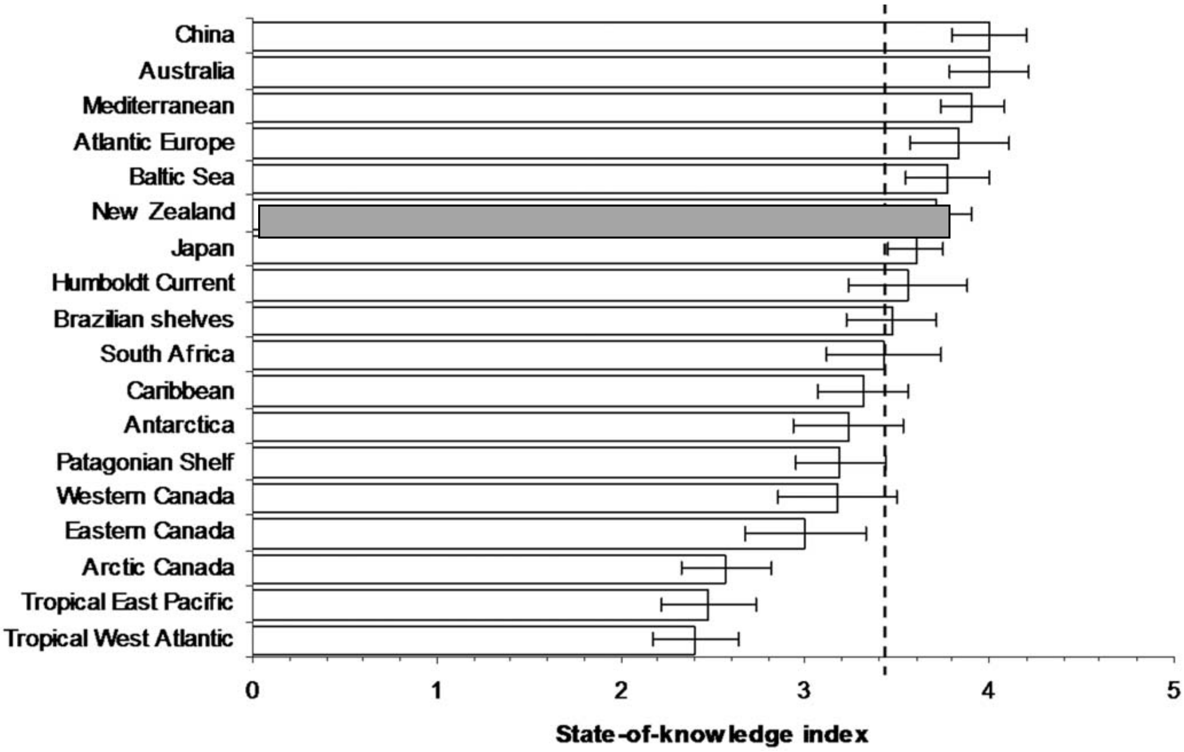


Figure 9.4: The regions are ranked by their state-of-knowledge index (mean ± standard error) across taxa. Dashed line represents the overall mean. (Image Source Costello *et al.* 2010).

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).

9.2.5. Global monitoring and indicators for marine biodiversity

There are numerous schemes within and between nations to monitor the marine environment, including physical, chemical and biological components. Marine biodiversity indicators have been developed for the UK and the EU[60]. 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[61]) which stimulates, encourages, coordinates and otherwise facilitates observations by national or international organizations. A Southern Ocean Observing System (SOOS) is under development[62]

Others include:

- ARGOS an international deepwater monitoring system of free floating buoys that are part of the integrated global observation strategy[63].
- The Ocean Observation Systems (OOS) in Canada have demonstrated many positive benefits.

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[60] http://jncc.defra.gov.uk/page-4233
[61] www.ioc-goos.org/index.php?option=com_content&view=article&id=12&Itemid=26&lang=en
[62] http://www.scar.org/soos/
[63] http://www.qc.dfo-mpo.gc.ca/publications/science/evaluation-assessment-eng.asp.

- 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[64]. 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[65].
- 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[66].
- 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[67]) which coordinates long-term marine biodiversity monitoring at a European level.

Oceans 2025[68] 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 MFish and New Zealand researchers is whether or 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.

9.2.6. Economic valuation of biodiversity

The Economics of Ecosystems and Biodiversity (TEEB 2010)[69] and the concept of natural capital are gaining traction internationally. Long overlooked and difficult to capture, methods to evaluate the benefits of ecosystem goods and services (including biodiversity) and to identify the costs of not managing aquatic ecosystems sustainably are emerging.

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 NZ 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. 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.

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)[70] demonstrates the application of economic

[64] www.sahfos.ac.uk/
[65] www.sahfos.ac.uk/sister-survey/sister-surveys/-southern-ocean-continuous-plankton-recorder-survey-(scar).aspx
[66] http://www.mba.ac.uk/MECN/
[67] http://www.marbef.org/
[68] http://www.oceans2025.org/
[69] TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.
[70] 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/

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.

9.3. State of knowledge in New Zealand

The past 200 years of human activity have impacted on marine environments, not just near population centres, but also in the most remote areas and to depths in excess of 1000 metres. In some cases by looking back to 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.

Current trends in the status of New Zealand's marine biodiversity are difficult to determine for several reasons, which 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. Despite this, observations of significant decline in some marine species in some areas indicates that there is a continuing decline occurring in New Zealand's marine biodiversity and ecosystems.

The most recent State of the Environment Report in New Zealand (MfE 2007) covers terrestrial and freshwater organisms in its Biodiversity section[71]. Comment on marine biodiversity is provided 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 that hinder management identified by MfE 2007 are:

- sparse biodiversity baseline information for management areas; 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 *et al.* (2010). They report that there are 17,135 living species in the EEZ, including 4,315 known undescribed species in collections. Species diversity for the most intensively studied phylum-level taxa (Porifera, 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 NZ region biodiversity is richer than the ERMS region (Figure 9.5).

[71] *State of the Environment* MfE 2007.

Taxonomic group	No. Species[1]	State of knowledge	No. Introduced species	No. Experts	No. ID guides[2]
Domain Archaea	0	1	0	1	0
Domain Bacteria[3] (including Cyanobacteria)	**109**	**3**	**0**	**3**	**1**
Domain Eukarya[3]	**17,026**	**3-4**	**159**	**58**	**75**
Kingdom Chromista[3]	**860**	**3-4**	**11**	**7**	**2**
Phaeophyta	153	4-5	11	1	1
Kingdom Plantae[3]	**668**	**4-5**	**12**	**12**	**3**
Chlorophyta	142	3-4	0	12	1
Rhodophyta	520	3-4	12	0	1
Angiospermae	6	5	0	3	2
Kingdom Protozoa[3]	**1,628**	**2-3**	**4**	**5**	**4**
Dinoflagella	241	3-4	0	2	0
Foraminifera	1,076	4-5	3	2	2
Kingdom Animalia[3]	**13,813**	**3-4**	**150**	**40**	**66**
Porifera	1,435	3	7	1	4
Cnidaria	1,116	4	23	0	6
Platyhelminthes	324	2	2	1	1
Mollusca	3,593	4	14	1	3
Annelida	791	4	32	1	2
Crustacea	2,573	3-4	27	13	17
Bryozoa	953	4	24	1	4
Echinidermata	623	5	0	3	6
Tunicata	192	5	0	3	6
Other invertebrates	646	2-5	3	7	12
Vertebrata (Pisces)	1,387	4-5	6	6	7
Other vertebrates	179	5	0	4	4
TOTAL REGIONAL DIVERSITY[3]	**17,135**	**3-4**	**177**	**62**	**76**
[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 as reported in Table S1. Gordon *et al.* 2010					

Figure 9.5: Diversity of marine species found in the New Zealand region (after Gordon *et al.* 2010).

9.3.1. The MFish Biodiversity Research Programme

The biodiversity research programme set up under the NZBS was established with a multi-stakeholder biodiversity research advisory group (BRAG), chaired by the Ministry of Fisheries. 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, MFish 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 in found the review of the NZBS in 2005.

The MFish 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.

Science Objectives developed below have been modified by BRAG over time and 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, 53 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 100s km^2 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 long-term climate change and its effects 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.

9.3.2. Overall progress in marine biodiversity research

Progress in the MFish Biodiversity Programme (as driven by the science objectives 2000–2010) is summarised in Figure 9.6. 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 MFish Biodiversity Medium Term research programme 2010-2014.

Progression of research understanding	***Science objective*** [†]	***Estuarine/ Coastal 0-30 m***	***Shelf 30-200 m***	***Slope 200-1500 m***	***Deep/Abyss >1500 m***	***Antarctica All depths***
1. Review extent of knowledge of biodiversity (desktop)	1-7					
2. Identify & characterise species and habitat diversity (field work, qualitative analysis, taxonomy & systematics)	1					
3. Quantify biodiversity distribution, abundance (replication, purpose designed surveys)	1					
4. Model and predict biodiversity distribution and abundance	1					
5. Assess or measure functional processes in healthy marine ecosystems (experiments, process studies)	2, 3					
6. Assess the role of genetic diversity	4					
7. Assess interactions and connectivity on ecosystem scale, (genetics, modelling)	2, 5					
8. Develop indicators and measures to monitor bio-diversity, ecosystem health	6					
9. Define key risks and threats to biodiversity	5, 7					
10. Define standards for maintaining biodiversity and healthy ecosystem functioning	6					
11. Examine strategies to mitigate remedy or avoid threats to biodiversity	6					
12. Monitor risks and compliance with standards	6					

Figure 9.6. Progress on biodiversity research commissioned by MFish* 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 MFish (e.g. FRST (MSI) funded Outcome Based Investment projects, DOC Marine Coastal Services, MAFBNZ marine biosecurity research).

[†] *Science objectives are1 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 Ministry of Fisheries Biodiversity Programme: Part 2. Medium Term Research Plan 2011-2014.*

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 in Antarctica lags behind EEZ-based research, simply because of the difficulty in securing additional funding to access and work in such a remote 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.

9.3.3. Progress on Science Objective 1. Characterisation and Classification of Biodiversity

The characterisation and classification of biodiversity requires an assessment of the abundance and distribution of marine life. Building on earlier research to map fish and squid species (Anderson *et al*. 1998, Bagley *et al*. 2000) and the biodiversity of the New Zealand WWF 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 and Fenwick 2001, 2002; Fenwick and Bradford-Grieve 2002a, 2002b, Varian 2005)
> ZBD2000-06 "The Living Reef: The Ecology of New Zealand's Rocky Reefs" (eds. Andrew and Francis 2003)
> ZBD2000-08 A review of current knowledge describing New Zealand's Deepwater Benthic Biodiversity (Key 2002),
> ZBD2000-09 Antarctic fish taxonomy (Roberts and Stewart 2001)
> ZBD2001-02 Documentation of New Zealand Seaweed (Nelson *et al.* 2002)
> ZBD2001-04 "Deep Sea 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.* 2007)
> ZBD2003-09 Macquarie Ridge Complex Research Review (Grayling 2004)
> ZBD2008-27 Scoping investigation into New Zealand abyss and trench biodiversity (Loerz *et al.* in press).

In addition a major work which includes marine species – "The New Zealand Inventory of Biodiversity" (Gordon 2009, Gordon in press), is nearing completion. Field identification guides have also been published by MFish on deepsea invertebrates (–projects ENV2005-20 Tracey *et al.* 2005, 2007, Clark *et al*. 2009, Williams *et al.* 2010), bryozoans (project IPA2009/14 Smith and Gordon 2011) and on fish species (IDG2006-01 MacMillan *et al.* in press (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 and Roberts 2008); MSI's Seamount Programme, mainly commissioned through public-good science, supplemented by MFish projects ZBD2000-04, e.g., Rowden *et al.* 2002 and 2003, ZBD2001-10 (Rowden et. al 2004), ZBD2004-01 (Rowden *et al.* 2010) and MFish projects ENV2005-15, ENV2005-16 (Clark *et al.* 2010, Rowden *et al.* 2008); 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 ZBD2004-07 (Farr *et al.* 2009); 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.* in press; Hewitt *et al.* in press; Bowden *et al*. 2011a, Bowden and Hewitt in press; 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 MFish 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, 2006), ZBD2003-03 (Rowden *et al*. in press), ZBD2005-03 (MacDiarmid and Stewart in press), ZBD2006-03 (Cummings *et al.* 2003, 2006; Norkko *et al.* 2002) and IPY2007-01 (Bowden *et al.* in press, Clark *et al.* 2010, Eakin *et al.* 2009, Hanchet, *et al.* 2008a Hanchet 2008b, Hanchet 2008c, Hanchet *et al.* 2008d. Hanchet 2009, Hanchet 2010, Koubbi *et al.* in press, Loerz and Coleman 2009, Loerz in press, Loerz *et al.* in press, Mitchell 2008, O'Driscoll *et al.* 2009. O'Driscoll 2009, O'Driscoll, *et al.* 2010, O'Loughlin *et al.* 2010)

Habitat diversity, classification and characterisation

The development of the Marine Environment Classification or "MEC" (Snelder *et al*. 2004) 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 and ecological characterisation were absent from the classification. In 2005, DOC and MFish 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. MFish project (BEN2006-01) has further improved the fish optimised MEC to produce the Benthic Optimised MEC. Ecological studies to improve habitat classification and vulnerability indices have also been completed through MFish AEWG projects on seamounts (ENV2005-15, ENV2005-16) and to supplement other studies funded by MFish, 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.* in press; the fish optimised MEC in project ZBD2005-02 (Leathwick *et al.* 2006a, 2006b, 2006c), the benthic optimised MEC (Leathwick *et al.* 2010) and Chatham-Challenger project ZBD2007-01 (Hewitt *et al*. in press, Bowden *et al.* in press).

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, MFish implemented spatial management tools (Benthic Protection Areas[72]) implemented on the basis of the Marine Environment Classification[73] [74] 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 is drawing to its conclusion. 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 6).

[72] www.fish.govt.nz/en-nz/Environmental/Seabed+Protection+and+Research/Benthic+Protection+Areas.htm
[73] Marine Environmental Classification. (2005). Can be viewed online at http://www.mfe.govt.nz/publications/ser/marine-environment-classification-jun05/index.html
[74] http://seafoodindustry.co.nz/bpa and use of MEC (2005)

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 FRST-Otago University]. Completed
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. (Bowden 2011a).
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 2011a).
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. AEBR in press.
6. To calculate and compare the performance of a suite of diversity measures (species and taxonomic based) at varying levels of resolution. Completed. AEBR in press.
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 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 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 and Hewitt 2010.
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 press.
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.* in press).
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. Underway in conjunction with Bay of Islands Ocean Survey 20/20 Portal[75].
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 review.
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*. 2011.
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 and Hewitt (in press).

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

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 will be analysed relative to these environmental variables.

ZBD2008-50 Chatham Rise biodiversity hotspots.

This survey was linked to CenSeam and the FRST Seamounts project, now under the MSI Vulnerable deep-sea communities. The data from that survey are being worked up under the latter project(see Clark *et al.* 2009).

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.

This programme seeks to improve knowledge about the location, extent or ecosystem functioning of rhodolith beds in New Zealand. As a result of this study, understanding growth rates of rhodoliths and the impacts of disturbance on them will facilitate evaluation of the risks to these habitats, and provide resource managers with support in prioritising environmental protection measures.

This 2.5 year project is at the half-way point. To date, both of the two planned field trips have been successfully completed (February and September 2010), achieving the collection of biological samples of macroalgae, macroinvertebrates, and fishes, as well as sampling for sediment, light, temperature, and other physical parameters. Mapping of the beds was carried out successfully during September 2010 fieldwork.

The two field sites chosen, both in the Bay of Islands and identified during previous studies (OS2020 Bay of Islands survey; ZBD2004-07), comprise a "clean" site with abundant associated macroalgal cover, and a "sedimented" site rich with macroinvertebrates. The clean rhodolith bed is dominated by small, spherical *Lithothamnion superpositum* rhodoliths, with viable rhodoliths more or less in a single layer over rhodolith- and shell-derived gravel. There is abundant macroalgal cover associated with the rhodolith bed. Three-dimensional structure is enhanced by binding with branching red algae, e.g. *Chondracanthus chapmanii*.

The sedimented rhodolith bed is dominated by larger, branched *Sporolithon durum* rhodoliths (the predominant rhodolith-forming species in New Zealand to date). A more or less single layer of live rhodoliths overlays dead (dark-grey, anoxic) rhodoliths in a fine sediment (graded as sandy silt), with the anoxic rhodolith/sediment sublayer extending to a depth of at least 10 cm in some cases. The top layer of live rhodoliths in the sedimented site is covered by a thin layer of sediment. Three-dimensional structure is enhanced by binding of rhodoliths with various invertebrates, e.g. "turret" sponge and *Chaetopterus* sp. worm tubes.

Live rhodoliths were collected from both the major study sites in February and September 2010 and transferred to holding tanks in Wellington, as source material for growth rate and impact experiments. Comparative experiments have been set up with the two species of rhodoliths, *Lithothamnion superpositum* and *Sporolithon durum*, each of which exhibits a distinct morphology and growth form. Growth in the field will be determined from rhodoliths measured, tagged and stained in February 2010 that were retrieved from the field in September 2010. Live *Sporolithon durum* rhodoliths were also collected from a third site on the Whangaparaoa Peninsula; these very shallow, intertidal rhodoliths exhibit a different growth form to the *Sporolithon durum* rhodoliths from the deeper Bay of Islands beds.

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.

There are relatively few data available on the distribution of VME species or taxa in the South Pacific Ocean (Parker *et al.* 2009) although studies have been conducted in Antarctica (Tracey *et al*. 2010, Parker *et al*. 2009) 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 by high seas fishing), and the level of uncertainty around the predictions is variable or still unknown.

Phase 1 using predictive modelling for VMEs in the SPRFMO area has now been initiated between the US and New Zealand (ZBD2010-40). The objectives of the project is to develop and test spatial habitat modelling approaches for predicting distribution patterns of vulnerable marine ecosystems in the SPRFMO Convention Area with agreed international partners.

Other research relevant or specifically linked to the projects above, are listed in Table 9.1.

Table 9.1:Other research linked to Objective 1 habitat classification and characterisation.

MFISH	ENV2005-15 Information for managing the Effects of Fishing on Physical Features of the Deep-sea Environment] ENV2005-16 Investigate the Effects of Fishing on Physical Features of the Deep-sea Environment ENV2005-20 Benthic invertebrate sampling and species identification in trawl fisheries ENV2005-23 Monitoring recovery of the benthic community between North Cape and Cape Reinga BEN2006-01 Mapping the spatial and temporal extent of fishing in the EEZ 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 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 ZBD2005-16 Information on benthic impacts in support of the Southern Blue Whiting Fishery Plan ZBD2006-02 NABIS ongoing development IPA2009-14 Bryozoan Guide ZBD2008-50 Chatham Rise seamounts Ocean Survey 20/20
MSI	C01X501 Coasts & oceans OBI IO 3, 4 ecosystem based management, habitat model development with Auckland Regional Council C01X502 Biodiversity & Biosecurity OBI IO 1. C01X0508 Seamount fisheries (linking acoustic backscatter to habitat type and biota) CO1X0906 Vulnerable deep-sea communities (mapping and sampling a range of deep-sea habitats (seamounts, slope, canyons, seeps, vents) CO1X0702 Kermadec Arc minerals (mapping and sampling the biodiversity of several Kermadec Arc seamounts)
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?	

9.3.4. Progress on Science Objective 2. Ecosystem-scale research

Marine ecosystems influence, and are influenced by, a wide array of oceanic, climatic, and ecological processes across a broad range of spatial and temporal scales. Marine communities are generally dynamic, can occur over large areas and have strong links to other communities through processes such as migration and long-distance physical transport (e.g. of larvae, nutrients, and biomass). Patterns observed on a small scale can interact with larger and longer-scale processes that in turn result in large scale patterns. Marine food webs are usually complex and dynamic over time (Link 1999). To distinguish useful descriptors of long-term ecosystem change from short-term fluctuations requires innovative approaches to integrate broad-scale correlative studies from smaller scale manipulative experiments (Hewitt *et al.* 1998, 2007).

Recent theoretical and technical advances show great promise toward the goal of understanding the role of biodiversity in ecosystems. Technologies for remote sensing and deepwater surveying, combined with powerful integrative and interpretive tools such as GIS, climate modelling, qualitative ecosystem modelling, and trophic ecosystem modelling, will contribute to the development of an ecosystem-based approach to management (Thrush *et al*. 1997, 2000), with potential benefits for marine conservation and management. Ecosystem modelling of species distribution (and habitats) with respect to known and projected environmental parameters will improve predictability for both broad and fine-scale biodiversity distribution. This has already resulted in improved definition of environmental classifications addressing biodiversity assessment. It is also important to make progress in establishing the links between biodiversity and the long-term viability of fish stocks under various harvesting strategies. It is also important that modellers consider processes from all ecosystem function perspectives i.e., top-down effects such as predation (e.g. trophic modelling), bottom-up effects such as the environment (eg., 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*. in press, Dunn *et al.* 2010a, b, c, Eakin *et al*. 2009, Forman and Dunn 2010, Horn *et al*. 2010, Stevens and Dunn 2010. Follow-up research on isotope signatures to improve the trophic data from ZBD2004-02 has been incorporated into the NIWA's Coast and Ocean programme and trophic modelling is underway in this programme.

ZBD2004-19 Ecological function and critical trophic linkages in New Zealand soft-sediment habitats. Project completed. (see Lohrer *et al*. 2010.)

ZBD2004-08 Sea-grass meadows as biodiversity and connectivity hotspots.

This contract links closely with the 'Coasts and Oceans' OBI. It builds on work done under a FRST project looking at juvenile fish habitat.

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 NZ 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. 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.

IPA2009-11. Trophic Review.

This project publishes a report prepared on the feeding habits of New Zealand fishes 1960 to 2000 (Stevens *et al.* in press)

Other research relevant or specifically linked to the projects above, are listed in Table 9.2.

Table 9.2: Other research linked to ecosystem scale understanding of biodiversity in the marine environment.

MFISH	SAM2005-02 Effects of climate on commercial fish abundance 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
FRST/MS	C01X501 coasts & oceans productivity plankton-mesopelagic fish trophic relations Chatham Rise IO 2
OTHER	AUT deepsea and subtidal food web dynamics; offshore & coastal biodiversity post graduate studies

9.3.5. Progress on Science Objective 3. The role of biodiversity in the functional ecology of nearshore and offshore communities.

An identified outcome of the Biodiversity Strategy is that by 2020 "*New Zealand's natural marine habitats and ecosystems are maintained in a healthy functioning state. Degraded marine habitats are recovering.*" Sustaining ecosystem integrity in marine habitats requires a thorough understanding of the ecological and anthropogenic drivers affecting biodiversity and ecosystem function, and of thes 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 MFish 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. MFish 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[76]. Although this workstream applies to offshore areas as well as near-shore, research to date has focussed on the near-shore.

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

Projects

ZBD2005-09 Rocky reef ecosystems - how do they function?

This multiyear project comprises four objectives:

- To develop a qualitative numerical model of how New Zealand's rocky reef systems are functionally structured
- To advance our understanding of how subtidal reef systems are fuelled through primary and secondary production, the role that biodiversity plays, and how this varies across different reef settings.
- To quantify the effects of human predation, and environmental degradation across reef gradients – top-down, or bottom-up functioning?
- 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.

Objective 1 is complete. Briefly, 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 predictive 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 work and analysis in Objective 3 is complete but remains to be reported. Final analyses and interpretations of some elements in Objectives 2 and 4, specifically stable isotope analysis and otolith micro-chemistry respectively in the two objectives have yet to be completed.

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

The influence of estuaries on adjacent open coastal environments is being evaluated using a combination of laboratory and field investigations. Estuarine productivity (phytoplankton, resuspended phytobenthos and plant debris) is often exported to the open coast on outgoing tides and may contribute to secondary production in the vicinity of an estuary mouth. However, land-derived sediments and contaminants that are discharged from estuaries can stress open coastal populations in areas of greatest concentration. The balance of these competing processes likely influences community composition, shellfish condition and scope for growth on the open coast.

A survey of two coastal locations (Whangapoua and Tairua) was initiated to quantify any shifts in community structure in mollusc dominated habitats along estuary-to-coast gradients. Nine sites per location have been sampled, using distance from the estuary mouth as a proxy for estuarine influence. Collections were made of various estuarine food sources (seagrass, mangrove, estuarine phytoplankton and phytobenthos). The isotopic signatures of the primary food resources will be determined and the tissues of dominant shellfish at each of the 9 sites per location will be analysed to quantify the incorporation of estuarine foods into bivalve body tissues. The field work will be supplemented with laboratory feeding trials, with the goal of ground-truthing isotopic uptake rates in bivalve body tissues in a carefully controlled experimental setting. Finally, reciprocal transplantations of bivalves will be performed at each of the 9 study sites per location to determine relative rates of growth and condition. This comprehensive work plan will provide insights into estuary-coast interactions and the influences on key species in coastal carbonate sediments. Long-lived suspension feeding bivalves are a primary focus of this investigation, as the condition and growth of suspension-feeding bivalves is dependent upon the characteristics of water masses that they filter, integrated over extended temporal scales.

Other research relevant or specifically linked to the projects above, are listed in Table 9.3.

Table 9.3: Other research linked to investigation of the role of biodiversity in the functional ecology of nearshore and offshore marine communities.

MFish	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
FRST	C01X0501 coasts & oceans IO 3, 4 ecosystem based management, habitat perturbation experiments Hauraki Gulf and Kaikoura; C01X0502 Biodiversity& Biosecurity OBI; C01X0xxx Estuarine eco-diagnostics
DOC	Conservancy surveys
BNZ	Biosecurity surveys
OTHER	Universities
EMERGING ISSUES	
Cumulative footprint of fishing, aquaculture, recreation and other spatial allocations to inshore areas	
Land-base effects on marine biodiversity and inshore/offshore habitats; pollution in offshore	

9.3.6. Progress on Science Objective 4. Marine genetic biodiversity

Genetic biodiversity can be measured directly by measurement made at the genes and chromosomes scale or indirectly by measuring physical features at the organism scale (assuming 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 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 or 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 are carrying out field work, genetic analyses, and writing up (in the form of two theses) of this research. Both studies are underway. Fieldwork has begun on two flatfish species and two species of shellfish. The project may also be extended to incorporate a subtidal species of shellfish.

Other research relevant or specifically linked to the projects above, are listed in Table 9.4.

Table 9.4: Other research linked to marine genetic biodiversity.

MFISH	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
FRST	C01X0502 Biodiversity& Biosecurity OBI; IO2
MAFBNZ	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 identify biodiversity source-sink relationships within ecosystems?	

9.3.7. Progress on Science Objective 5. Effects of climate change and variability on marine biodiversity

Cyclical changes or trends in climate and oceanography and associated effects such as increased ocean acidification and how they affect the marine ecosystem as a whole has 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[77] 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.* 2011). 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, coccolithophores, which rely on calcium to grow and mature.

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.

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[78] and has been identified as a gap in biodiversity research in New Zealand[79]

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 study utilises archeological, paleoecological, and historical anecdote and data to retrospectively model ecosystem states during different historical and prehistoric time periods. Comparison of ecosystem models from different periods will aid understanding of current ecosystem states in the context of longer-term ecological changes arising from cumulative human impacts and natural climatic variation. There are five objectives:

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

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

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

- Assess changes in marine productivity via fluctuations in ocean climate over the last 1000 years.
- Assess change in the shelf marine ecosystem in two areas of contrasting human occupation over last 1000 years.
- Develop oral histories from Māori and non-Māori fishers and shellfish gathers
- Carry out mass-balance ecosystem modelling over 5 critical time periods
- Conduct qualitative modelling to determine the critical interactions amongst species and other ecosystem components in order to identify those that should be a priority for future research.

Objectives 1–3 and 5 have final reporting requirements to complete. A new synthesis of NZ's terrestrial climate variation over the last 1000 yrs was completed based on a nationwide review of appropriate climate proxies. Information from ancient snapper and red cod otoliths sourced from middens indicates little contrast in coastal marine temperature between 1400 AD and the present day. Information from archaeological, historical and contemporary sources indicate profound changes in the biomass of some key species since humans arrived in NZ. Oral histories have proved to be highly informative for some exploited species and fill gaps between historical accounts and modern catch data. Qualitative modelling has helped to identify the consequences of sequential disappearance of mega-predators from one ecosystem.

Objective 4 uses information from Objective 2. Progress has been very slow in building Ecopath models of the Hauraki Gulf and Otago-Catlins shelf study areas for 5 time periods ranging from the present day back to 1000 years ago. These two regions were chosen because they have contrasting histories of human occupation as well as adequate archaeological, historical and modern data available.

Reports are in preparation on: Natural drivers of environmental change in New Zealand's marine environment during the last millennium; Insights into historical marine productivity using ancient fish otoliths; Estimating the magnitude of pre-European Māori marine harvest in two New Zealand study areas; Historical evidence for exploitation of the marine environment in the Hauraki Gulf and along the Otago/Catlins shelf 1790-1930; Estimating 19th and 20th century right whale catches and removals around east Australia and New Zealand; Taking Stock: the historical demography of the New Zealand right whale (the *Tohora*) 1830-2008; Rapid re-colonisation of south-eastern New Zealand by New Zealand fur seals *Arctocephalus forsteri;* Estimates of annual food consumption by a population of New Zealand fur seals; Estimates of annual food consumption by a population of New Zealand sea lions; A History of the Firth of Thames Dredge Fishery for Mussels: Use and Abuse of a Coastal Resource; Trends in the exploitation of finfish from the Hauraki Gulf, 1850−2006; Biological parameters and biomass estimates for some commercial fish stocks in the Hauraki Gulf and Otago-Catlins shelf for the period 1930-2006; Archaeological, historical and fisheries time-series evidence for the entire 700 year catch-history for snapper, *Pagrus auratus*, in the Hauraki Gulf, New Zealand; Risks of shifting baselines highlighted by anecdotal accounts of New Zealand's snapper fishery; Oral histories of resource state and use in the Hauraki Gulf and along the Otago/Catlins coast 1940-2000; Changes to the Hauraki Gulf shelf ecosystem since 1200 AD; Changes to the Otago Catlin's shelf ecosystem since 1200 AD; Modelling the consequences of historical removal of top predators from rocky reef ecosystems in north-eastern New Zealand; Large, isolated, late-settled islands; potential tests of human impacts on marine ecosystems; Taking Stock – the impacts of humans on NZ marine ecosystems since first settlement in 1280 AD (synthesis of major findings, and policy and management implications of the NZ Taking Stock project).

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 NZ 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.
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 document the spatial, seasonal and inter-annual distribution of the key diazotroph *Trichodesmium* spp. in archived ocean colour images using a predictive ocean-colour algorithm.

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 NZ 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 NZ 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 NZ waters for 2002-3. 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*. (in press).

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 CaCO3 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 NZ calcifying species will respond to this change.

This project is using laboratory experiments to quantify responses of key NZ mollusc species (paua, *Haliotus irus*, and cockles, *Austrovenus stutchburyi*) to levels of ocean CO_2 saturation predicted to occur in NZ 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 NZ coastal waters expected in the following decades.

Other research relevant or specifically linked to the projects above, are listed in Table 9.5.

Table 9.5: Other research linked to effects of climate change and variability on marine biodiversity.

MFISH	SAM2005-02 Effects of climate on commercial fish abundance ENV2007-04 Climate and oceanographic trends relevant to New Zealand fisheries
FRST	C01X502 Coasts & Oceans OBI IO 1. plankton productivity and natural variability
DOC	Baseline surveys; protected deepsea corals (Tracey *et al.* in press)
OTHER	University of Otago-NIWA shelf carbonate geochemistry and bryozoans Geomarine Services-foraminiferal record of human impact Regional Council monitoring programmes
NEW BRAG PROJECTS FOR 2011-12 under negotiation	
ZBD2010-41	Ocean acidification in fisheries habitat
ZBD2010-42	Environmental Monitoring (MEMP)
EMERGING ISSUES	
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 2003, Chang *et al.* 2003)	

9.3.8. Progress on Science Objective 6. Biodiversity metrics and other indicators for monitoring change

In the mid 1990s, monitoring of marine biodiversity and the marine environment was a topic of considerable discussion, yielding several reports on developing MfE indicators[80] 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[81]. A new international initiative launched in 2010 "Biodiversity Indicators Partnership[82]" 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 and Clarkson (2006)[83] 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.]

[80] 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

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

[82] www.bipnational.net/IndicatorInitiatives

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

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. [how might these results be used in a biodiversity management context?]

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[84].

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

This project adopts 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[85]. This 5-year MFish project aims to map changes in the quantitative distribution of epipelagic plankton, including phytoplankton, zooplankton and euphausiid (krill) life stages annually when vessels depart from

[84] The Department of Conservation Biodiversity Monitoring and Reporting System Fact Sheet July 2010
[85] Southern Ocean CPR programme http://data.aad.gov.au/aadc/cpr/

New Zealand on their journey to the Ross Sea toothfish fishery each year in November/December, traversing key water masses and ocean fronts in New Zealand's EEZ as well as south to the Ross Sea. Two years of sampling have been collected and processed and staff have been trained in plankton ID work.

Other research relevant or specifically linked to the projects above, are listed in Table 9.6.

Table 9.6: Other research linked to biodiversity metrics and other indicators for monitoring change.

MFISH	ENV2006-15: Database and indicator development on seamount habitats (Rowden *et al*) BEN2009-02 (Tuck *et al*. 2010) ENV2006-04: Fisheries indicators from trawl surveys (Tuck 2009)
MSI	C01X0502 Biodiversity and biosecurity, Measuring biodiversity, methodologies, representativeness
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 is a major gap that has been stalled by lack of cross-government commitment and lack of Oceans Policy development.	
Some key monitoring sites are in danger of losing continuity through lack of funding	

9.3.9. Scientific Objective 7. Identifying threats and impacts to biodiversity and ecosystem functioning

Many marine ecosystems in New Zealand have been modified in some way through the harvesting of marine biota, the selective reduction of certain species and size/age classes, modification of food webs, including the detrital 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[86]

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. Coastal margin development has had a major impact on some inshore marine communities.

A recent project commissioned by the MFish Aquatic Environment Programme, identifies key threats to the marine environment (BEN2007-05) is almost complete and has listed and ranked the top threats to New Zealand's marine environment, as perceived by expert opinion. Preliminary 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.* in press).

Projects

ZBD2009-25 Predicting impacts of increasing rates of disturbance on functional diversity in marine benthic ecosystems. The objectives of this project are to:

[86] 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

1. Further develop landscape/seascapes ecological model of disturbance/recovery dynamics in marine benthic communities, incorporating habitat connectivity, based on 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 process, 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 9.7.

Table 9.7: Other research linked to threats to and impacts on biodiversity.

MFish	BEN2007-05 key threats to the marine environment
EMERGING ISSUES	
The socio-economic value of biodiversity in NZ has not been adequately addressed.	
The cumulative footprint of anthropogenic activities on the NZ marine environment has not been assessed.	

9.3.10. Biodiversity in Antarctica: Bioross Project Summaries and Progress

The objectives of BioRoss are to improve understanding of the biodiversity and functional ecology of selected marine communities in the Ross Sea. These objectives are being achieved by commissioning directed research on the diversity and function of selected marine communities in the Ross Sea region. BioRoss is committed to linking with ongoing Ross Sea ecosystems research through the Antarctic Working Group, and supporting climate change related research, especially at high latitudes.

Data acquisition from the Antarctic marine environment is logistically difficult and expensive. Nevertheless, the seven biodiversity Science Objectives listed above also drive BioRoss research projects. The BioRoss survey in 2004 and the Latitudinal Gradient Project ICECUBE have provided significant new information on biodiversity, species abundance and distribution that are now facilitating research into functional ecology and longer term monitoring programmes. This research has the potential to lead into other research on genetic diversity, climate variability and the development of indicators. The research results are also being used in the MFish Antarctic Research Programme projects on ecosystem modelling of the Ross Sea.

The MFish Antarctic Research and BioRoss Programmes are also directly involved in supporting the development of protection measures around the Balleny Islands. In 2005 MFish 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, MFish 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 FRR). This project acquired funding for three seasons (2007/08, 08/09, 09/10) as part of the FRST IPY contestable round. (see also Cummings *et al.* 2011 and Thrush and Cummings in press). Published reports and papers from the MFish Ross Sea coastal projects include Cummings *et al.* 2003, 2006, 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 in press.

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. Two AEBR reports were produced by Rowden *et al.* (in press, a and b) and a Voyage Report, Mitchell and Clark 2004.

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 has six objectives:

1. To test the feasibility of obtaining estimates of demersal fish relative abundance using cameras with and without flood lights.
2. To utilise deepwater camera transects, supported by other direct sampling methods, to characterise the relative abundance, distribution, and diversity of demersal fish species and of benthic macro-invertebrates, and to examine relationships between demersal fishes and benthic habitats/communities.
3. To collect specimens/tissues of selected benthic and pelagic organisms with priority in the vicinity of the Balleny Islands.

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 meso-pelagic species.
5. To undertake routine identification and abundance estimates of marine mammal and seabird species.
6. To undertake automated water sampling in order to monitor the identities and spatial and temporal distributions of plankton in the Ross Sea region.

All objectives are complete apart from final reporting. 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. The Voyage Report Mitchell and MacDiarmid 2006 is available.

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 2 new records for the Ross Sea in addition to the 3 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.

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) was 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.

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

Overall science objectives for the Project were developed by MFish, 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

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.* 2008)

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 in progress.)

The distributions of the seabird 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. Similar data are available for marine mammal taxa, but are not reported yet. The distributions include the presence data of taxa over waters south of about 60° S to the Ross Sea.

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. Phytoplankton analysis is progressing. In addition to the work described above, ICOMM (International census of marine microbes) samples collected during the IPY-CAML survey (10 m depth x 4 stations) have been analysed by collaborators in the USA. A paper by Maas *et al.* (2010) is underway.

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 addresses background physical and surface biological conditions at the time of the IPY-CAML survey. The objective is 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 will be used to validate satellite data of temperature and surface chlorophyll distributions, providing a synoptic overview of physical and biological conditions during the survey. The objective is not yet complete.

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.

Results from this objective were presented at three conferences: 1) CAML-IPY Symposium in Genoa, Italy, May 2009; 2) CCAMLR SG-ASAM meeting in Genoa, Italy, May 2009; and 3) Antarctic New Zealand conference in Auckland, July 2009. 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.* in press, and O'Driscoll 2009, O'Driscoll *et al*. 2009 *et al.* 2010.

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

This objective addresses 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. The mesozooplankton identifications have been completed and preliminary results based on MOCNESS tows at 4 stations are available: two in the north (283, 232), one on the slope (122), and one in the south (095). The mesozooplankton in the surface layers at all stations were dominated by copepods, but the principal species varied between sites. The southern site was dominated by *Ctenocalanus* species, whereas the slope and northern stations were dominated by *Oithona* species. The slope station differed from the northern stations by having a higher proportion of *Microcalanus pygmaeus*. Salps were the main macrozooplankton species recorded in the MOCNESS samples and a manuscript 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 recently been accepted for publication in Polar Biology (Pakhamov *et al.* in press)

Samples were also preserved in ethanol for the analysis of meroplankton species composition and DNA sequencing. Preliminary analysis shows that molluscan velligers, crustacean nauplii, and polychaete larvae dominated the meroplankton during the IPY-CAML voyage. A number of useable genetic sequences have been produced from subsamples of crustacean, echinoderm, molluscan and polychaete larvae (Heimeier *et al.* 2010).

*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 MFish 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.

Analysis of the photographic data collected using NIWA's Deep Towed Imaging System (DTIS) has now been completed. A total of 791 (6.05%) of the still images contained fish with a total of 1156 individual fish observed overall. Of these, 94% could be identified to species level, resulting in at least 31 different species being identified. The most diverse families were the Bathydraconidae, Channichthyidae and Nototheniidae with members of the latter group (mainly *Lepidonotothen squamifrons*) being most abundant. Analysis of the video footage from 55 stations has also now been completed. A total of 2891 fish were observed from these stations and 38 different species recorded. In general, the total number of fish observed in the videos was 2-3 times higher than with the still images, but the level of identification was worse. However, the greater coverage by the video meant that several species (e.g., skates) were seen in the video but not in the stills images.

Many of the provisional identifications completed at sea have now been confirmed and include several new records for the Ross Sea as well as a number of new and undescribed taxa. There are still a number of problematic families including the Liparidae, Zoarcidae, and Myctophidae. There may be up to 11 new species from the IPY survey collection. Identification of the myctophids has been hindered by freezer damage of the diagnostic photophores on some specimens.

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.* (2010). 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.

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.

Identification of benthic invertebrate specimens is complete for all major taxonomic groups and data have been entered in the "Specify" database at NIWA Great Point. Some groups remain to be fully identified but these are with the relevant taxonomists abroad and will be completed in due course. Isopods from the Brenke sled samples are being identified to species level for selected families to enable a circum-Antarctic comparison of diversity using data from three different national IPY programmes. The next phase is to link these identifications with barcoding data from Objective 11. Initial comparisons show interesting spatial divergences and some discrepancies between identifications based on morphological and genetic characters.

All seabed video transects from the shelf, slope, and abyssal sites have been analysed for benthic substrates, invertebrate fauna, and bioturbation marks. In these transects, 30,594 individual organisms were counted, representing 244 separate taxa. Initial analyses of these data match those from the epibenthic sled data and show strong similarity among sites on the shelf and greater variability among slope sites. Video transects from the seamounts will be analysed working from still photographs, rather than video to enable direct comparisons with existing data from Macquarie Ridge and Chatham Rise seamounts.

Sediment grain size, total organic matter, and chlorophyll a content have been analysed for all multicore samples. Macro infauna from these cores have been sorted and identified. Bacterial analyses from sediment samples are complete for abundance (number of cells per unit volume) and these have been converted to amount of carbon per unit wet weight of sediment. Both values were highest at shelf sites, lowest at abyssal sites, and intermediate, albeit with high variability, at slope sites.

Researchers have attended CAML workshops, as invited speakers, in Germany and the USA, have made three presentations, and have four papers accepted or in press (Eleaume *et al.* 2010, Bowden *et al.* 2011, Hanchet *et al.* 2008a,b,c,d, Loerz and Coleman, 2009, Loerz 2009, 2010, Loerz *et al*. (in press), O'Loughlin (2010), Schiaparelli *et al*. (2010).

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 has 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. A conclusion subsequently supported by meristic and morphometric examination of specimens.

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. 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. Large numbers of echinoderms have been tissue sampled and sequenced for COI and include the Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, and the crinoids (Allcock *et al*. 2010). 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. 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 9.8.

Table 9.8: Other research linked to MFish Ross Sea Antarctica biodiversity programme.

MFISH	ANT2009-01 Biology of fishes in the toothfish fishery ANT2009-02 Stock assessment for the toothfish fishery ANT2009-03 Ecosystem modelling of the Ross Sea
MSI	C01X0(number unknown) Adelie penguin dataset C01X0505 Ross Sea Sustainability C01X0502 Biosecurity and Biodiversity OBI, IO2
DOC	Antarctic whale survey
OTHER	Universities
EMERGING ISSUES	
Coastal research and functional ecology-ongoing?	
Taxonomy issues for fish and invertebrates (from IPY)	
Water samples from throughout water column to assess microbial content (from IPY)	

9.4. Progress and re-alignment

Given that the MFish Biodiversity programme has been running for 10+ 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 MFish Biodiversity Research Programme:

That by 2010:

i) the MFish 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) *MFish 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 MFish 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 4 and part of the 5th of the 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 53 projects were commissioned and managed within this 10 year period, yielding over 100 final research reports, most of which have been published through MFish 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, University of Victoria 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 FRST 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 unique habitats such as those of 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. A glance at the presentation programmes for the New Zealand Marine Sciences and the GeoHab Conferences in 2010 alone resulted in 25 papers that derive from research projects commissioned from the Biodiversity Programme.

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 MFish 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 MFish obligations to maintain biodiversity, and to MFish 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 helped DOC with MPA decisions. This strong 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 MFish Aquatic Environment research programme, the National Aquatic Biodiversity Information System (NABIS), an MFish web-based interactive data access and mapping tool) and the MFish 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 MFish 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 MFish, 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 Govt Open Source awards. It will also incorporate data access from Chatham Challenger and IPY projects. Data from a number of MFish 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 2011-12 and beyond will include a re-alignment of the current research programme to take account of new developments such as Fisheries 2030, MfE's National Monitoring programme, DOC's integrated coastal monitoring programme, Statistic New Zealand's Environmental Domain Plan[87], 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 very effective in 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 MFish and now the merger with MAF, and the move to Fisheries 2030 and Fisheries Plans, it important that the Programme develops strong relationships with the Fisheries Management and Strategy (International) groups within MFish and at MAF.

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 and VME biodiversity, 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 (MFish-LINZ, first NZ survey of biodiversity in the Ross Sea); Chatham-Challenger (LINZ-MFish-NIWA-DOC first Ocean Survey 20/20 project), NZ IPY-CAML (MFish-LINZ-NIWA (with international and NZ wide collaboration) survey of the Ross Sea as part of International Polar Year; Biodiversity of seamounts (MFish-NIWA-LINZ-FRST 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 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

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

were introduced. Some were experimental and on a local scale while others were on a regional scale. Recent projects have addressed patterns of marine biodiversity in relation to environmental drivers with ecosystem function. This enabled modelling to predict the distribution of biodiversity in unsurveyed areas of ocean, and evaluation of the vulnerability of biodiversity to perturbations such as climate change, as well as the modelling of trophic interactions among key fish species. Presentations of research results have been made to numerous overseas and New Zealand science audiences, and publications in the mainstream literature have been encouraged.

v) Have results generated by 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). MFish biodiversity advice is frequently requested to contribute to cross-government initiatives including Ocean Survey 20/20, DoC Sub-Antarctic Islands Forum National Monitoring, Stats 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 MFish 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 MFish and across government.

9.4.1. 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 and Wright 1990), and new environmental legislation is proposed for the EEZ and extended continental shelf[88]. Changes inshore are also taking effect with the Environmental Protection Authority Act passed by Parliament on 11 May 2011. This Act establishes a new

[88] http://www.treasury.govt.nz/publications/informationreleases/ris/pdfs/ris-mfe-eez-jun11.pdf

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 dependant 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. 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 nation-wide monitoring and reporting schemes to measure the effects of ocean climate change, regular assessment of the cumulative effects of anthropogenic activities in the ocean and the effectiveness of their management. Without these, we face the risk is that New Zealand will lose its green 'ocean' image, and that tipping points in the health of the aquatic environment will be reached too soon for evasive action to be taken.

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9.6. 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.

10. Appendices

10.1. *Terms of Reference for the Aquatic Environment Working Group in 2011*

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 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, including trophic effects
- effects of aquaculture and fishery enhancement on the environment and on fishing

Where appropriate, 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 the MFish Fisheries Management Group and the Minister of Fisheries).

Preparatory tasks

1. Prior to the beginning of AEWG meetings each year, MFish 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, MFish fisheries or standards managers will alert MFish science managers and the Chief Scientist at least six 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, 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.

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 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 alternative rebuilding scenarios to levels that are likely to ensure long-term viability based on input from AEWG, fisheries plan advisers and fisheries and standards 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 any existing 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 an "Aquatic Environment Plenary"

10. To include in contributions to an analogue of the Fishery Assessment Plenary Report (the "Aquatic Environment Plenary") 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 Fishery Assessment Working Groups.

11. To provide information and advice on management considerations (e.g. area boundaries, bycatch 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.

13. 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 Plenary, 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 Chief Scientist, Ministry of Fisheries, about issues of particular importance that may require review by a plenary meeting or summarising in the "Aquatic Environment Plenary", 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 "Aquatic Environment Plenary" 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
- Consistent performance outside accepted reference points or Standards

Membership and Protocols for all Science Working Groups
(paragraph numbers from the May 2011 Fishery Assessment Plenary)

17. Membership of Working Groups is open to all interested parties who agree to the following standards of participation. 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 repetitions 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

18. Key roles are:

- Chair: MFish scientist – required. The Chair is an active participant in Working Groups, 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 Working Group recommendations, conclusions and action items, and ensuring follow-up; and communicating with the MFish Chief Scientist, relevant MFish Fisheries Management staff, and other key stakeholders
- 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 MFish Fisheries Management teams

19. Working Group participants will be asked to declare any relevant affiliations.

Working Group papers:

20. Working group papers will be posted on the MFish 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.

21. 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 MFish Chief Scientist and the authors of the paper.

22. 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.

23. 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).

24. A quorum will be reached when the Chair (a Ministry of Fisheries scientist), 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.

25. 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 environmental standards or targets

26. The Chair is responsible for facilitating a consultative and collaborative discussion.

27. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.

28. A record of recommendations, conclusions and action items will be posted on the MFish website after each meeting has taken place.

29. Other principles guiding the operation of all MFish Science Working Groups include:

- Data upon which analyses presented to the Working Groups are based must be provided to MFish in the appropriate format and level of detail in a timely manner (i.e., the data must be available and accessible to MFish; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members)
- Methods of analysis must be technically sound
- Working Groups will seek to draw on the best available expertise, and will encourage and seek peer review
- Working Groups will maintain high standards of professional integrity and science ethics
- Working Groups will operate with openness and transparency

30. 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.

31. MFish scientists and science officers will provide administrative support to the Working Groups.

Record-keeping

32. The overall responsibility for record-keeping rests with the Chair of the Working Group, and includes:

- To keep 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 Chief Scientist, Ministry of Fisheries 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.
- To compile 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.

10.2. AEWG Membership 2011

Convenors: Martin Cryer or Nathan Walker (protected species) and Rich Ford (other issues)

Members: Ed Abraham, Rachel Alexander, Robert Anderson, Simon Anderson, Ian Angus, Cindy Bailey, Suze Baird, Barry Baker, Andrew Baxter, Michelle Beritzhoff, Rebecca Bird, Shelley Biswell, Laura Boren, Christine Bowden, Paul Breen, Martin Cawthorn, Louise Chilvers, Tom Clarke, Malcolm Clark, Deanna Clement, George Clement, Spencer Clubb, Paul Creswell, Rohan Currey, Martin Cryer, James Dare, Igor Debski, Matt Dunn, Tyler Eddy, Dominique Filippi, Rich Ford, Barrie Forrest, Chris Francis, Malcolm Francis, Dave Gilbert, Simon Goldsworthy, Paul Grimes, Steve Halley, Keith Heather, Jeremy Helson, Peter Horn, Rosie Hurst, Neil Jackson, Nigel Keeley, Kirstie Knowles, Phillipe Lallemand, Baukje Lenting, Mary Livingston, Craig Loveridge, Greg Lydon, Jeremy Lyle, Pamela Mace, Darryl Mackenzie, Aoife Martin, Rob Mattlin, Eric Mellina, Laureline Meynier, David Middleton, Sophie Mormede, Mark Morrison, Geordie Murman, Richard O’Driscoll, Andrew Penney, Roland Pitcher, Kris Ramm, Vicky Reeve, Pat Reid, Yvan Richard, Wendi Roe, Paul Sagar, Murray Smith, Robert Smith, Ros Squire, Tony Stallard, Darren Stevens, Paul Starr, Kevin Sullivan, Ronni Symon, Finlay Thompson, Ian Tuck, Mike Tudman, Demelza Turnbull, Nathan Walker, Susan Waugh, John Wilson, Barry Weeber, Richard Wells, King Yang, Diana Young, Bob Zuur.

10.3. BRAG Input to the Annual Aquatic Environment and Biodiversity Review 2011

The Biodiversity chapter (Chapter 9) of this document was drawn largely from the Biodiversity Medium Term Research Plan 2010-2014 as discussed and amended by the Biodiversity Research Advisory Group (BRAG) in December 2010. The chapter was circulated to all members of BRAG for input and was independently reviewed by a reviewer appointed by MFish.

10.4. 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.

10.5. 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

Other strategic policy documents

10.5.1. 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.*"

10.5.2. 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.

10.5.3. 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. 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

10.5.4. 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).

10.5.5. Management of Activities in the EEZ

In August 2007 the Ministry for the Environment (MfE) released a discussion paper "*Improving regulation of environmental effects in New Zealand's Exclusive Economic Zone*" seeking comment on a preferred legislative option for managing the impacts of activities in the EEZ. The discussion paper stated that environmental effects in the EEZ were, at that time, managed by sector-specific legislation, which creates the following problems:

- gaps and inconsistencies in the operational control of environmental effects
- unclear environmental outcomes against which activities and their effects should be assessed
- uncertainty for investors about the regulatory environment
- uncertainty about how the effects of activities on each other should be managed.

The MfE website (http://www.mfe.govt.nz/issues/oceans/current-work/index.html) states that EEZ legislation is a priority for the current government. In response to the Gulf of Mexico oil spill, the Ministry of Economic Development is commissioning an independent study on New Zealand's health, safety and environmental provisions around minerals activities such as deep sea drilling. This report, along with the proposed legislation developed by the last government, will be considered by Ministers before making final policy and timeline decisions for EEZ legislation.

Proposals for 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).

10.5.6. Ministry for Science Research and Technology Roadmaps

The Ministry for Science Research and Technology (MRST, now a component of the Ministry of Science and Innovation, MSI) stated in its 2006 overview "*Science for New Zealand*" that our science system aims to set long-term direction for RS&T, but allows flexibility to alter direction as needs and opportunities change. Recent direction setting has replaced periodic national processes with a range of continuous processes, often focused on particular areas or topics including:

- Government-led strategy processes around particular areas of national need or opportunity. The Biodiversity Strategy and Biosecurity Strategy are recent examples that have led to changes in institutional arrangements, policies, and funding in RS&T.
- More focused processes by research organisations and or user communities around how a particular area of science could better support national needs, or may be needed to retain or build new capability. These may be endorsed by Ministers or implemented directly by research organisations.
- 'Roadmaps for Science', led by MRST, aimed at developing and coordinating RS&T directions and bringing a stronger RS&T perspective to other Government strategies. Roadmaps describe New Zealand's current research activity, interpret Government's objectives and strategies in the area, and provide guidance to public research investment agencies as well as other participants in the science system.

Roadmaps for Science were published by MRST for Energy Research (December 2006), Nanoscience & Nanotechnologies (February 2007), Biotechnology Research (March 2007), and Environment Research (June 2007). Probably the most relevant of these is that for Environment Research which can be found at MRST's website at:

http://www.morst.govt.nz/current-work/roadmaps/

(noting that the material on the MRST website will be progressively migrated to the MSI website such that these links may change).

It is important to note that these roadmaps relate primarily to research funded by the erstwhile Foundation for Research Science and Technology (FRST, now also part of MSI) and much less to applied, operational research purchased by the Ministry of Fisheries and some other government departments. However, the Environmental Roadmap for Science noted that environmental management decisions increasingly require an understanding of whole system processes and a multi-dimensional approach. More integrated and systems-based approaches can offer environmental managers and decision-makers answers to many of the questions they are facing. A crucial task then becomes one of creating a New Zealand science environment within which systems-based approaches can develop and flourish, acknowledging that small-scale studies remain important to underpin these approaches. MRST identified three overarching themes that require additional focus: systems understanding and integration (e.g., ecosystem aspects of fisheries management); transfer and uptake (including adaptive management to advance scientific understanding); and information systems (including management of databases and collections.

From a suite of six key research areas (global environmental change, land, water and coasts, including the coastal marine area, urban design and hazards, biosecurity, biodiversity, and oceanic systems), MRST identified five key research directions, two of which are of most relevance to fisheries interests:

Direction 4: Over the next few years, the government will give priority to developing more integrated multidisciplinary approaches, and to improving transfer, uptake and information systems in the following areas:

- global environmental change – with a focus on providing the knowledge for integrated ecological, physical and socio-economic modelling of climate change impacts on water and soil resources, land use, biosecurity, biodiversity and potential global impacts;
- land, water and coasts – with a focus on sustainable land and coastal aquatic use, including the impacts of land use on freshwater and the impacts of freshwater, land management and aquatic production on coastal marine environments;
- biosecurity – reflecting the directions set in the Biosecurity Science Research and Technology Strategy.

Direction 5: Over the longer-term, the government will focus on more integrated multidisciplinary approaches, and improved transfer and uptake, and information systems in the biodiversity and oceanic systems areas.

MRST believes that the Environmental Science Roadmap will make a difference by:

- Equipping environmental managers with integrated research results and tools which will help them avoid, remedy or mitigate future environmental problems.
- Enhancing New Zealand's potential as a test bed and world leader for new innovations and business developments in environmental technologies.
- Improved predictions of and responses to natural hazards events.
- Improved responses to climate change.

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