Ministry for Primary Industries
Manatū Ahu Matua

Aquatic Environment and Biodiversity Annual Review 2015

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

Growing and Protecting New Zealand

ACKNOWLEDGEMENTS

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DISCLAIMER

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PREFACE

This, the 2015 edition of the Aquatic Environment and Biodiversity Annual Review, expands and updates previous editions. It summarises information on a range of issues related to the environmental effects of fishing and aspects of marine biodiversity and productivity relevant to fish and fisheries. This review is a conceptual analogue of the Ministry's annual Fisheries Assessment Plenary reports. It summarises the most recent data and analyses on particular aquatic environment issues and, where appropriate, assesses current status against any specified targets or limits. Whereas the Fisheries Assessment Plenary reports are organised by fishstock, the Aquatic Environment and Biodiversity Annual Review is organised by issue (e.g. protected species bycatch, benthic impacts), and almost all issues involve more than one fishstock or fishery.

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

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

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

I am pleased to endorse this document as representing the best available scientific information relevant to those aspects of the environmental effects of fishing and marine biodiversity covered, as at December 2015.

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CONTENTS

1 INTRODUCTION

1.1 CONTEXT AND PURPOSE

This document contains a summary of information and research on aquatic environment issues relevant to the management of New Zealand fisheries. It is designed to complement the Ministry's annual Reports from Fisheries Assessment Plenaries (e.g., the November Plenary, MPI 2015b, and the May plenary, MPI 2015a) and emulate those documents' dual role in providing an authoritative summary of current understanding and an assessment of status relative to any overall targets and limits. However, whereas the Reports from Fisheries Assessment Plenaries have a focus on individual fishstocks, this report has a focus on aquatic environment fisheries management issues and biodiversity responsibilities that often cut across many fishstocks, fisheries, or activities, and sometimes across the responsibilities of multiple agencies.

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

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

1.2 LEGISLATION

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

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

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

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

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

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

1.3 POLICY SETTING

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

The Ministry for Primary Industries is the principal adviser to the Government on agriculture, horticulture, aquaculture, fisheries, forestry, and food industries, animal welfare, and the protection of New Zealand's primary industries from biological risk. MPI's Strategic Intentions (Formerly called Statement of Intent, SOI), document is an

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

important guiding document for the short to medium term. That for 2015–20 is available on the Ministry's website at: http://www.mpi.govt.nz/document-vault/9602

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

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

The Strategic Intentions document (SI) sets out the Ministry's strategic direction for the coming 5 years, primarily through implementation of *Our Strategy 2030* (Page 4). This strategy was agreed by Cabinet in August

2011 and sets out MPI's vision of "growing and protecting New Zealand" and defines the focus and overall approach of the organisation. The strategy includes four focus areas and outcomes: maximising export opportunities; improving sector productivity; increasing sustainable resource use; and protecting from biological risk. Seven specific organisational priorities have been developed to focus resources on: smart regulation; operational excellence; international access; provenance and traceability; precision production and investment; enduring relationships; and integrated information, insight and knowledge.

Aspects of the strategy specific to fisheries in the SI include supporting the understanding of sustainable limits to natural resource use as part of Medium-Term Objective 5 *The primary sector maximises the use and productivity of natural resources within environmentally sustainable limits and is resilient to adverse climatic and biosecurity events*. The primary industries are reliant on natural resources to provide significant economic benefits to New Zealand. How we all use and manage these natural resources affects New Zealand's future prosperity and the natural capital that underpins New Zealand's production systems. There SI notes a growing demand for more support for the primary sector's market claims about product attributes that help capture premium prices, including assurances about sustainability in fishing. For these claims to be effective, they need to be underpinned by science-based, transparent, verifiable information.

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

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

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

1.3.2 FISHERIES 2030

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

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

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

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

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

At the time this edition went to press, MPI had commenced initial public and stakeholder engagement on a review of New Zealand's fisheries management system to ensure it remains fit-for-purpose and maintains sustainable fisheries for current and future generations (See: http://www.mpi.govt.nz/law-and-policy/legal-overviews/fisheries/fisheries-management-system-review/). Fisheries 2030 may be modified once that review has been completed.

1.3.3 FISHERIES PLANS

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

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

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

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

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

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

1.3.4 OTHER STRATEGIC DOCUMENTS

A number of strategies or reviews have been published that potentially affect fisheries values and research. These include: the New Zealand Biodiversity Strategy (2000, currently being refreshed and updated by DOC); the Biosecurity Strategy (2003, followed by its science strategy 2007); the MPA Policy and Implementation Plan (2005); MfE's discussion paper on Management of Activities in the EEZ (2007, now translated to the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012); MRST's Roadmap for Environment Research (2007); the Revised Coastal Policy Statement (2010); the National Plan of Action to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries (2004, revised and updated by MPI in 2013); and the New Zealand National Plan of Action for the Conservation and Management of Sharks (2008, a revision is currently under consultation). Links to these documents are provided in Appendix 17.8 because they provide some of the broad policy setting for aquatic environment issues and research across multiple organisations and agencies.

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

1.4 SCIENCE PROCESSES

1.4.1 RESEARCH PLANNING

Until 2010 the Ministry of Fisheries ran an iterative planning process to determine, in conjunction with stakeholders and

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

For deepwater fisheries and highly migratory stocks (HMS), the transition to the new research planning approach is well advanced because fisheries plans for these areas have been approved by the Minister. Research for these fisheries are already being developed using Fisheries Plan and Annual Operating Plan processes as primary drivers, and, as necessary, Research Advisory Groups (RAGs) to develop the technical detail of particular projects. The Ministry's website contains more information on this approach, developed during the Research Services Strategy Review, at: http://www.fish.govt.nz/NR/rdonlyres/04D579E5-6DCC-42A6-BF68-9CAB800D6392/0/Research_Services_Strategy_Review_Report.pdf (see Section 5.2, pages 14 to 21) and in summary at:http://www.fish.govt.nz/NR/rdonlyres/432EA3A0-AEA7-41DD-8E5C-D0DCA9A3B96B/0/RSS_letter.pdf. Generic terms of reference for Research Advisory Groups are in Appendix 17.5. For inshore fisheries, the three Fisheries Plans (inshore finfish, shellfish, and freshwater) are still under development, so a transitional research planning process was established for 2010 and developed slightly in 2011. This included the following steps:

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

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

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

1.4.2 CONTRIBUTING WORKING GROUPS

The main contributing working groups for this document are the Ministry's Aquatic Environment Working Group (AEWG) and Biodiversity Research Advisory Group (BRAG). The Department of Conservation's Conservation Services Programme and National Plan of Action Seabirds Technical Working Group (CSP/NPOA-TWG, see http://www.doc.govt.nz/conservation/marine-and-coastal/commercial-fishing/marine-conservation-services/meetings-and-project-updates/) also considers a wide range of DOC-funded projects related to protected species, sometimes in joint meetings with the AEWG. The Ministry's Fishery Assessment Working Groups occasionally consider research relevant to this review. Terms of reference for AEWG and BRAG are periodically revised and updated (see Appendix 17.1 and 17.3 for the 2013 Terms of Reference for AEWG and BRAG, respectively).

AEWG is convened for the Ministry's peer review purposes with an overall purpose of assessing, based on scientific information, the effects of fishing, aquaculture, and enhancement on the aquatic environment for all New Zealand fisheries. The purview of AEWG includes: bycatch and unobserved mortality of protected species, fish, and other marine life; effects of bottom fisheries on benthic biodiversity, species, and habitat; effects of fishing on biodiversity, including genetic diversity; changes to ecosystem structure and function as a result of fishing, including trophic effects; and effects of aquaculture and fishery enhancement on the environment and on fishing. Where possible, AEWG may explore the implications of any effects, including with respect to any standards, reference points, and relevant indicators. The AEWG is a technical forum to assess the effects of fishing or environmental

status and make projections. It has no mandate to make management recommendations or decisions. Membership of AEWG is open (attendees for 2014 are listed in Appendix 17.2).

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

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

1.5 REFERENCES

Ministry for Primary Industries (2015). Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

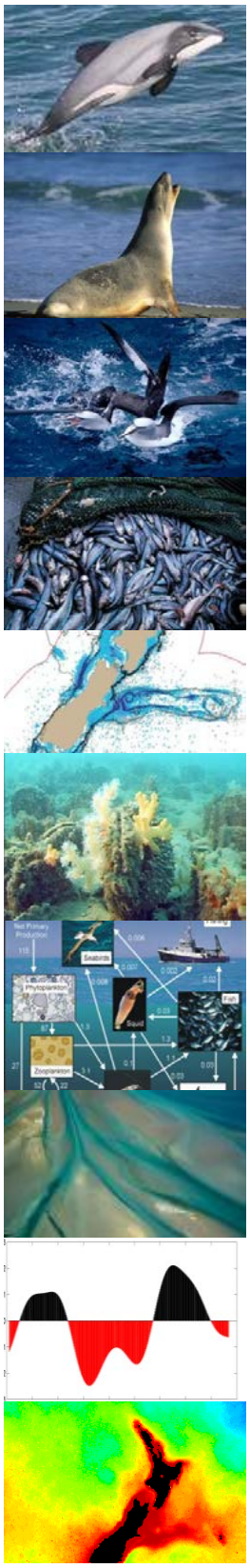
Ministry for Primary Industries (2015). Fisheries Assessment Plenary, November 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 533

2 RESEARCH THEMES COVERED IN THIS DOCUMENT

The Ministry has identified four broad categories of research on the environmental effects of fishing (

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

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



THEME	RESEARCH QUESTIONS	CURRENT WORK
1.PROTECTED SPECIES • Marine mammals • Seabirds • Turtles • Protected fish • Corals	• How many of each NZ-breeding protected species are caught and killed in our fisheries (and out of zone)? • How many unobserved deaths are caused? • What is the likely effect of fishing-related mortality on protected species populations? • Which species/populations are most at risk? • Which fisheries cause the most risk and where can the most cost-effective reductions in risk be gained? • 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 • Semi-quantitative risk assessment for all marine mammals • Full quantitative risk assessment for selected populations • Modelling to assess links between bycatch and population outcomes
2. OTHER BYCATCH • Non-QMS fish & invertebrates	• How much non-target fish is caught and discarded in our fisheries? • What is the effect of that bycatch? • What do trends in bycatch show?	• Continued monitoring cycle for deepwater and highly migratory • Risk assessment for tier 3 deepwater species and all sharks
3. BENTHIC EFFECTS • Distribution of habitats & trawling • Effects of trawling on each	• What seabed habitats occur where in our TS/EEZ and how much of each is affected by trawling or shellfish dredging? • How sensitive is each habitat to disturbance and what do we lose (or gain) when each is disturbed? • What are the likely consequences of different management approaches?	• Testing of habitat classifications • Monitoring the recovery rate of some key inshore habitats • Assessment of relative sensitivity of habitats • Mapping of deepwater and inshore trawl footprints • Development of a 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?	• Habitat of significance: Marlborough Sounds blue cod habitat • Monitoring and indicators of environmental change for deepwater fisheries • Much of the more strategic work in this theme is conducted under the biodiversity programme (see below)
5. MARINE BIODIVERSITY • Characterising NZ biodiversity • Functional ecology • Genetic diversity • Ocean climate • Metrics & indicators • Threats & impacts • Ross Sea	• 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 are the major risks and opportunities from ocean-climate variability and trends? • 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?	• Climate change risk & opportunity for the seafood industry • SPRFMO benthic habitats • Genetic connectivity between New Zealand and the Louisville Ridge • Ocean acidification modelling • Experimental response of shellfish to warming and acidification • Monitoring surface plankton • BPA biodiversity • Sublethal effects of OA on fish productivity • Coralline and macroalgae habitats

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

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. • Semi-quantitative risk assessments have been completed for almost all seabirds and marine mammals. • Fully quantitative risk assessments have been completed for five 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 and reported using observer records for the main deepwater and highly migratory fisheries. • Bycatch and discards for inshore vessels remain poorly known. • Some mitigation approaches have been assessed (e.g., for scampi trawl).
• Modelled predictions are available of the distribution of seabed habitats at a broad scale using classifications (BOMEC) and at finer scale for seamounts and some biogenic habitats. • Excellent understanding of the distribution of bottom trawling in offshore waters, good understanding in coastal waters, but poor understanding for most shellfish dredge fisheries. • Good understanding of the effects of trawling on some nearshore and deepwater habitats. • General understanding of the effects of trawling on biogeochemical processes. • General understanding of the relative sensitivity of different habitats. • Tools to design candidate spatial management measures have been developed and tested (including for High Seas fisheries)
• The nature and variability in the diets of key commercial species in the Chatham Rise ecosystem are reasonably well understood. • A preliminary trophic model of the Subantarctic ecosystem suggests a low productivity system supporting a simple food chain with high transfer efficiencies. • The distribution of spawning, pupping, egg-laying, and juveniles of key species has been described in public atlases. • Land-based effects on fish habitat and coastal biodiversity have been reviewed and documented. • Basic monitoring of ecosystem change over time (through fish-based indicators calculated from trawl survey data and acoustic time series of mesopelagic biomass) has started. • Ocean climate variability and historical change are reasonably well understood. • 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 MBIE, DOC, universities and the MPI 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. • Two measures of marine conditions and marine biodiversity have been evaluated as tier 1 statistics • Demersal fish trophic studies on the Chatham Rise have been completed. • A multidisciplinary study of longterm (1000 years) changes to NZ shelf ecosystems is complete. • Latitudinal gradient project, ICECUBE and 2 large scale surveys in the Ross Sea have been conducted. • The MPI Marine Biodiversity Research Programme theme has links and synergies with MBIE, DOC, MfE, universities and MPI AEWG programmes

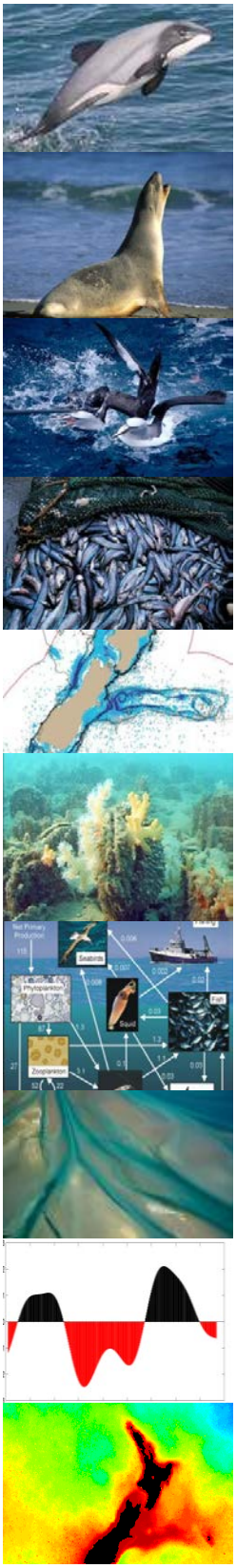


Figure 2.1: continued: Summary of Themes in the Aquatic Environment & Biodiversity Review 2015

THEME 1: PROTECTED SPECIES

3 NEW ZEALAND SEA LION (*PHOCARCTOS HOOKERI*)

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

Note: This chapter has been partially updated (capture estimates) for the AEBAR 2015

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3.1 CONTEXT

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

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

The Minister of Conservation gazetted the NZ sea lion as a threatened species in 1997. In 2009, DOC approved the *New Zealand sea lion species management plan*[1]*: 2009–2014* (DOC 2009). It aims: "*To make significant progress in facilitating an increase in the New Zealand sea lion population size and distribution.*" The plan specifies a number of goals, of which the following are most relevant for fisheries interactions:

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

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

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

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

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

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

a. A rule should provide for an increase in the sea lion population to more than 90% of carrying capacity[2], 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.

[1] 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.

[2] 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.

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.

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

3.2 BIOLOGY

3.2.1 TAXONOMY

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

3.2.2 DISTRIBUTION

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

NZ sea lion breeding colonies[3] are highly localized, with most pups being born at two main breeding areas, the Auckland Islands and Campbell Island (Wilkinson et al 2003, Chilvers 2008). At the Auckland Islands, there are three breeding colonies: Enderby Island (mainly at Sandy Bay and South East Point); Dundas Island; and Figure of Eight Island. On Campbell Island there is one breeding colony at Davis Point, another colony at Paradise Point, plus a small number of non-colonial breeders (Wilkinson et al 2003, Chilvers 2008, Maloney et al 2009, Maloney et al 2012). Breeding on the Auckland Islands represents 71–87% of the pup production for the species, with the remaining 13–29% occurring on Campbell Island (based on concurrent pup counts in 2003, 2008 and 2010; see Section 3.2.5).

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

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

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

3.2.3 FORAGING ECOLOGY

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

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

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

Chilvers et al 2006). NZ sea lions that exhibit benthic diving profiles are estimated to exceed their ADL on 82% of dives, compared with 51% for meso-pelagic divers (Chilvers 2008).

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

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

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

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

NZ sea lions are generalist predators with a varied diet that includes marine mammal prey (NZ fur seal *Arctocephalus forsteri*), seabirds (yellow-eyed penguin *Megadyptes antipodes*, blue penguin *Eudyptula minor*, southern royal albatross *Diomedea epomophora*), elasmobranchs (rough skate *Raja nasuta*), teleost fish (e.g. opalfish *Hemerocoetes* spp., hoki *Macruronus novaezelandiae*, red cod *Pseudophycis bachus*, jack mackerel *Trachurus* spp., barracouta *Thyrsites atun*), cephalopods (e.g. octopus *Enteroctopus zelandicus* and *Macroctopus maorum*, squid *Nototodarus sloanii*), crustaceans (e.g. lobster krill *Munida gregaria*, scampi *Metanephrops challengeri*) and other invertebrates (e.g. salps) (Cawthorn et al 1985; Moore & Moffat 1992; Bradshaw et al 1998; Childerhouse et al 2001; Lalas et al 2007; Moore et al 2008; Meynier et al 2009; Augé et al 2012; Lalas et al 2014; Lalas & Webster 2014). The three main methods used to assess NZ sea lion diets involve analyses of stomach contents, scats and regurgitate, and the fatty acid composition of blubber (Meynier et al 2008).

Stomach contents of by-caught animals tend to be biased towards the target species of the fishery concerned (e.g. squid in the SQU6T fishery), whereas scats and regurgitates are biased towards less digestible prey (Meynier et al 2008). Stomach, scat and regurgitate approaches tend to reflect only recent prey (Meynier et al 2008). By contrast, analysis of the fatty acid composition of blubber provides a longer-term perspective on diets ranging from weeks to months (although individual prey species are not identifiable). This approach suggests that the diet of female NZ sea lions at the Auckland Islands tends to include proportionally more arrow squid and hoki and proportionally fewer red cod and scampi than for male NZ sea lions, while lactating and non-lactating females do not differ in their diet (Meynier et al 2008; Meynier 2010). Within a sample of lactating female NZ sea lions, Meynier et al (2014) used fatty acid analyses to show that the diet of benthic-diving and meso-pelagic-diving animals consisted of similar prey, though different mass contributions for each prey species.

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

3.2.4 REPRODUCTIVE BIOLOGY

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

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

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

3.2.5 POPULATION BIOLOGY

For NZ sea lions, the overall size of the population is indexed using estimates of the number of pups that are born each year (Chilvers et al 2007). Since 1995, the Department of Conservation (DOC) has conducted mark-recapture counts at each of the main breeding colonies at

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

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

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

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

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

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

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

Year	Pup production estimate		Population size estimate	
	Mean	Standard error (for mark recapture estimates)*	Median	90% confidence interval
1995	2 518	21	15 675	14 732–16 757
1996	2 685	22	16 226	15 238–17 318
1997	2 975	26	16 693	15 656–17 829
1998	3 021	94	16 911	15 786–18 128
1999	2 867	33	15 091	13 932–16 456
2000	2 856	43	15 248	14 078–16 586
2001	2 859	24	15 005	13 870–16 282
2002	2 282	34	13 890	12 856–15 079
2003	2 518	38	14 141	13 107–15 295
2004	2 515	40	14 096	13 057–15 278
2005	2 148	34	13 369	12 383–14 518
2006	2 089	30	13 110	12 150–14 156
2007	2 224	38	13 199	12 231–14 215
2008	2 175	44	12 733	11 786–13 757
2009	1 501	16	12 065	11 160–13 061
2010	1 814	36		
2011	1 550[4]	41		
2012	1 684	22		
2013**	1 940	50		
2014**	1 575	19		

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

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

(Gales 1995); and incidental captures in fisheries (see below).

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

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

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

3.2.6 RELATING DEMOGRAPHIC RATES TO DRIVERS OF POPULATION CHANGE

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

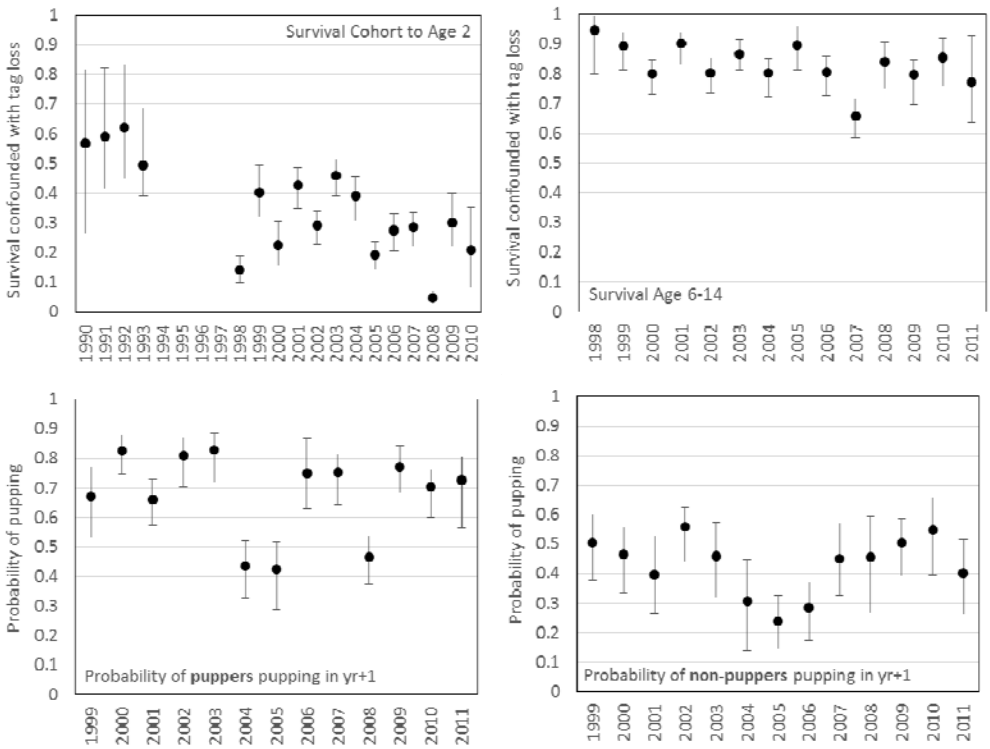


Figure 3.1: Annual estimates of cohort-specific survival to age 2 (top-left), survival at age 6-14 (top-right), probability of puppers pupping (bottom-right) and non-puppers pupping (bottom-right) of female NZ sea lions at Sandy Bay; survival estimates confounded with tag loss and likely to be lower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

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

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

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

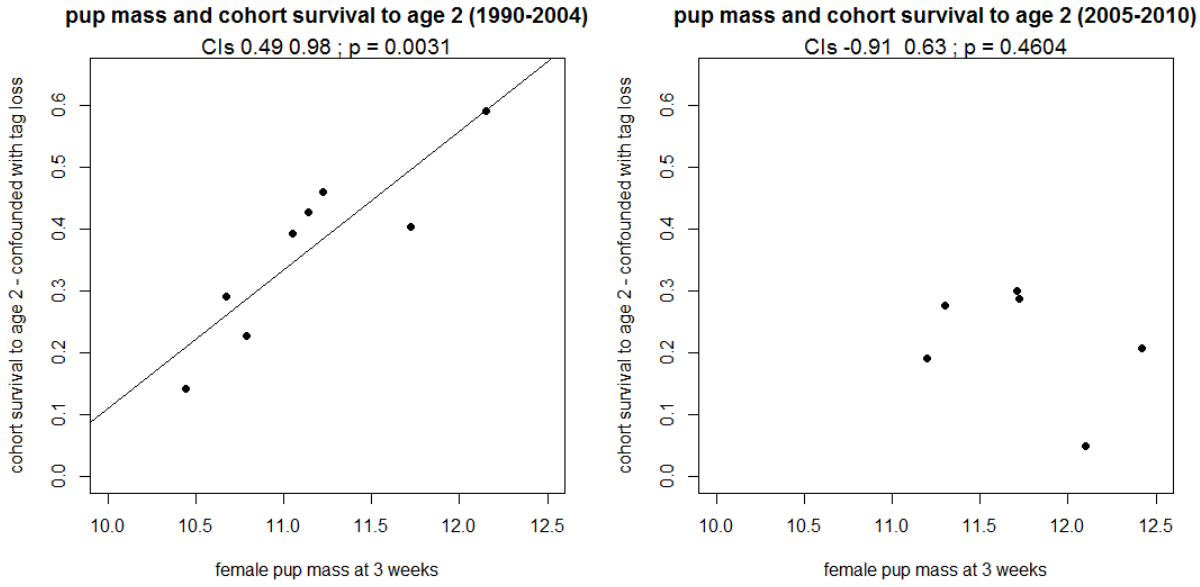


Figure 3.2: Pup mass of females and demographic modelling estimate of cohort survival to age 2; survival estimates confounded with tag loss rate; regression line shown for correlations significant at the 5% level.

3.2.7 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

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

In 2008, the IUCN updated the Red List status of NZ sea lions, listing them as Vulnerable, A3b[5] 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[6] to Nationally Critical under criterion C[7] with a Range Restricted qualifier based on the recent rate of decline (Baker et al 2010).

[5] 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).

[6] 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).

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

3.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

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

3.4 STATE OF KNOWLEDGE IN NEW ZEALAND

NZ sea lions interact with some trawl fisheries resulting in incidental capture and subsequent drowning of the sea lion. These interactions are confined to trawl fisheries in Sub-Antarctic waters (Figure 3.3); particularly the Auckland Islands arrow squid fishery (SQU6T), but also the Auckland Islands scampi fishery (SCI6A), other Auckland Islands trawl fisheries, the Campbell Island southern blue whiting (*Micromesistius australis*) fishery (SBW6I) and the Stewart-Snares shelf fisheries targeting mainly arrow squid (SQU1T; Thompson & Abraham 2010, Thompson et al 2011, 2013).[8]NZ sea lions forage to depths of up to 600 m (Table 3.1) and overlap with trawling at up to 500 m depth for arrow squid, 250–600 m depth for spawning southern blue whiting, and 350–550 m depth for scampi (Tuck 2009, Ministry of Fisheries 2011). There is seasonal variation in the distribution overlap between NZ sea lions and the target species fisheries (

Table 3.3). Breeding male sea lions are ashore between November and January with occasional trips to sea, then migrate away from the Auckland Island area (Robertson et al 2006). Breeding females are in the Auckland Island area year round, ashore to give birth for up to 10 days during December and January and then dividing their time between foraging at sea (~2days) and suckling their pup ashore (~1.5 days; Chilvers et al 2005a). The SQU6T fishery currently operates between February and July, peaking between 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.

3.4.1 QUANTIFYING FISHERIES INTERACTIONS

Since 1988, incidental captures of NZ sea lion have been monitored by government observers on-board a proportion of the fishing fleet (Wilkinson et al 2003). Between 1995 and 2012, observers observed an overall average of 10–42% of trawl tows each year (Table 3.4). In the SQU6T fishery, observer effort was generally around 20–40% in the same period, but reached almost 100% during the 200001 season (Table 3.4). Observer coverage in non-squid trawl fisheries operating adjacent to Auckland Islands was 0–15% in scampi fisheries, and 4–66% in other target fisheries (e.g., jack mackerel, orange roughy and hoki) (Table 3.6). In the Campbell Island southern blue whiting fishery, observer coverage was 27–76%, compared with 8–50% observer coverage in Stewart-Snares shelf trawl fisheries (primarily targeting squid, but also hoki, jack mackerel and barracouta; Table 3.4). Unobserved trips tended to report NZ sea lion captures at a lower rate than observed trips across all observed fisheries. Fishers reported 177 NZ sea lion captures between 1998–99 and 2008–09, compared with 196 captures reported by observers over the same period (Abraham & Thompson 2011)[9].

[8] 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.

[9] As part of its data reconciliation processes, MPI has identified that less than 2% of observed protected species captures between 2002 and 2015 were not recorded in the Centralised Observer Database (COD). Steps are being taken to update the database and estimates of protected species captures and associated risks.

Note that no observed captures of New Zealand sea lions have been identified as absent from COD.

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

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

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

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

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

3.4.2 MANAGING FISHERIES INTERACTIONS

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

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

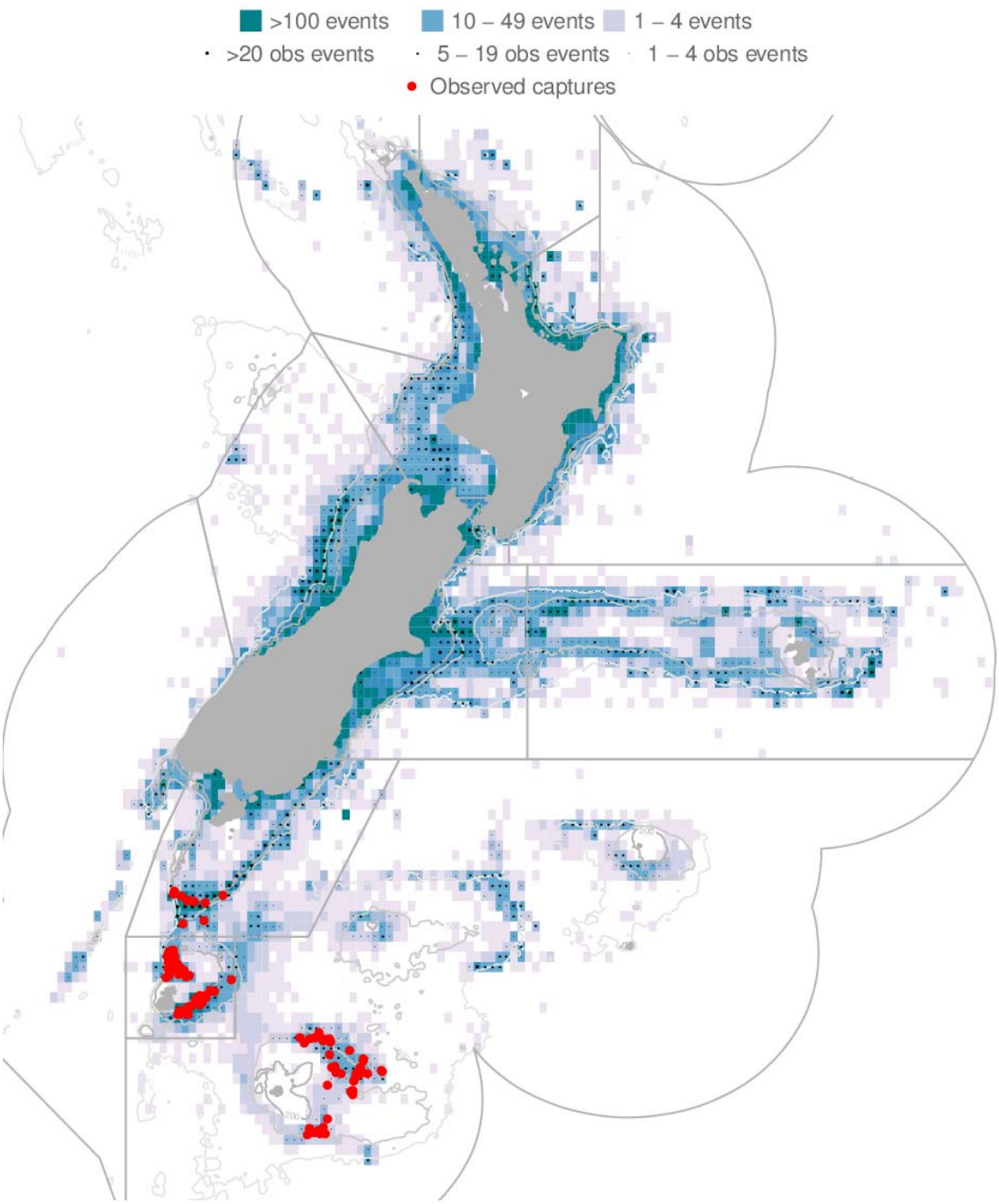


Figure 3.3: Distribution of trawl fishing effort and observed NZ sea lion captures, 2002-03 to 2013-14 (http://data.dragonfly.co.nz/psc/ Data Version v2015003). Fishing effort is mapped into 0.2-degree cells, with the colour of each cell indicating the amount of effort (number of fishing events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 94.2% of the effort is shown.

Table 3.4: Sea lion captures in all modelled commercial trawl fisheries (squid, scampi and other targets around the Auckland Islands, Campbell Island southern blue whiting, and Stewart-Snares shelf trawl) in New Zealand's Exclusive Economic Zone between 1995 and 2014 (http://data.dragonfly.co.nz/psc/ Data version v20150003). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model, ratio estimate, or both combined), the number of estimated sea lion captures, estimated interactions, and estimated strike rate (with 95% confidence intervals, c.i.). Interactions are defined as the number of sea lion that would have been caught if no Sea Lion Exclusion Devices (SLEDs) had been used, with a corresponding strike rate (the estimated number of interactions per 100 tows)(see Thompson et al (2013) and Abraham et al. (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures			Estimated interactions		Estimated strike rate	
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995-96	10 075	10	16	1.5	Both	143	81-239	143	81-234	1.4	0.8-2.4
1996-97	10 954	15	28	1.7	Both	152	102-225	152	101-224	1.4	0.9-2.1
1997-98	9 972	14	14	1	Both	74	45-116	74	43-118	0.7	0.5-1.2
1998-99	10 566	16	6	0.4	Both	31	19-46	31	17-48	0.3	0.2-0.4
1999-00	9 049	23	28	1.4	Both	87	60-125	87	58-129	1	0.7-1.4
2000-01	8 928	39	46	1.3	Both	59	51-70	82	58-111	0.7	0.6-0.8
2001-02	9 946	19	23	1.2	Both	62	44-83	92	60-137	0.6	0.4-0.8
2002-03	8 311	19	11	0.7	Both	31	21-44	59	35-90	0.4	0.3-0.5
2003-04	10 021	23	21	0.9	Both	59	41-81	221	120-384	0.6	0.4-0.8
2004-05	11 083	23	14	0.5	Both	51	34-73	187	93-339	0.5	0.3-0.7
2005-06	9 303	21	14	0.7	Both	49	33-71	172	85-332	0.5	0.4-0.8
2006-07	6 724	24	15	0.9	Both	42	28-61	116	55-237	0.6	0.4-0.9
2007-08	6 534	33	8	0.4	Both	30	20-43	137	38-514	0.5	0.3-0.7
2008-09	6 664	27	3	0.2	Both	20	10-33	114	24-478	0.3	0.2-0.5
2009-10	5 522	34	15	0.8	Both	45	30-64	160	51-563	0.8	0.5-1.2
2010-11	6 455	31	6	0.3	Both	27	16-41	87	25-316	0.4	0.2-0.6
2011-12	5 466	42	1	0.0	Both	12	5-21	58	11-253	0.2	0.1-0.4
2012-13	5 581	64	25	0.7	Both	32	27-39	109	53-313	0.6	0.5-0.7
2013-14	4 701	59	3	0.1	Both	10	5-16	52	14-184	0.2	0.1-0.3

Table 3.5: Sea lion captures in the Auckland Islands squid trawl fishery between 1995 and 2014 (http://data.dragonfly.co.nz/psc/ Data version v20150003). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model, ratio estimate, or both combined), the number of estimated sea lion captures, estimated interactions, and estimated strike rate (with 95% confidence intervals, c.i.). Interactions are defined as the number of sea lion that would have been caught if no Sea Lion Exclusion Devices (SLEDs) had been used, with a corresponding strike rate (the estimated number of interactions per 100 tows) (see Thompson et al (2013) and Abraham et al. (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures			Estimated interactions		Estimated strike rate	
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
1995-96	4 466	12	13	2.4	Model	128	67-222	128	66-218	2.9	1.6-4.8
1996-97	3 716	19	28	3.9	Model	140	91-213	140	89-212	3.8	2.5-5.6
1997-98	1 441	22	13	4.2	Model	59	32-101	59	30-102	4.1	2.4-6.8
1998-99	402	39	5	3.2	Model	14	46204	14	46844	3.5	2.1-5.8
1999-00	1 206	36	25	5.7	Model	69	45-106	70	42-110	5.8	4.0-8.6
2000-01	583	99	39	6.7	Model	39	39-40	62	39-89	10.6	8.7-13.4
2001-02	1 648	34	21	3.7	Model	42	29-62	73	42-116	4.4	3.0-6.7
2002-03	1 466	29	11	2.6	Model	18	13-28	47	24-80	3.1	1.9-4.9
2003-04	2 594	31	16	2	Model	39	26-59	203	100-366	7.8	4.0-14.0
2004-05	2 693	30	9	1.1	Model	30	17-51	168	73-330	6.1	2.8-11.7
2005-06	2 459	22	10	1.8	Model	26	15-43	154	65-316	6.1	2.7-12.3
2006-07	1 317	41	7	1.3	Model	15	9-26	91	30-214	6.8	2.4-15.6
2007-08	1 265	47	5	0.8	Model	12	6-21	132	22-527	9.4	1.8-39.8
2008-09	1 925	40	2	0.3	Model	7	2-15	114	12-531	5.3	0.7-24.5
2009-10	1 188	26	3	1	Model	12	5-26	133	18-560	10.8	1.9-44.8
2010-11	1 583	35	0	0	Model	4	0-10	70	5-323	4	0.3-17.9
2011-12	1 281	44	0	0	Model	2	0-6	48	2-243	3.5	0.3-16.5
2012-13	1 027	86	3	0.3	Model	4	3-6	58	7-263	5.3	0.8-24.5
2013-14	737	84	2	0.3	Model	2	2-4	37	4-167	5.0	0.7-22.8

* SLEDs introduced.

^ SLEDs standardised and in widespread use.

Table 3.6 Sea lion captures in trawl fisheries targeting scampi and targeting other species adjacent to the Auckland Islands between 1995 and 2013 (http://data.dragonfly.co.nz/psc/ Data version v20150003). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model or ratio estimate), and the number of estimated sea lion captures (with 95% confidence interval, c.i.)(see Thompson et al (2013) and Abraham et al (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.
Auckland Islands scampi							
1995-96	1 306	5	2	3.1	Ratio	10	4-18
1996-97	1 224	15	0	-	Ratio	6	4-14
1997-98	1 107	12	0	-	Ratio	6	1-13
1998-99	1 254	2	0	-	Ratio	8	2-16
1999-00	1 383	5	0	-	Ratio	8	2-16
2000-01	1 417	6	4	4.8	Ratio	12	6-21
2001-02	1 604	9	0	-	Ratio	9	3-18
2002-03	1 351	11	0	0.0	Ratio	7	2-15
2003-04	1 363	12	3	1.8	Ratio	10	5-18
2004-05	1 275	0	0	NA	Ratio	8	2-16
2005-06	1 331	9	1	0.9	Ratio	8	3-16
2006-07	1 328	8	1	1.0	Ratio	8	3-17
2007-08	1 327	7	0	0	Ratio	8	2-16
2008-09	1 457	4	1	1.6	Ratio	10	3-18
2009-10	940	10	0	0.0	Ratio	5	1-11
2010-11	1 401	15	0	0.0	Ratio	7	2-15
2011-12	1 247	10	0	0.0	Ratio	7	2-15
2012-13	1 093	12	0	0.0	Ratio	6	1-12
2013-14	850	6	0	0.0	Ratio	5	1-11
Auckland Islands other							
1995-96	406	6	1	4	Ratio	2	1-6
1996-97	296	4	0	-	Ratio	1	0-4
1997-98	684	17	1	0.8	Ratio	3	1-8
1998-99	525	10	1	1.8	Ratio	3	1-7
1999-00	750	13	0	-	Ratio	3	0-8
2000-01	578	7	0	-	Ratio	2	0-7
2001-02	589	4	0	-	Ratio	2	0-7
2002-03	543	13	0	-	Ratio	2	0-6
2003-04	289	17	0	-	Ratio	1	0-4
2004-05	170	7	0	-	Ratio	1	0-3
2005-06	39	15	0	-	Ratio	0	0-1
2006-07	38	5	0	-	Ratio	0	0-1
2007-08	147	45	0	-	Ratio	0	0-2
2008-09	121	50	0	-	Ratio	0	0-2
2009-10	77	66	0	-	Ratio	0	0-1
2010-11	131	37	0	-	Ratio	0	0-2
2011-12	57	30	0	-	Ratio	0	0-1
2012-13	60	43	0	-	Ratio	0	0-1
2013-14	203	23	0	-	Ratio	1	0-3

Table 3.7 Sea lion captures in Campbell Island southern blue whiting (SBW) and in Stewart-Snares shelf trawl fisheries between 1995 and 2014 (http://data.dragonfly.co.nz/psc/ Data version v20150003). Annual fishing effort (total number of tows), observer coverage (percentage of tows observed), number of observed sea lion captures (both dead and alive), observed capture rate (captures per 100 tows), the estimation method used (model or ratio estimate), and the number of estimated sea lion captures (with 95% confidence interval, c.i.) (see Thompson et al (2013) and Abraham et al (in prep) for details).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.
Campbell Island SBW							
1995-96	474	27	0	0	Model	0	0-3
1996-97	641	34	0	0	Model	0	0-3
1997-98	963	29	0	0	Model	1	0-5
1998-99	788	28	0	0	Model	1	0-5
1999-00	447	52	0	0	Model	0	0-3
2000-01	672	60	0	0	Model	0	0-2
2001-02	980	28	1	0.4	Model	4	1-11
2002-03	599	43	0	0	Model	0	0-3
2003-04	690	34	1	0.4	Model	3	1-9
2004-05	726	37	2	0.7	Model	5	2-12
2005-06	521	28	3	2.1	Model	10	3-22
2006-07	544	32	6	3.5	Model	15	6-29
2007-08	557	41	2	0.9	Model	8	5-14
2008-09	627	20	0	0	Model	1	0-7
2009-10	550	43	11	4.7	Model	24	15-37
2010-11	886	39	6	1.7	Model	15	8-24
2011-12	592	77	0	0	Model	1	0-3
2012-13	693	100	21	3	Model	21	21-22
2013-14	588	100	2	0.3	Model	1	1-1
Stewart-Snares (mainly squid)							
1995-96	3 423	8	0	-	Ratio	3	0-7
1996-97	5 077	10	0	-	Ratio	4	0-9
1997-98	5 777	10	0	-	Ratio	5	1-10
1998-99	7 597	16	0	-	Ratio	6	1-12
1999-00	5 263	23	3	0.3	Ratio	7	3-11
2000-01	5 678	43	3	0.1	Ratio	6	3-10
2001-02	5 125	18	1	0.1	Ratio	5	1-10
2002-03	4 348	16	0	-	Ratio	3	0-8
2003-04	5 085	21	1	0.1	Ratio	5	1-9
2004-05	6 206	24	3	0.2	Ratio	7	4-12
2005-06	4 950	19	1	0.1	Ratio	5	1-9
2006-07	3 494	24	1	0.1	Ratio	3	1-7
2007-08	3 238	36	1	0.1	Ratio	3	1-6
2008-09	2 534	31	0	-	Ratio	2	0-5
2009-10	2 765	43	1	0.1	Ratio	2	1-5
2010-11	2 451	36	0	-	Ratio	1	0-4
2011-12	2 289	50	1	0.1	Ratio	2	1-4
2012-13	2 735	68	1	0.1	Ratio	2	1-4
2013-14	2 323	63	0	-	Ratio	1	0-3

*SLEDs introduced in that year

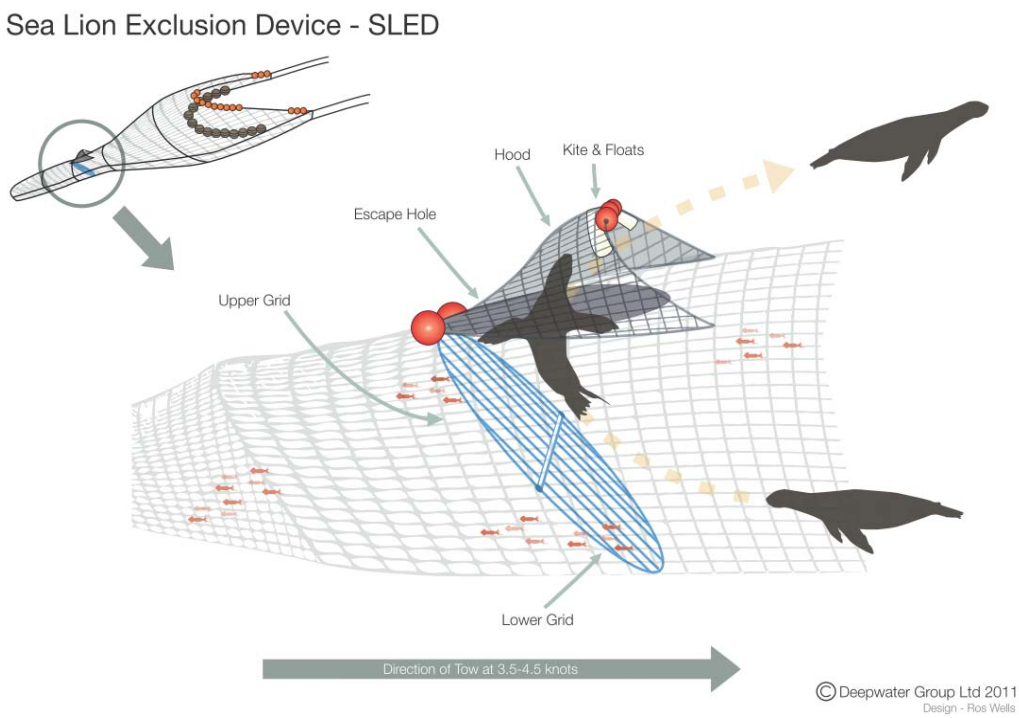


Figure 3.4: Diagram of a NZ sea lion exclusion device (SLED) inside a trawl net. Image courtesy of the Deepwater Group.

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

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

Year	MALFiRM or FRML	Discount rate	Management actions
1991–92	16 (female only)		
1992–93	63		
1993–94	63		
1994–95	69		
1995–96	73		Fishery closed by MFish (4 May)
1996–97	79		Fishery closed by MFish (28 March)
1997–98	63		Fishery closed by MFish (27 March)
1998–99	64		
1999–00	65		Fishery closed by MFish (8 March)
2000–01	75		Voluntary withdrawal by industry
2001–02	79		Fishery closed by MFish (13April)

2002–03	70		Fishery closed by MFish (29 March), overturned by High Court
2003–04	62 (124)	20%	Fishery closed by MFish (22 March), overturned by High Court FRML increased
2004–05	115	20%	Voluntary withdrawal by industry on reaching the FRML
2005–06	97 (150)	20%	FRML increased in mid-March due to abundance of squid
2006–07	93	20%	
2007–08	81	35%	
2008–09	113 (95)	35%	Lower interim limit agreed due to the decrease in pup numbers
2009–10	76	35%	
2010–11	68	35%	
2011–12	68	35%	
2012–13	68	82%	
2013–14	68	82%	

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

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

3.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

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

Since 2000, an integrated Bayesian management procedure evaluation model having both population and fishery components has been used to assess the likely performance of a variety of management control rules, each of which can be used to determine the FRML for a given SQU6T season (Breen et al 2003, Breen & Kim 2006a, Breen & Kim 2006b, and Breen, Fu & Gilbert 2010). The model underwent several iterations. An early version, developed in 2000-01, was a relatively simple deterministic, partially age-structured population model with density-dependence applied to pup production (Breen et al 2003). An updated version called the Breen-Kim model was built in 2003 to render it fully age-structured and to incorporate various datasets supplied by DOC (Breen & Kim 2006a, 2006b). This model was further revised in 2007-08 to incorporate the latest NZ sea lion population data and to address various model

uncertainties and called the BFG model (after its authors, Breen, Fu & Gilbert 2010). In 2009, the model was again updated to incorporate the low NZ sea lion pup counts observed in 2008-09 (and thus better reflect the observed variability in pup survival and pupping rates), as well as incidental captures in fisheries other than SQU6T. The BFG model was re-run in 2011 using the same underlying data and structure as in 2009 to evaluate the effect of different model assumptions about the survival of NZ sea lions that exit trawl nets via SLEDs (see below). Additional details on the NZ sea lion population model can be found in Breen et al (2010).

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

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

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

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

In the absence of sufficient video footage of NZ sea lion interacting with SLEDs, footage of fur seals (thought to be Australian fur seals) interacting with SEDs in the Tasmanian small pelagic mid-water trawl fishery has been

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

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

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

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

For the base case, the simulation results indicated there was a 3.3% chance of a single head-first collision resulting in MTBI with a 95 percentile of 15.7% risk of MTBI (Abraham 2011). Sensitivities modulating single parameters resulted in up to 6.2% probability of a single collision resulting in MTBI. One sensitivity trial involving changes in multiple parameters resulted in a 10.9% probability of MTBI. This scenario considered impact speeds 20% above those measured for fur seals, multiple collisions with the grid, and the least favourable values of scaling exponents used in scaling the test HIC values and calculating MTBI from the HIC (Abraham 2011). These results are probabilities of MTBI resulting from a single head first collision but, because each individual can have multiple interactions with the grid while in a trawl, and some of these will not be head-first. Using Australian observations, Abraham (2011) estimated the number of head-first collisions per interaction as 0.74, leading to an estimated probability of MTBI for a NZ sea lion interacting

with a trawl of 2.7%. Single parameter sensitivity runs increased this to up to 4.6% and the multiple parameter sensitivity using the scenario described above increased it to 8.2% (Abraham 2011). Assuming synergistic interaction between successive head-first strikes (each collision carrying 5 times more risk than previous ones) did not appreciably increase the overall risk because few fur seals had multiple head-first collisions. These results indicate that the risk of mortality for NZ sea lions interacting with the SLED grid is probably low, although some remaining areas of uncertainty were identified (see below).

3.4.4 PBR ASSESSMENT FOR CAMPBELL ISLAND POPULATION

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

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

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

The latest pup census at Campbell Island (681 pups in 2009-10; Maloney et al, 2012) was taken as a robust lower estimate of total pup production. A matrix modelling analysis was conducted to estimate plausible pup to whole of population multipliers of 4.5 and 5.5, which were applied to the pup census estimate to calculate N_{min} values of 3 065 and 3 746. The rate of increase in pup counts from a time series of pup censuses was used as an approximation to whole of population growth rate for estimating a credible lower limit of R_{max}. Values of 0.06, 0.08 and 0.10 were used in PBR calculations, with the upper and lower limits considered as plausible bounds for this parameter used in a sensitivity analysis. The Auckland Islands and Campbell Island sub-populations are likely to constitute demographically independent populations (DIPs) and so, according to the latest guidelines on PBR assessment, may be assessed as separate stocks (Moore & Merrick 2011). Therefore the recovery factor (F_R) of 0.5 was used for stocks of a threatened species with unknown (or not declining) population trajectory. The latest PBR guidance literature recommends a more conservative F_R of 0.1 for stocks of an endangered species and is the lower limit that might be considered for declining populations of a threatened species (Roberts, Roux & Ladroite 2014).

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

3.4.5 SOURCES OF UNCERTAINTY

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

uncertainty relating to the biomechanical modelling (Ponte et al 2010, 2011, Abraham 2011, Lyle 2011).

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

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

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

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

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

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

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

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

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

The panel made several suggestions for further testing and modification of the model and expected these to resolve many of the issues identified. Specific recommendations included consideration of a female-only model and an assessment of the sensitivity of outputs to the choice of

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

Year	No. of tows	Mean tow duration (hours)	Percentage of tows		
			Less than 4 hours	Between 4 & 8 hours	More than 8 hours
1995	4 014	3.7	64.2	33.5	2.2
1996	4 474	3.6	64.3	34.2	1.5
1997	3 719	3.8	62.7	33.7	3.7
1998	1 446	3.2	74.4	24.7	0.9
1999	403	3.5	73.0	24.3	2.7
2000	1 213	3.5	70.3	27.0	2.7
2001	583	3.3	72.9	26.6	0.5
2002	1 647	3.8	59.8	38.8	1.4
2003	1 467	4.1	52.4	44.0	3.6
2004	2 598	5.0	36.7	53.6	9.7
2005	2 693	4.7	43.7	48.6	7.7
2006	2 462	6.3	26.0	49.6	24.3

2007	1 317	7.3	18.9	46.3	34.8
2008	1 265	6.2	20.4	58.7	20.9
2009	1 925	6.5	21.1	51.4	27.5
2010	1 190	7.9	16.4	37.4	46.2
2011	1 585	6.8	24.7	42.8	32.4
2012	1 283	6.6	23.5	49.3	27.3
2013	1 027	7.1	18.7	49.4	31.9
2014	737	6.9	17.8	51.5	30.7

time series of incidental captures, including pre-1980 estimates. Where no data exist, and are likely to be difficult to obtain, the panel suggested explicit acknowledgement of all subjective judgements and assumptions in the model and its predictions. The panel concluded that, until the model has been modified, tested and re-run, it would not be possible to test explicitly whether the current limits upon the SQU6T fishery will succeed in meeting the agreed management criteria. MPI is working through these comments and recommendations.

3.4.6 POTENTIAL INDIRECT THREATS

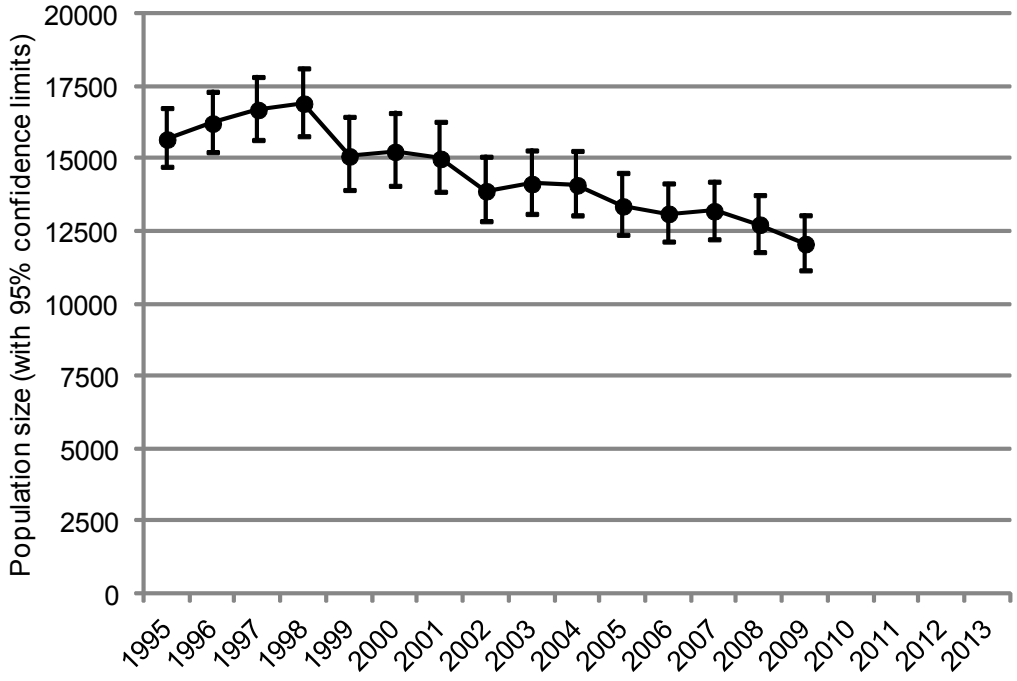
In addition to sources of uncertainty associated with direct fisheries interactions, there is the possibility that indirect fisheries effects may have population-level consequences for NZ sea lions. Such indirect effects may include competition for food resources between various fisheries and NZ sea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

3.5 INDICATORS AND TRENDS

Population size	12 065 animals (including pups < 1 yr old) at the Auckland Islands (90% CI: 11 160–13 061) in 2009 (most recent model estimate)[10] 1 575 pups at the Auckland Islands in 201314[11]

[10] Breen et al (2010).

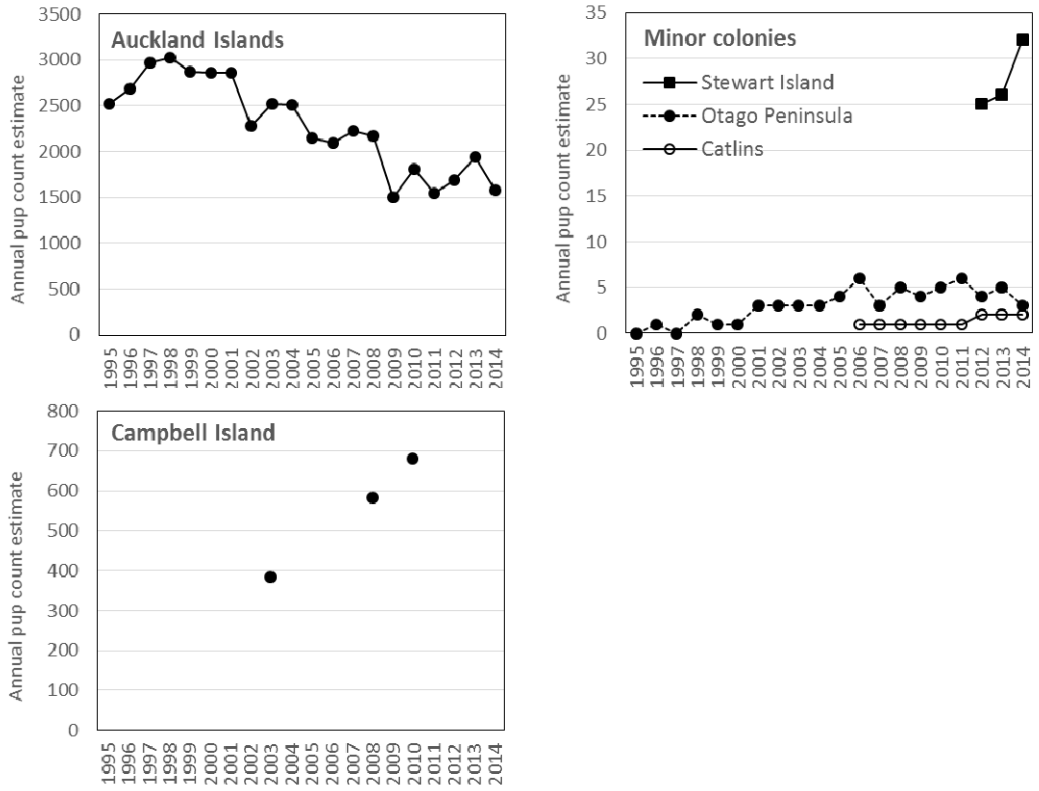
[11] Childerhouse et al (2014)

	681 pups at Campbell Island in 2010[12] 32 pups tagged at Stewart Island in 2014[13] 3 pups at the Otago Peninsula in 201314[14]
Population trend	Estimated abundance at the Auckland Islands:  Estimated pup production at the Auckland Islands, Campbell Island and minor colonies:

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

[13] Chilvers (2014)

[14] Fyfe pers. comm.

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

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

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

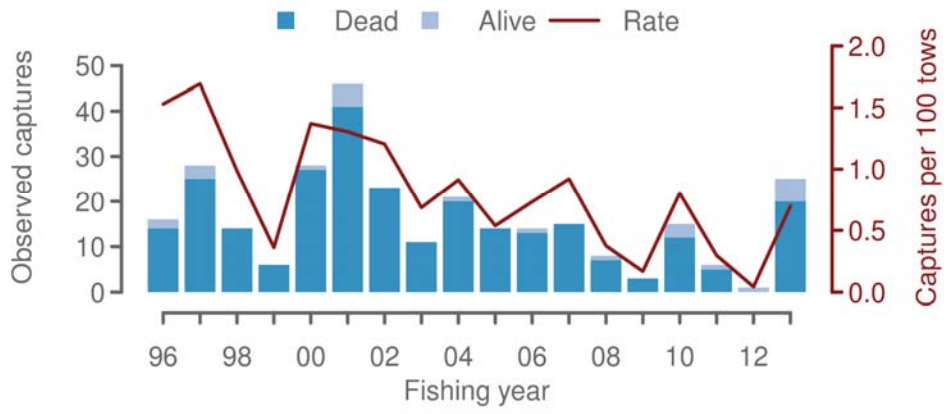
[17] Baker et al (2010)

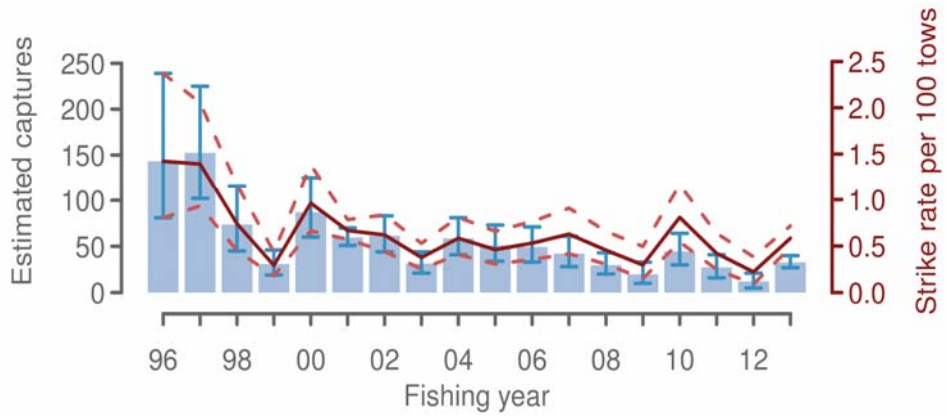
[18] A taxon is listed as 'Vulnerable' if it is considered to be facing a high risk of extinction in the wild. A3b refers to a reduction in population size (A), based on a reduction of ≥ 30% over the last 10 years or three generations (whichever is longer up to a maximum of 100 years (3); and when considering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

[19] Gales (2008)

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

Trends in interactions





Note that these images do not display "all trawl" effort in New Zealand's EEZ. These figures (and those shown in the 2013 AEBAR) display the modeled dataset (Abraham et al. 2014) which included only those trawl fisheries relevant to the incidental captures of New Zealand sea lions.

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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, Stewart-Snares shelf, Campbell Rise, and the Bounty Islands, plus offshore of Bay of Plenty-East Cape. Interactions also occur off the west coast of the North Island.
Key issues	Improving estimates of incidental bycatch in some fisheries, and assessing the potential for populations to sustain the present levels of bycatch.
Emerging issues	Improving data and information sources for future ecological risk assessments.
MPI Research (current)	PRO2010-01 *Estimating the nature & extent of incidental captures of seabirds, marine mammals & turtles in New Zealand commercial fisheries*; PRO2012-02 *Assess the risk posed to marine mammal populations from New Zealand fisheries*.
NZ Government Research (current)	DOC Marine Conservation Services Programme (CSP): INT2014-01 *To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities*; INT2013-03 *To determine which marine mammal, turtle and protected fish species are captured in fisheries and their mode of capture*; INT2013-04 *To review the data collected by fisheries observers in relation to understanding the interaction with protected species, and refine efficient protocols for future data collection*; MIT2014-01 *Protected species bycatch newsletter*.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts
Related chapters/issues	See the New Zealand sea lion chapter.

Note: This chapter has been partially updated (capture estimates) for the AEBAR 2015

4.1 CONTEXT

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

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

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

In 2004, DOC approved the *Department of Conservation Marine Mammal Action Plan for 2005–2010*[1] (Suisted & Neale 2004). The plan specifies a number of species-specific key objectives for NZ fur seals, of which the following is most relevant for fisheries interactions: "*To control/mitigate fishing-related mortality of NZ fur seals in trawl fisheries (including the WCSI hoki and Bounty Island southern blue whiting fisheries).*"

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

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

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

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

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

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

4.2 BIOLOGY

4.2.1 TAXONOMY

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

4.2.2 DISTRIBUTION

Pre-European archaeological evidence suggests that NZ fur seals were present along much of the east coasts of the North Island (except the less rocky coastline of Bay of Plenty and Hawke Bay) and the South Island, and, to a lesser extent, on the west coasts, where fewer areas of

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

suitable habitat were available (Smith 1989, 2005, 2011). A combination of subsistence hunting and commercial harvest resulted contraction of the species' range and in population decline almost to the point of extinction (Smith 1989, 2005, 2011, Ling 2002, Lalas 2008). NZ fur seals became fully protected in the 1890s and, with the exception of one year of licensed harvest in the 1950s, have remained protected since.

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

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

4.2.3 FORAGING ECOLOGY

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

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

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

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

NZ fur seals are opportunistic foragers and, depending on the time of year, method of analysis, and location, their diet includes at least 61 taxa (Holborow 1999) of mainly

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

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

4.2.4 REPRODUCTIVE BIOLOGY

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

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

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

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

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

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

4.2.5 POPULATION BIOLOGY

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

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

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

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

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

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

the "*Breeding colonies distribution of New Zealand fur seal*" layer[2].

Baker et al (2010a) conducted an aerial survey of the South Island west coast from Farewell Spit to Puysegur Point and Solander Island in 2009, but their counts were quite different, i.e. lower than ground counts collected at a similar time at the main colonies (Melina and Cawthorn 2009). This discrepancy was thought to be a result mainly of the survey design and the nature of the terrain. However, the aerial survey confirmed the localities shown by Wilson (1981) of potentially large numbers of pups at sites such as Cascade Point, Yates Point, Chalky Island, and Solander Island.

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

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

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

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

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

4.2.6 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

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

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

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

4.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

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

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

4.4 STATE OF KNOWLEDGE IN NEW ZEALAND

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

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

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

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

Table 4.1). In August–October, NZ fur seals are caught in southern blue whiting effort near the Bounty Islands and Campbell Island. In September–October captures may occur in hoki and ling fisheries off Puysegur Point on the southwestern coast of the South Island. Captures are also reported from the Stewart-Snares shelf fisheries that

operate during summer months, mainly for hoki and other middle depths species and squid, and from fisheries throughout the year on the Chatham Rise though captures have not been observed east of longitude 180° on the Chatham Rise.

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

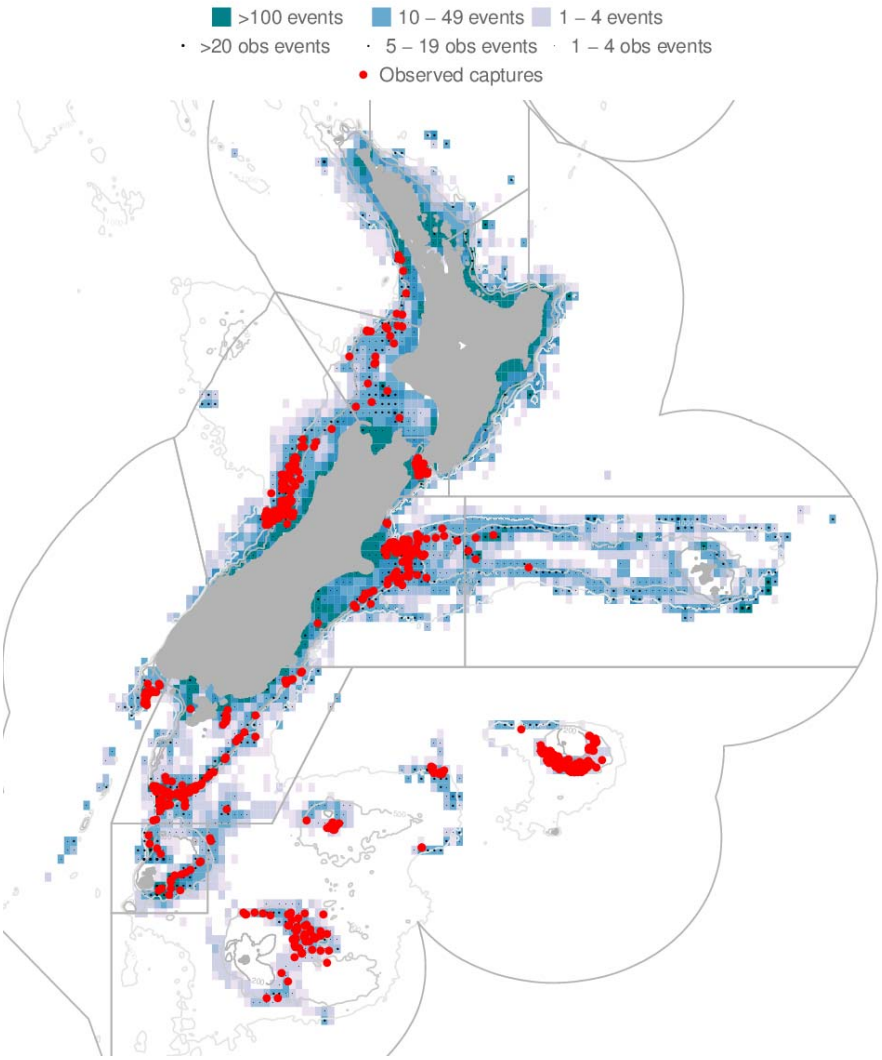


Figure 4.1: Distribution of trawl fishing effort and observed NZ fur seal captures, 2002-03 to 2013-14 (for more information see MPI data analysis at http://data.dragonfly.co.nz/psc/ data version v20150003). Fishing effort is mapped into 0.2-degree cells, coloured to represent the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing effort is shown for all tows with latitude and longitude data, where three or more vessels fished within a cell.

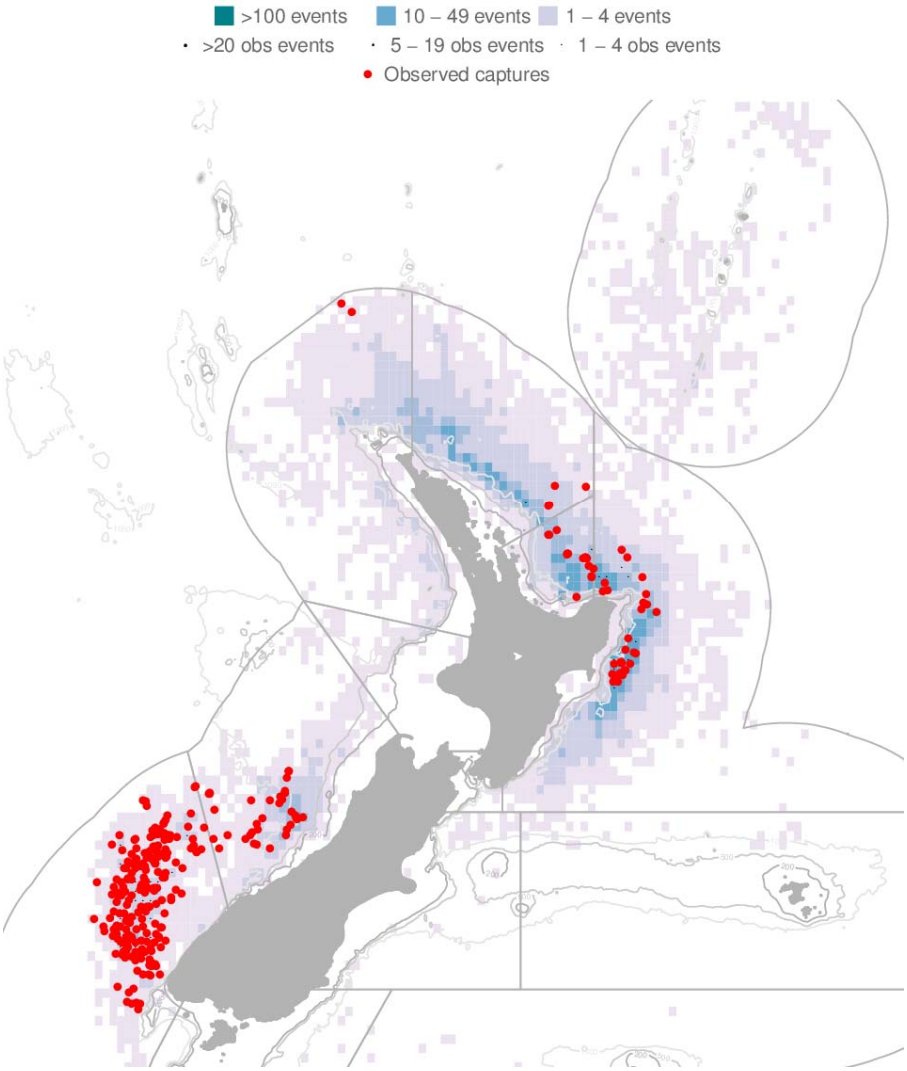


Figure 4.2: Distribution of surface longline fishing effort and observed NZ fur seal captures, 2002-03 to 2013-14 (for more information see MPI data analysis at http://data.dragonfly.co.nz/psc/ data version v20150003). Fishing effort is mapped into 0.2-degree cells, coloured to represent the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing effort is shown for sets with latitude and longitude data, where three or more vessels and three or more companies or persons fished within a cell. For these years, 89.4% of the effort is shown

4.4.1 QUANTIFYING FISHERIES INTERACTIONS

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

fisheries and Bounty Platform, Pukaki Rise, and Campbell Rise southern blue whiting fisheries, based on observed catches and stratified by area, season, and gear type (Baird 1994).[3]

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

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

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

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

[3] As part of its data reconciliation processes, MPI has identified that less than 2% of observed protected species captures between 2002 and 2015 were not recorded in Centralised Observer Database (COD). Steps are being taken to update the database and estimates of protected species captures and associated risks.

Accordingly, some estimates of protected species captures or risk in this fur seal chapter may have a small negative bias. Updated estimates will be reviewed by the Aquatic Environment Working Group in the second quarter of 2016.

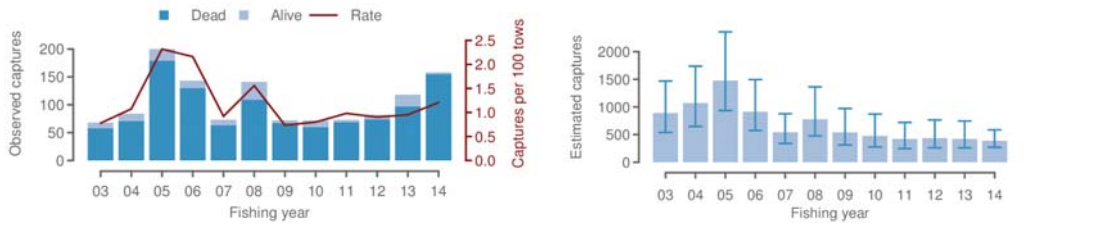
Table 4.1: Monthly distribution of NZ fur seal activity and the main trawl and longline fisheries with observed reports of NZ fur seal incidental captures.

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

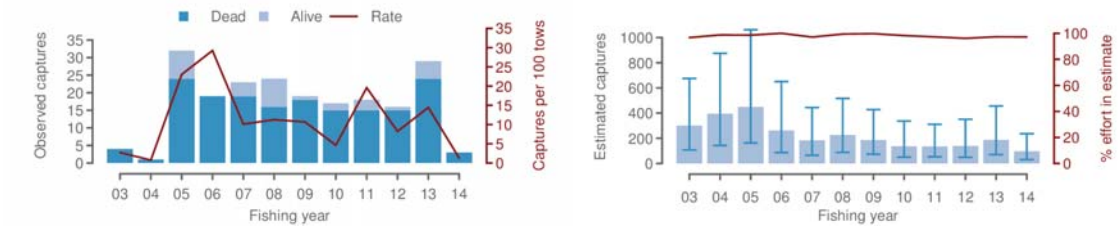
Table 4.2: Fishing effort and observed and estimated NZ fur seal captures in trawl and surface longline fisheries by fishing year in the New Zealand EEZ (Abraham et al in prep. and see MPI data analysis at http://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the total number of tows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

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Method	Mean	95% c.i.
Trawl fisheries							
1998-1999	153 412	4.7	190	2.62	Ratio	1 591	1 454-1 744
1999-2000	139 057	5.5	203	2.65	Ratio	1 539	1 400-1 693
2000-2001	134 243	6.8	170	1.87	Ratio	1 490	1 348-1 649
2001-2002	127 883	6	157	2.03	Ratio	1 273	1 164-1 394
2002-2003	130 172	6.7	68	0.78	Model	891	539-1 470
2003-2004	120 868	6.5	84	1.07	Model	1 070	647-1 737
2004-2005	120 447	7.2	200	2.32	Model	1 476	935-2 358
2005-2006	109 950	6.0	143	2.16	Model	912	574-1 495
2006-2007	103 316	7.7	73	0.92	Model	541	339-877
2007-2008	89 526	10.1	141	1.56	Model	777	476-1 362
2008-2009	87 551	11.2	72	0.73	Model	539	312-972
2009-2010	92 888	9.7	72	0.8	Model	475	277-871
2010-2011	86 090	8.6	73	0.98	Model	420	246-720
2011-2012	84 422	10.8	82	0.9	Model	436	261-764
2012-2013	83 839	14.8	118	0.95	Model	421	259-746
2013-2014	85 091	15.4	158	1.21	Model	387	270-586
Surface longline fisheries							
1998-1999	6 855 124	18.9	102	0.08	Ratio	138	120-160
1999-2000	8 258 537	10.4	42	0.05	Ratio	67	54-83
2000-2001	9 698 805	10.8	43	0.04	Ratio	64	51-83
2001-2002	10 833 533	9.1	44	0.04	Ratio	75	61-93
2002-2003	10 770 488	20.4	56	0.03	Ratio	185	148-230
2003-2004	7 386 484	21.8	40	0.03	Ratio	139	112-171
2004-2005	3 679 765	21.3	20	0.03	Ratio	71	54-91
2005-2006	3 690 869	19.1	12	0.02	Ratio	57	41-77
2006-2007	3 739 912	27.8	10	0.01	Ratio	56	41-73
2007-2008	2 246 139	18.8	10	0.02	Ratio	42	30-55
2008-2009	3 115 633	30.1	22	0.02	Ratio	55	42-69
2009-2010	2 995 264	22.2	19	0.03	Ratio	67	51-86
2010-2011	3 188 179	21.2	17	0.03	Ratio	58	43-76
2011-2012	3 100 177	23.5	40	0.05	Ratio	95	77-114
2012-2013	2 876 932	19.5	21	0.04	Ratio	80	62-100
2013-2014	2 546 764	30.4	56	0.07	Ratio	103	88-121

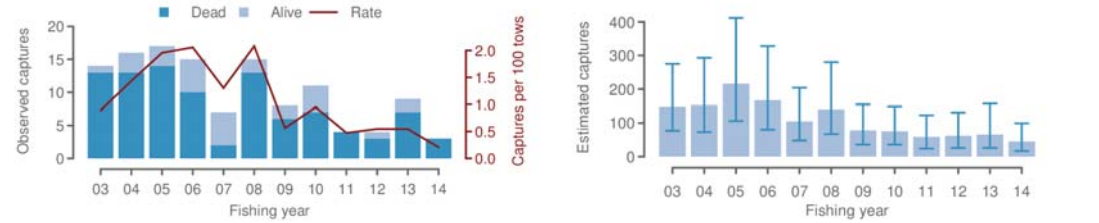
a) EEZ



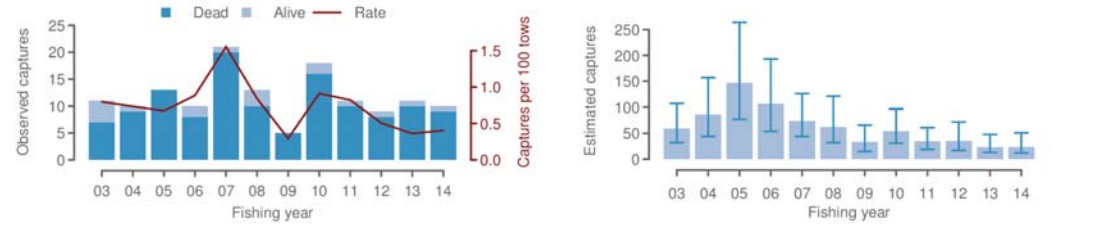
b) Cook Strait



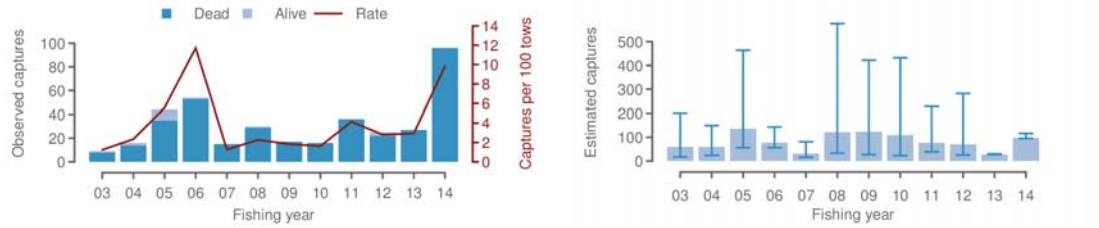
c) East Coast South Island



d) Stewart Snares shelf



e) Subantarctic area



f) West Coast South Island

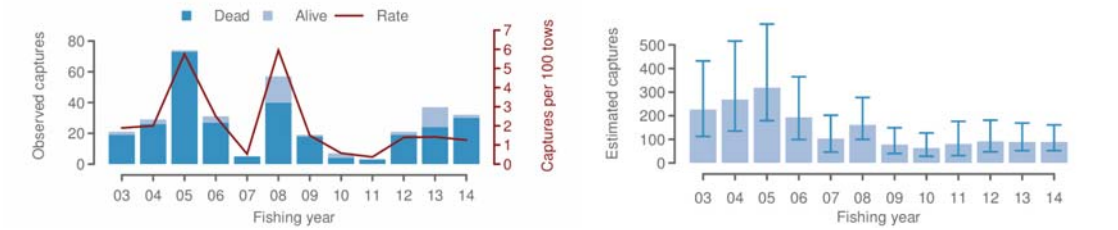


Figure 4.3: Observed captures of NZ fur seals (dead and alive) in trawl fisheries, the capture rate (captures per hundred tows) and the mean number of estimated total captures (with 95% confidence interval) by fishing year for regions with more than 50 observed captures since 2002-03: (a) New Zealand's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

4.4.2 MANAGING FISHERIES INTERACTIONS

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

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

4.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

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

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

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

4.4.4 SOURCES OF UNCERTAINTY

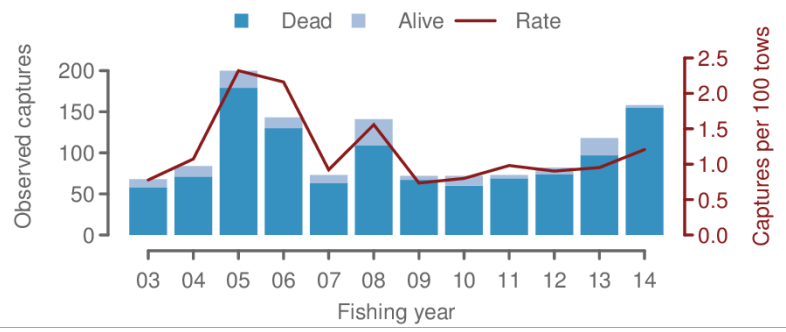
Any measure of the effect of NZ fur seal mortality from commercial fisheries on NZ fur seal populations requires adequate information on the size of the populations at different colonies. Although there is reasonable information about where the main NZ fur seal breeding colonies exist, the size and dynamics of the overall populations are poorly understood. At present, the main sources of uncertainty are the lack of consistent data on: abundance by colony and in total; population demographic parameters; and at-sea distribution (which would ideally be available at the level of a colony or wider

geographic area where several colonies are close together) (Baird 2011). Collation and analysis of existing data, such as that for the west coast South Island, would fill some of these gaps; there is a 20-year time series of pup production from three west coast South Island colonies, a reasonably long data series from the Otago Peninsula, and another from Kaikoura. Maximum benefit could be gained through the use of all available data, as shown by the monitoring of certain colonies of NZ fur seals in Australia to provide a measure of overall population stability (see Shaughnessy et al 1994, Goldsworthy et al 2003).

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

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

4.5 INDICATORS AND TRENDS

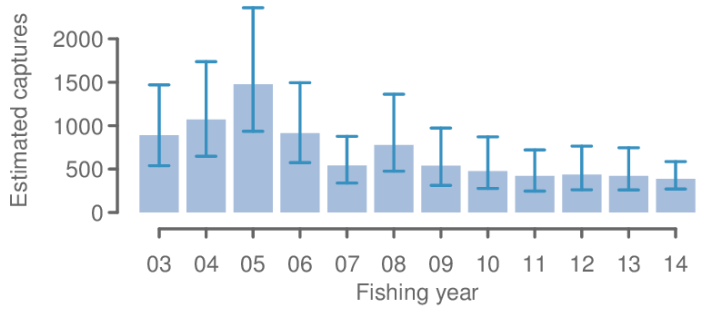
Population size	Unknown, but potentially ~100 000 in the New Zealand EEZ[4].
Population trend	Increasing at some mainland colonies but unknown for offshore island colonies. Range is thought to be increasing.
Threat status	NZ: Not Threatened, Increasing, Secure Overseas, in 2010[5]. IUCN: Least Concern, in 2008[6].
Number of interactions[7]	398 estimated captures (95% c.i.: 236–713) in trawl fisheries in 2012–13 110 estimated captures (95% c.i.: 65–171) in surface-longline fisheries in 2012–13 114 observed captures in trawl fisheries in 2012–13 21 observed captures in surface-longline fisheries in 2012–13
Trends in interactions	Trawl fisheries: 

[4] Taylor (1990), Harcourt (2001).

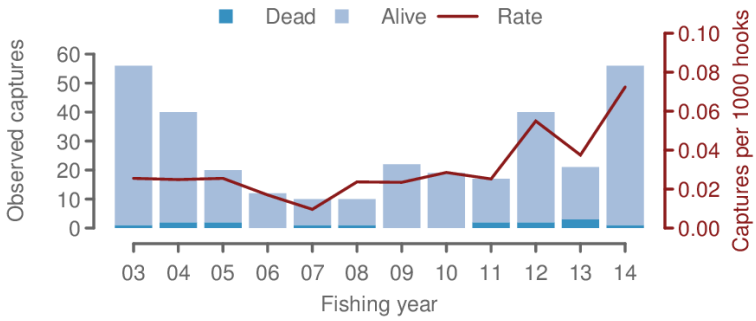
[5] Baker et al (2010b).

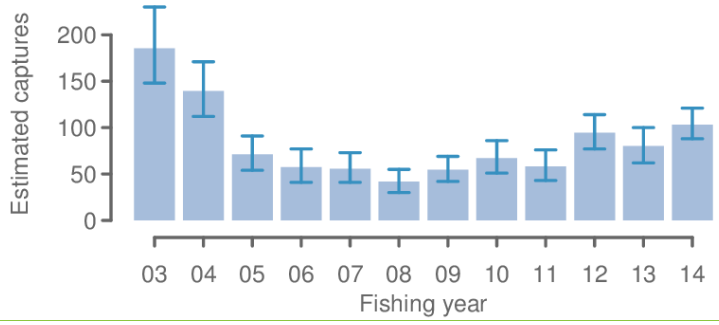
[6] Goldsworthy & Gales (2008).

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



Surface longline fisheries:





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

Scope of chapter	This chapter outlines the biology of Hector's dolphin (*Cephalorhynchus hectori hectori*) and Māui dolphin (*C. h. maui*), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	Areas with significant fisheries interactions include waters over or close to the continental shelf surrounding the South Island and the west coast of the North Island.
Key issues	Improving estimates of incidental capture in set net and trawl fisheries, and assessing the potential for populations to sustain the present levels of incidental capture.
Emerging issues	Improving data and information sources for future assessments of residual risk.
MPI Research (current)	PRO2009-01C *Abundance, distribution and productivity of Hector's (and Maui's) dolphins* (ECSI survey); PRO2012-02 *Assess the risk posed to marine mammal populations from New Zealand fisheries*; PRO2013-01 *Estimating the nature & extent of incidental captures of seabirds, marine mammals & turtles in New Zealand commercial fisheries*; PRO2013-06 *Abundance & distribution of WCSI Hector's dolphins*; PRO2013-08 *Reanalysis of aerial line transect surveys where best practice analysis was not used*; PRO2013-09 *Population viability of Maui's dolphins*.
NZ Government Research (current)	DOC Marine Conservation Services Programme (CSP): MIT2012-03 *Review of mitigation techniques in set net fisheries;* INT2013-01 *To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities*; INT2013-03 *To determine which marine mammal, turtle and protected fish species are captured in fisheries and their mode of capture*; INT2013-04 *To review the data collected by fisheries observers in relation to understanding the interaction with protected species, and refine efficient protocols for future data collection*; Additional conservancy-level work including aerial and boat surveys in Taranaki, genetic sampling and necropsies of recovered animals.
Other Research[1]	Otago University: Long term study of Hector's dolphins at Banks Peninsula, including distribution and abundance, survival rates, reproductive rates, movements, feeding ecology. Auckland University: Population monitoring of Maui's dolphins and population genetics of Hector's and Maui's dolphins. Massey University: Necropsy of recovered Hector's / Maui's dolphins.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts
Related chapters/issues	See the New Zealand sea lion and New Zealand fur seal chapters.

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

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

5.1 CONTEXT

Hector's and Māui dolphin[2] (*Cephalorhynchus hectori*), comprising the South Island sub-species referred to as Hector's dolphin (*C. h. hectori*) and the North Island sub-species known as Māui dolphin (*C. h. maui*), is endemic to the coastal waters of New Zealand. Like most other small cetaceans, the species is at risk of fisheries related mortality (e.g. Read et al 2006; Reeves et al 2013; Geijer & Read 2013).

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

The latest DOC Marine Mammal Action Plan[3] (DOC MMPA; Suisted & Neale 2004) stated that actions required include:

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

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

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

These goals were re-stated in the Review of the Māui dolphin TMP consultation paper published in 2012 (MPI & DOC 2012). The review of the Māui portion of the TMP provided a comprehensive overview of information relating to the biology, distribution, threats to, and management of Māui dolphins. To inform the review of the Māui dolphin TMP, a spatially-explicit, semi-quantitative risk assessment was conducted using an expert panel, to identify, analyse and evaluate all threats to Māui dolphins (Currey et al 2012). The process involved

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

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

expert panellists mapping dolphin distribution, identifying and characterising threats, scoring the likely impact of each threat, and subsequent quantitative analysis to estimate risk posed by threats. The results of this process are described in the relevant sections below.

5.2 BIOLOGY

5.2.1 TAXONOMY

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

5.2.2 DISTRIBUTION

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

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

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

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

There are reported public sightings of Hector's and Māui dolphins from all around the North Island coast, including the Bay of Islands, Hauraki Gulf, Coromandel Peninsula, Hawkes Bay, Wairarapa and Kapiti Coast (Baker 1978, Cawthorn 1988, Russell 1999, DOC Incident Database 2013). Pichler & Baker (2000) reported genetic analysis of

samples of Hector's and Māui dolphins dating back to 1870 and suggest that abundance has declined and geographic range has contracted over the past 140 years. It has also been suggested that Māui dolphin's range has contracted off the west coast of the North Island in recent history coincident with a decline in abundance (MPI & DOC 2012).

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

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

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

A map of Māui dolphin distribution[4] was developed as part of the Māui dolphin risk assessment (Currey et al 2012). The distribution was generated via generalised additive modelling (Thompson & Richard 2012) of systematic survey data (Ferreira & Roberts 2003, Slooten et al 2005, 2006, Scali 2006, Rayment & du Fresne 2007, Childerhouse et al 2008, Stanley 2009, Hamner et al 2012a) and modification to incorporate expert panel feedback regarding the alongshore, offshore and inshore extent (Figure 5.1; see Currey et al 2012 for further details).

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

5.2.3 FORAGING ECOLOGY

Miller et al (2013) investigated the diet of Hector's and Māui dolphins through the examination of diagnostic prey remains in the stomachs of 63 incidentally captured and beach-cast animals. They concluded that Hector's dolphins take a wide variety of prey throughout the water column (in total 29 taxa were recorded), but that the diet is dominated by a few mid-water and demersal species, particularly red cod (*Pseudophycis bachus*), ahuru (*Auchenoceros punctatus*), arrow squid (*Notodarus* sp.), sprat (*Sprattus* sp.), sole (*Peltorhamphus* sp.) and stargazer (*Crapatulus* sp.). Prey items ranged from an estimated 0.5–60.8 cm in length, but the majority were less than 10 cm in length, indicating that the juveniles of some species were targeted (Miller et al 2013). The diets of dolphins from the South Island west and east coasts were significantly different, due largely to the importance of javelinfish (*Lepidorhynchus denticulatus*) on the west coast, and a greater consumption of demersal prey species on the east coast (Miller et al 2013). Only two samples were derived from the west coast of the North Island, containing only red cod, ahuru, sole and flounder (Rhomboselea sp.; Miller et al 2013). The stomachs of the six smallest dolphins in the sample (standard length under 90 cm) contained only milk, while the next largest (99 cm standard length) contained milk and remains of arrow squid (Miller et al 2013). Milk was not found in the stomachs of any dolphins longer than 107 cm (Miller et al 2013).

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

5.2.4 REPRODUCTIVE BIOLOGY

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

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

Hector's and Māui dolphins are typically found in small groups of 1–14 individuals (Slooten et al 2006, Rayment et al 2010, 2011b, Oremus et al 2012). Mean group sizes appear to be larger when estimated from boat based surveys (e.g. Webster et al 2009, Oremus et al 2012)

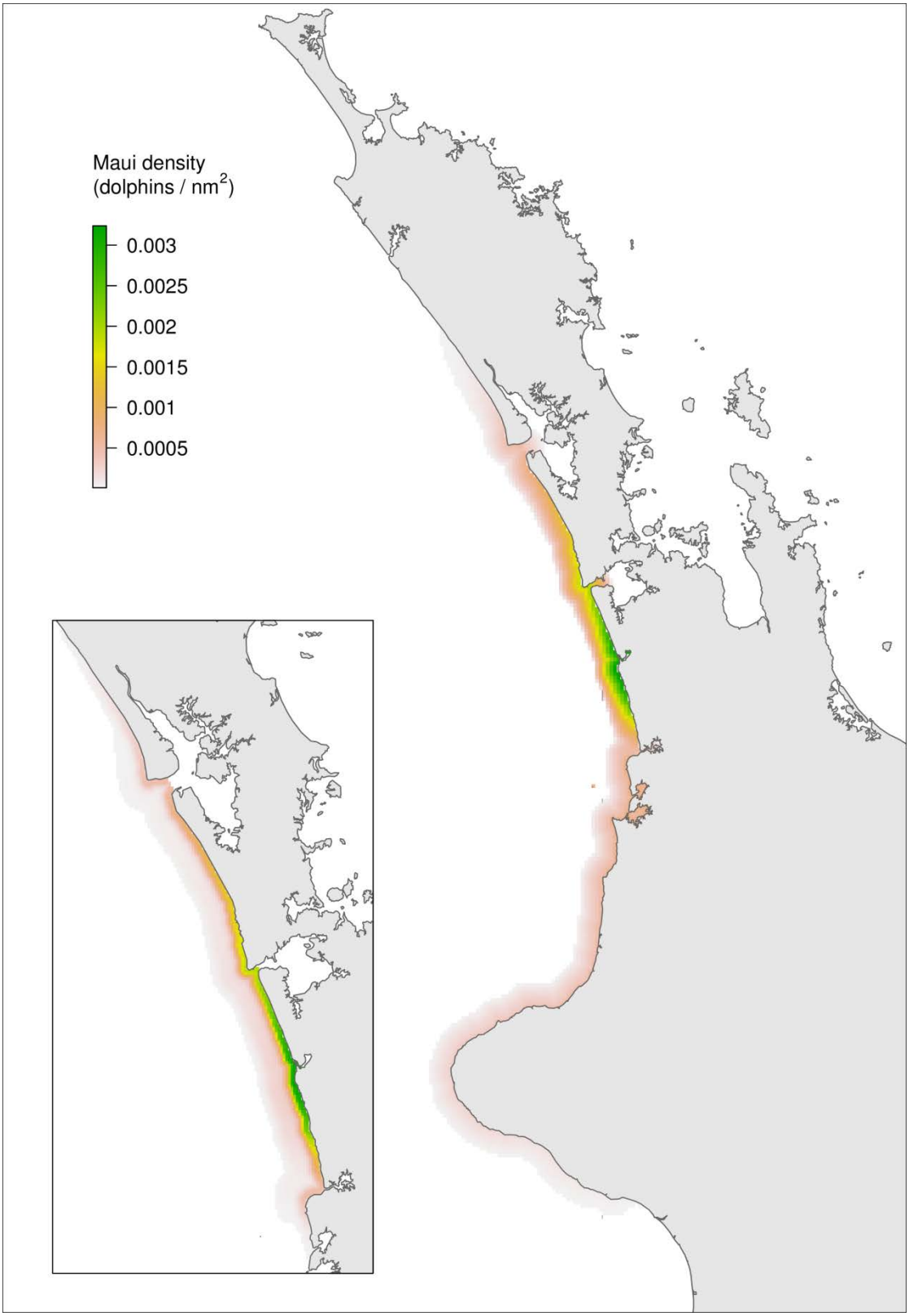

Figure 5.1: Māui dolphin distribution modelled from systematic survey data collected between 2000 and 2012 and modified to incorporate expert panel feedback (Currey et al 2012). The inset depicts the modelled distribution prior to modification (Thompson & Richard 2012).

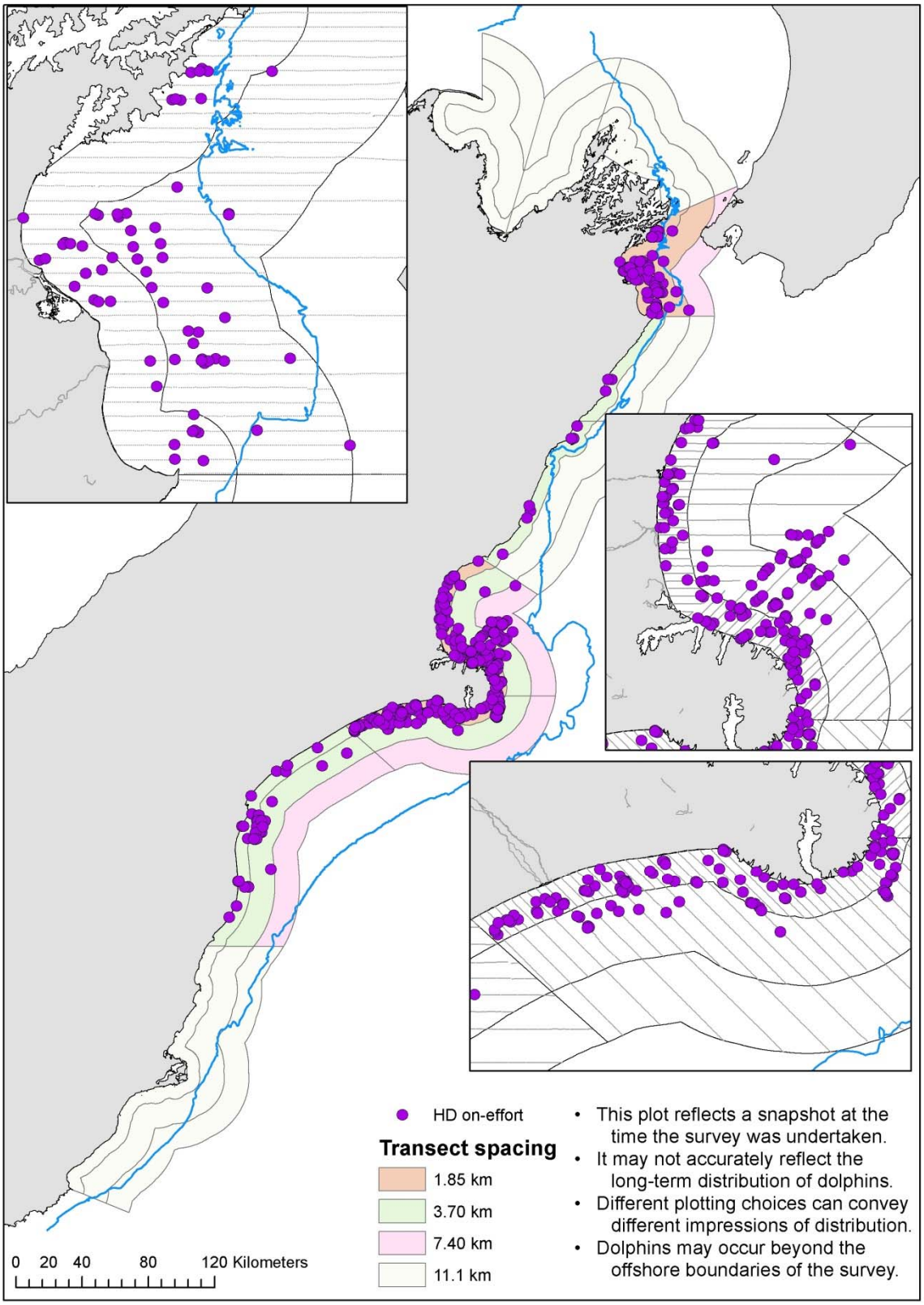

Figure 5.2: The distribution of all on-effort sightings of Hector's dolphins during the summer survey of the ECSI between 28 January and 13 March 2013. Reproduced from MacKenzie & Clement (2014).

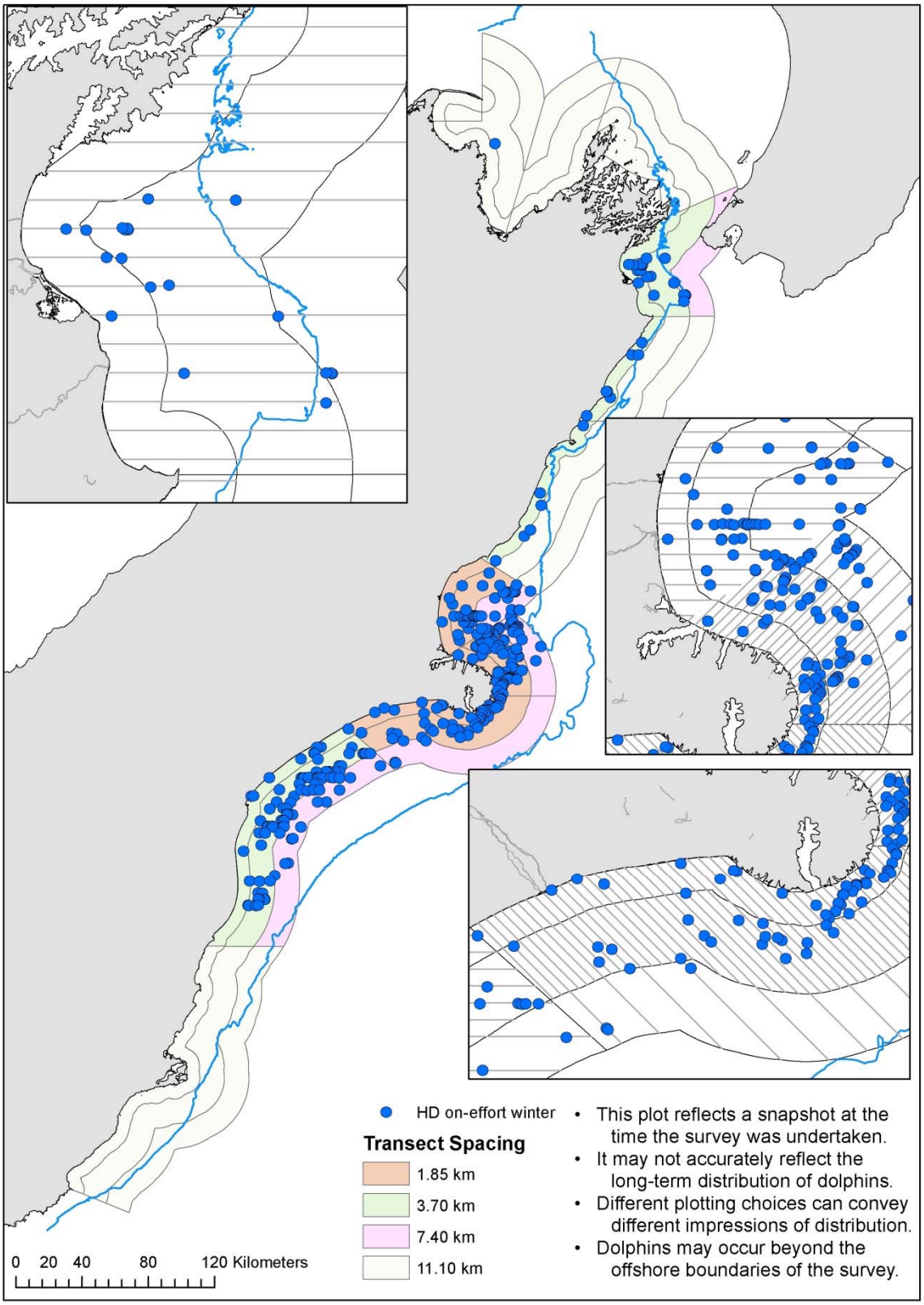

Figure 5.3: The distribution of all on-effort sightings of Hector's dolphins during the winter survey of the ECSI between 1 July and 18 August 2013. Reproduced from MacKenzie & Clement (2014).

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

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

5.2.5 POPULATION BIOLOGY

The earliest survey-based abundance estimate for Hector's and Māui dolphin (3408 animals with a suggested range of 3000 to 4000) was obtained via small boat-based strip transects surveys (Dawson & Slooten 1988, Table 5.1). These surveys were primarily focused on assessing alongshore distribution rather than abundance. Consequently survey effort was concentrated within 800 m of shore and calibrated with a limited number of 5 n.mi. offshore transects. Nationwide line transect surveys of Hector's and Māui dolphin were carried out between 1997 and 2004 (Dawson et al 2004, Slooten et al 2004, 2006). These resulted in a population estimate for Hector's dolphin around the South Island and offshore to 4 n.mi. of 7270 (CV = 16%; Slooten et al 2004) and for Māui dolphin of 111 (CV = 44%; Slooten et al 2006; The expert panel's assessment of mortalities can be treated as testable hypotheses (Currey et al 2012) and evaluated using new information. Roe et al 's (2013) finding that 2 of 3 Māui dolphins tested in the period 2007 to 2011 had died as a result of *Toxoplasma gondii* infection, possibly as a result of run off from terrestrial sources, indicates that the panel results (Table 5.3) may have underestimated mortality from this source. Roe et al (2013) note that toxoplasmosis may have other effects beyond direct mortality and could be an important cause of neonatal loss.

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

Conservation biology and threat classification

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

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

Table 5.1). Further aerial surveys focused on assessing seasonal and annual variation in distribution around Banks Peninsula (Rayment et al 2010) and in distribution and abundance in Cloudy and Clifford Bays (DuFresne & Mattlin 2009)[5]. There have also been a number of photo-ID mark-recapture estimates focused on sub-populations of Hector's dolphin (Bejder & Dawson 2001, Gormley et al 2005, Turek et al 2013; Table 5.1) and genotype mark-recapture estimates of abundance for Māui dolphin and Hector's dolphins in Cloudy Bay (Hamner et al 2012b, 2013, Baker et al 2013,Table 5.1). The genetic mark-recapture data yielded estimates of average annual population change for Māui dolphin of -0.13 (i.e. a 13% decrease p.a.; 95% CI = -0.40 to +0.14) for the period 2001 – 2007 (Baker et al 2013), and -0.03 (95% CI = -0.11 to +0.06) for the period 2001 – 2011 (Hamner et al 2012b). Population trends have also been inferred for Māui dolphins via other methods, including linear regression of the natural logarithm of abundance estimates obtained using a variety of survey methods over the period 1985 to 2011 (–0.032; 90% CI = –0.057 to –0.006 for aerial and boat surveys; –0.037; 90% CI = –0.042 to –0.032 for boat surveys alone; Wade et al 2012). Analysis of the Māui dolphin risk assessment expert panel's mortality scores yielded an estimated rate of population decline of 7.6% per annum (95% CI = 13.8% decline to 0.1% increase; Currey et al 2012). Across methods, estimates of Māui dolphin population trends indicate a high probability that the population is declining, with mean or median estimates suggesting a rate of decline at or above 3% per annum (Currey et al 2012, Hamner et al 2012b, Wade et al 2012, Baker et al 2013).

Recently, MPI-funded survey programmes (PRO2009-01A, PRO2009-01B, PRO2009-01C) were conducted to assess abundance and distribution of the SCSI and ECSI populations of Hector's dolphin (Clement et al 2011, MacKenzie et al 2012, MacKenzie & Clement 2014).The SCSI programme involved two aerial surveys undertaken during March 2010 and August 2010 between Puysegur Point and Nugget Point and out to the 100 m depth contour (PRO2009-01A, Clement et al 2011)[6]. Seven dolphin groups were sighted during summer/autumn surveys and ten groups were observed in winter. Sightings data pooled across seasons were analysed using mark-recapture distance sampling (MRDS) with helicopter-based dive cycle observations used to correct for availability bias. SCSI Hector's dolphin abundance was estimated to be 628 dolphins (CV = 38.9%, 95% CI = 301–1,311, Clement et al 2011).

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

Hector's dolphin is one of very few dolphin species for which estimates of survival are available. For long lived species, a long time-series of data is required to robustly estimate survival. The long term photo-ID study at Banks Peninsula has facilitated several survival rate estimates since its inception in 1984 (Slooten et al 1992, Cameron et al 1999, Du Fresne 2004, Gormley et al 2012). The most recent analysis utilises the most data and is therefore arguably the most powerful. Survival rate was estimated

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

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

as 0.863 (95% CI = 0.647 – 0.971) for the period 1986–1988, prior to the designation of the Banks Peninsula Marine Mammal Sanctuary, and 0.917 (95% CI = 0.802 – 0.984) from 1989–2006 after the designation (Gormley et al 2012). Given the reproductive parameters detailed above, these survival rate estimates equate to a mean estimated population growth rate of 0.939 (95% CI = 0.779 – 1.025) pre-sanctuary and 0.995 (95% CI = 0.927 – 1.048) post-sanctuary (Gormley et al 2012). In the post-sanctuary scenario, most of the uncertainty in the population growth estimate is due to uncertainty in the estimate of fecundity (Gormley et al 2012).

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

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

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

The presence of tourist vessels has been demonstrated to cause behavioural changes (Bejder et al 1999, Martinez et al 2012). There are potential negative effects due to bioaccumulation of organochlorines and heavy metals (reviewed by Slooten & Dawson 1994). Stockin et al (2010) reported elevated levels of PCBs and organochlorine pesticides in the tissues of Hector's and Māui dolphins but noted that no PCB concentrations were over the threshold considered to have immunological and reproductive effects. Additionally, both sub-species face pressures placed on coastal habitat through activities such as aquaculture, seabed mining, dredging and tidal energy installations (DOC & MFish 2007, Currey et al 2012, MPI & DOC 2012).

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

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

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

5.2.6 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

Threat classification is an established approach for identifying species at risk of extinction (IUCN 2013). The risk of extinction for Hector's and Māui dolphin has been

assessed under two threat classification systems: the New Zealand Threat Classification System (Townsend et al 2008) and the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2013).

The IUCN classifies Māui dolphin as Critically Endangered under criteria A4c,d and C2a(ii)[7] due to an ongoing and projected decline of greater than 80% over three generations, and there being fewer than 250 mature individuals remaining (Reeves et al 2013a). Critically Endangered is the most threatened status before "Extinct in the Wild". Hector's dolphin is classified by the IUCN as Endangered under criterion A4d[8] due to an ongoing and projected decline of greater than 50% over three generations (Reeves et al 2013b).

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

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

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

Sampling period	Sub-species	Survey area	Survey method	Analysis method	N	CV	95% CI	Reference
1984–1985	Hector's and Māui dolphin	North and South Islands	Small boat based strip-transect	Distance sampling	3408		3000 – 4000 (range)	Dawson & Slooten 1988
1989–1997	Hector's dolphin	Banks Peninsula	Photo-ID	Mark-recapture	1119	0.21	744 – 1682	Gormley et al 2005
1995–1997	Hector's dolphin	Porpoise Bay	Photo-ID	Mark-recapture	48		44 – 55	Bejder & Dawson 2001
1997–1998	Hector's dolphin	Motunau – Timaru (0 – 4 n.mi.)	Boat based line-transect	Distance sampling	1198	0.27	848 – 1693	Dawson et al 2004
1998–1999	Hector's dolphin	Timaru – Long Point (0 – 4 n.mi.)	Boat based line-transect	Distance sampling	399	0.26	279 – 570	Dawson et al 2004
1999–2000	Hector's dolphin	Farewell Spit – Motunau (0 – 4 n.mi.)	Boat based line-transect	Distance sampling	285	0.39	137 – 590	Dawson et al 2004
2000–2001	Hector's dolphin	Farewell Spit – Milford Sound (0 – 4 n.mi.)	Aerial line-transect	Distance sampling	5388	0.21	3613 – 8034	Slooten et al 2004
2001–2007	Māui dolphin	Kaipara Harbour – Tirua Point	Biopsy	Mark-recapture	59		19 – 181	Baker et al 2013
2004	Māui dolphin	Maunganui Bluff – Pariokariwa Point (0 – 4 n.mi.)	Aerial line-transect	Distance sampling	111	0.44	48 – 252	Slooten et al 2006
2004–2005	Hector's dolphin	Te Waewae Bay	Photo-ID	Mark-recapture	251 (autumn)	0.162	183 – 343	Green et al 2007
					403 (summer)	0.121	280 – 488	
2006–2009	Hector's dolphin	Cloudy and Clifford Bays (100 m contour)	Aerial line-transect	Distance sampling	951 (summer)	0.26	573 – 1577	DuFresne & Mattlin 2009
					927 (autumn)	0.30	520 – 1651	
					315 (winter)	0.31	173 – 575	
					188 (spring)	0.33	100 – 355	
2010	Hector's dolphin	Puysegur Point - Nugget Point (100 m contour)	Aerial line-transect	Distance sampling	628	0.39	301 – 1311	Clement et al 2011
2010–2011	Māui dolphin	Kaipara Harbour – New Plymouth	Biopsy	Mark-recapture	57*		49 – 71	Hamner et al 2012b
2010–2011	Hector's dolphin	Taiaroa Head – Cornish Head (Otago)	Photo-ID	Mark-recapture	42	0.41	19 – 92	Turek et al 2013
2011–2012	Hector's dolphin	Cloudy Bay	Biopsy	Mark-recapture	272	0.12	236 – 323	Hamner et al 2013
2012–2013	Hector's dolphin	Farewell Spit - Nugget Point (0 – 20 n.mi.)	Aerial line-transect	Mark-recapture distance sampling	9130 (summer)	0.19	6342 – 13144	MacKenzie & Clement 2014
					7456 (winter)	0.18	5224 – 10641	

Under the New Zealand Threat Classification System (Baker et al 2010), Māui dolphin is classified as Nationally Critical, the most threatened status, under criterion A(1), with the qualifier Conservation Dependent (CD)[9] and Hector's dolphin as Nationally Endangered, the second most threatened status, under criterion C(1/1), with the qualifier Conservation Dependent (CD)[10].

5.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

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

5.4 STATE OF KNOWLEDGE IN NEW ZEALAND

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

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

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

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

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

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

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

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

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

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

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

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

	Cause of death	ECSI	WCSI	SCSI	WCNI	Unknown population
Known entanglement[11]	Commercial setnetset net	41	2	0	0	2
	Recreational setnetset net	12	9	0	0	0
	Unknown setnetset net	15	6	0	2	1
	Trawl net	15	4	0	0	0
Probable entanglement[12]	Commercial setnetset net	0	0	0	0	0
	Recreational setnetset net	0	0	0	0	0
	Unknown setnetset net	1	4	0	0	0
	Unknown net	8	4	1	1	0
Possible entanglement[13]	Commercial setnetset net	0	0	0	0	0
	Recreational setnetset net	1	0	0	0	0
	Unknown setnetset net	16	10	0	0	0
	Unknown net	16	7	1	2	0

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

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

11 Animal was known (from incident report) to have been entangled and died.

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

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

5.4.1 QUANTIFYING FISHERIES INTERACTIONS

Prior to 2012, the only observer programme with sufficient coverage to yield a robust estimate of the rate of incidental capture of Hector's dolphins in inshore commercial set nets (Baird & Bradford 2000) was an observer programme in Statistical Areas 018, 020 and 022 (FMA 3) on the east coast of the South Island in the 1997-98 fishing year which observed 214 inshore set net events, targeting shark species and elephant fish. Eight Hector's dolphins were caught in five sets, of which two were released alive. Capture rates were most precise in area 022, where six of the catches were reported, following observer coverage of 39% (Baird & Bradford 2000). Capture rate was estimated at 0.064 dolphins per set (CV = 43%) in area 022 and 0.037 dolphins per set (CV = 39%) in areas 020 and 022 combined (Baird & Bradford 2000). A total of 16 dolphins (CV = 43%) were estimated caught in area 022 with 18 dolphins (CV = 38%)[14] estimated caught in areas 020 and 022 combined (Baird & Bradford 2000). The authors stress that the preceding estimates are of dolphins caught, and not necessarily of mortalities (Baird & Bradford 2000). Note also that these estimates are from statistical areas containing the Banks Peninsula Marine Mammal Sanctuary, which at that time effectively prohibited commercial set netting between Sumner Head and the Rakaia River out to 4 n.mi. from the coast (Dawson & Slooten 1993).

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

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

In the 2012-13 year, the inshore set-net fishery operating in Statistical Areas 022 and 024 was observed by human observers and electronic monitoring. During that time, at least two Hector's dolphins were captured, with one released alive. The percentage of observer coverage in this fishery and estimated captures will be estimated under PRO2013-01.[15]

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

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

Until recently, no attempt to quantify total captures of Māui dolphins in set nets or trawls using population-

[15] As part of its data reconciliation processes, MPI has identified that less than 2% of observed protected species captures between 2002 and 2015 were not recorded in Centralised Observer Database (COD). Steps are being taken to update the database and estimates of protected species captures and associated risks.
Note that no observed captures of Hector's or Māui dolphins have been identified as absent from COD.

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

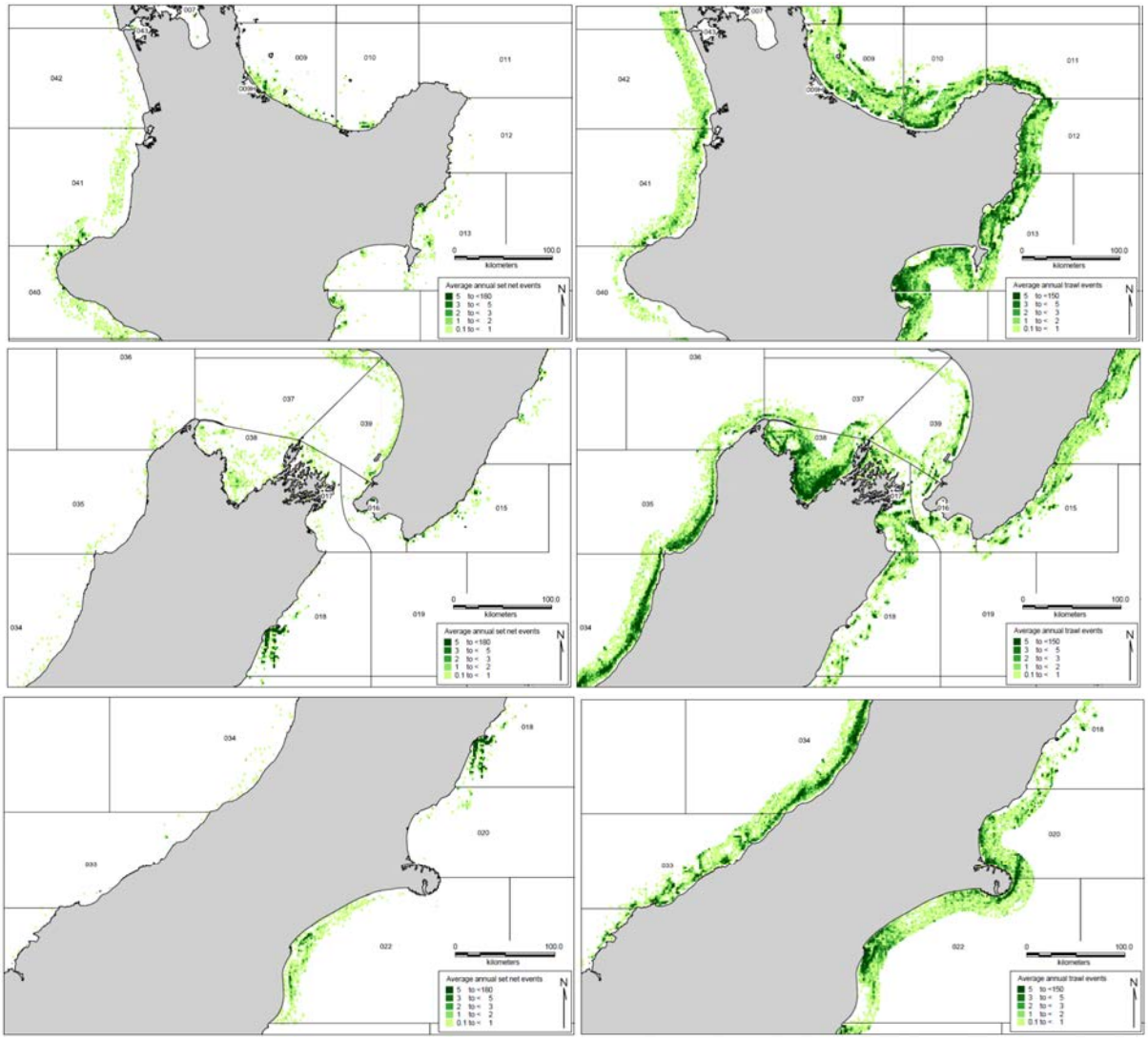

Figure 5.4: The distribution of set net (left) and trawl (right) fishing events 2007–08 to 2009–10 (from www.fish.govt.nz/en-nz/Commercial/About+the+Fishing+Industry/Maps+of+Commercial+Inshore+Fishing+Activity/) to show the general spatial pattern of fishing activity. The annual average number of events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

5.4.2 MANAGING FISHERIES INTERACTIONS

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

The first spatial closure implemented to mitigate the risk of Hector's dolphin incidental capture was designated at Banks Peninsula in 1988 (Dawson & Slooten 1993). Commercial set netting was effectively prohibited out to 4 n.mi. from the coast and recreational set netting was subject to seasonal restrictions (Dawson & Slooten 1993). A second was designated off the WCNI in 2003. All set nets were prohibited to 4 n.mi. offshore (DOC & MFish 2007). In 2008, a more extensive package of spatial closures was implemented by the Minister of Fisheries (see review by Slooten 2013), providing some protection in most of the areas where Hector's and Māui are found and largely superseding the two existing discrete closures. The set net restrictions on the WCNI were extended to 7 n.mi. offshore between Maunganui Bluff and Pariokariwa Point (including the entrances to the Kaipara, Manukau and Raglan Harbours and the entrance to the Waikato River), most set netting was prohibited within 4 n.mi. of the coast on the ECSI and SCSI, and recreational set netting was banned on the WCSI within 2 n.mi. of the coast and commercial set netting was subject to a seasonal restriction (Figure 5.5). Trawling was banned on the WCNI to 2 n.mi. offshore between Maunganui Bluff and Pariokariwa Point and 4 n.mi. offshore between Manukau Harbour and Port Waikato, and restricted within 2 n.mi. offshore on the ECSI and SCSI[16] (Figure 5.6). In 2012, the set net restrictions on the WCNI were extended further south, banning commercial and recreational set netting to 2 n.mi. offshore from Pariokariwa Point to Hawera and requiring an MPI observer on any commercial set net vessel operating between 2 and 7 n.mi. (Figure 5.5).

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

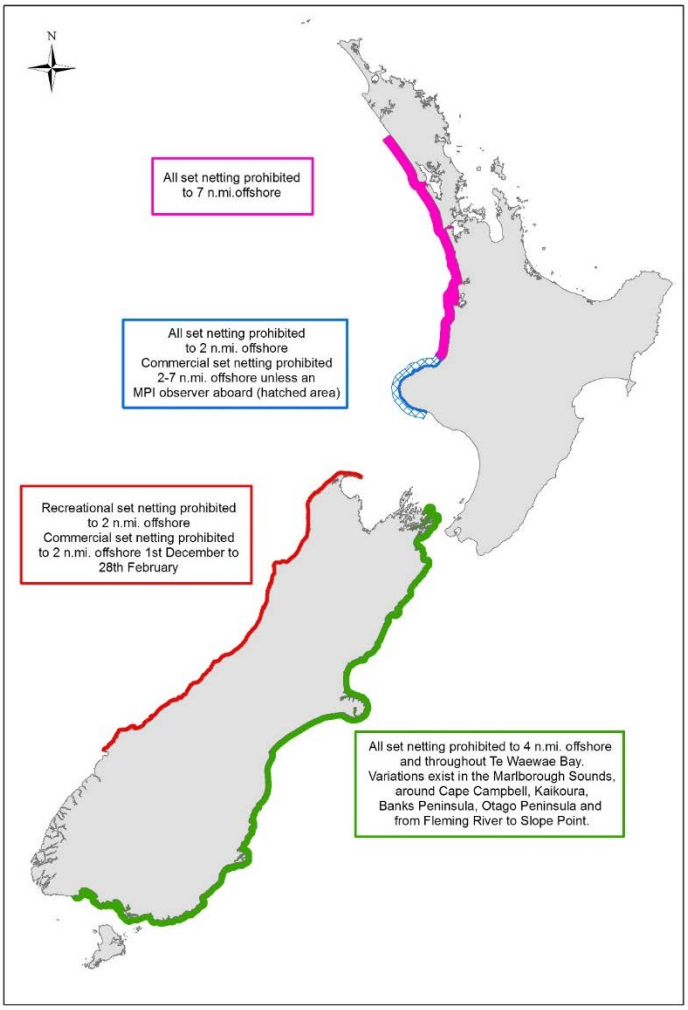

Figure 5.5: Summary of restrictions on commercial and amateur set netting. For a full description of the restrictions, for example in NIWC harbours and variations on ECSI and SCSI, see http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins.

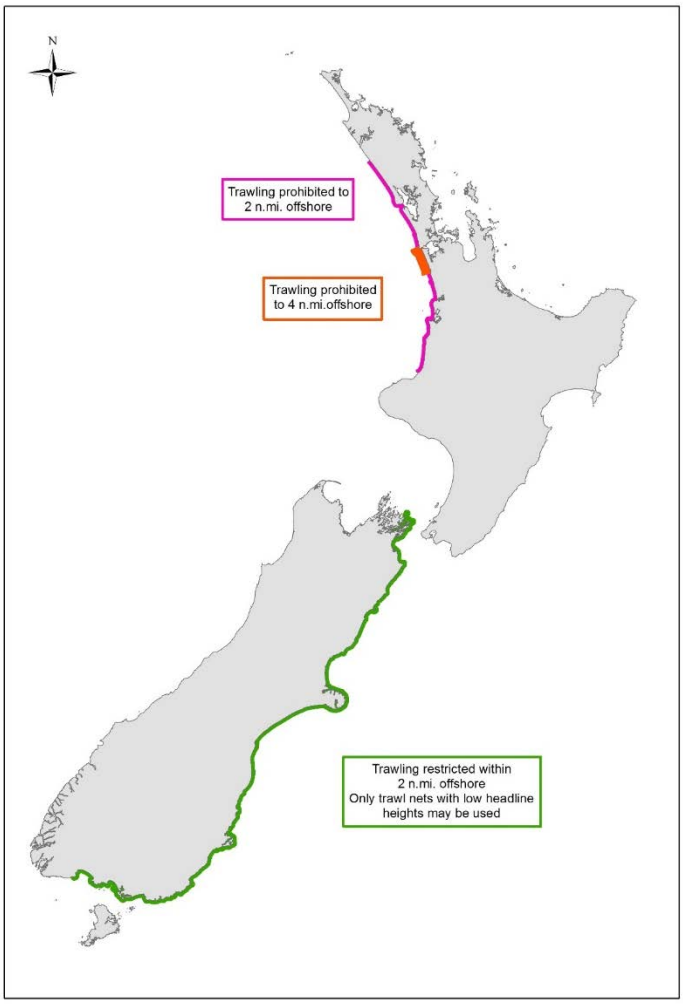

Figure 5.6: Summary of restrictions on trawling. For a full description of the restrictions see http://www.fish.govt.nz/en-nz/Environmental/Hectors+Dolphins.

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

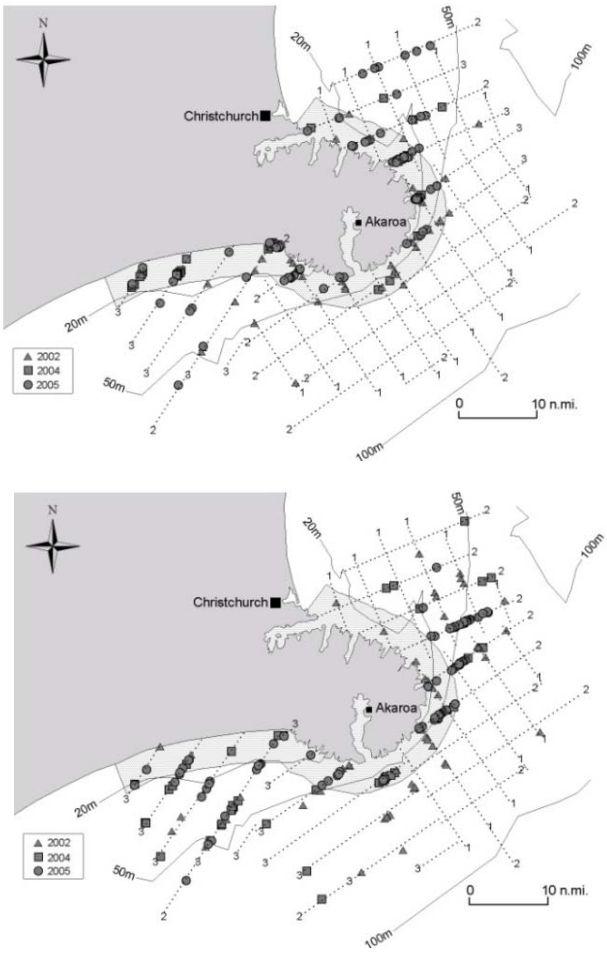

Figure 5.7: Transects and Hector's dolphin sightings on (top) three summer surveys, and (bottom) three winter surveys around Banks Peninsula. Numbers at the end of transect lines are the number of years each line was surveyed. Reproduced from Rayment et al (2010).

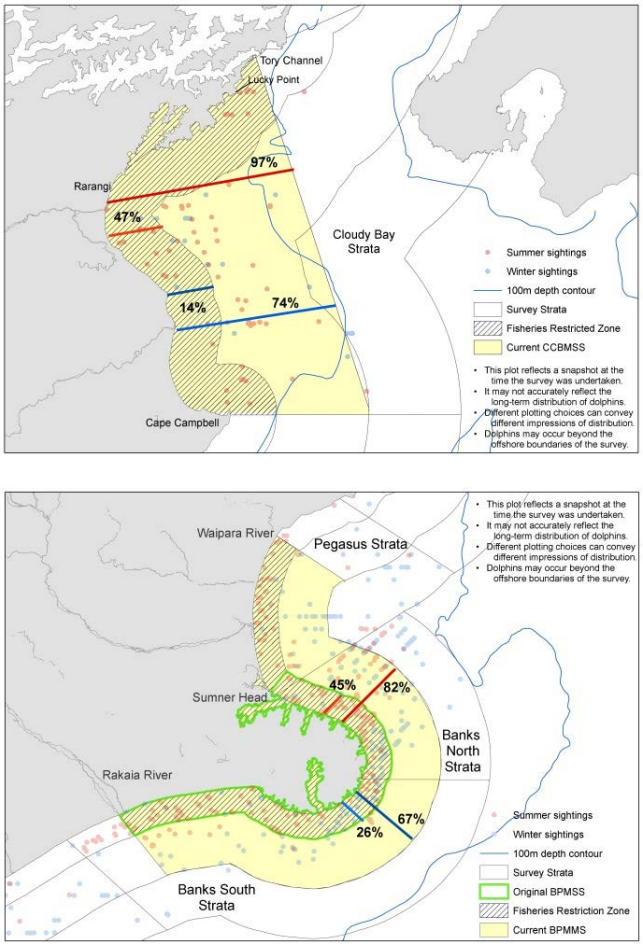

Figure 5.8: The location of summer (red) and winter (blue) survey sightings in relation to fisheries restriction zones and marine mammal sanctuary (MMS) boundaries around Clifford and Cloudy Bays (CCB, top) and Banks Peninsula (BP, bottom). Lines and associated percentages represent proportion of the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

5.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

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

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

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

Martien et al (1999) employed a simple logistic ("Schaefer") population model and projected numbers back to 1970, and forward 200 years, from the 1985 abundance estimate published by Dawson & Slooten (1988). Three separate populations were modelled (WCNI, WCSI and a population that included both ECSI and SCSI populations). Using Dawson's (1991) estimates of mortality from the ECSI area, the back calculation suggested a total of 7077 dolphins across the three populations in 1970, if maximum population growth rate

was 4.4%, and 7957 if maximum population growth rate was 1.8% per annum. Martien et al (1999) considered that the 1985 estimate of abundance was likely to be a slight underestimate (because transects to assess offshore distribution extended only 5 n.mi. offshore), but suggested that any resulting bias in the estimate of the level of the population as a proportion of carrying capacity was likely to be small. The ESCI population was projected to increase for all combinations of parameters except when the maximum growth rate was set to 1.8%.

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

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

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

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

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

The AEWG agreed that:

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

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

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

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

The likely magnitude of human induced impacts on Māui dolphin was estimated in a risk assessment workshop (Currey et al 2012). Population projections based on the estimated total mortalities indicated a 95.7% likelihood that the population would decline if the threats remain at the levels assessed to pertain before the introduction of

the 2012 interim measures (Currey et al 2012). The estimated human induced mortalities equate to a level of impact 75.5 times (95% CI = 12.4 to 150.7 times; Currey et al 2012) higher than the estimated PBR (one dolphin every 10 to 23 years, Wade et al 2012).

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

5.4.4 SOURCES OF UNCERTAINTY

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

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

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

CAPTURE ESTIMATES AND CAPTURE RATE

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

CRYPTIC MORTALITY

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

DEMOGRAPHIC PARAMETERS

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

POPULATION ESTIMATES FOR THE WCSI POPULATION

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

POPULATION CONNECTIVITY AND MOVEMENT

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

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

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

5.4.5 POTENTIAL INDIRECT THREATS

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

5.5 INDICATORS AND TRENDS

Population size	Māui dolphins: 55 (95% CI = 48–69) in 2010–2011. ECSI Hector's dolphins: 9130 (CV = 19%; 95% CI = 6342–13 144) in summer 2012-13 and 7456 (CV = 18%; 95% CI = 5224–10 641) in winter 2013. WCSI Hector's dolphins: 5388(CV = 21%; 95% CI = 3613–8034) in 2000-01. SCSI Hector's dolphins: 628 (CV = 38.9%; 95% CI = 301–1311) in 2011.
Population trend	Māui dolphins: Declining. Consistent evidence from multiple methods. ECSI Hector's dolphins: Probably declining. Inconsistent evidence from abundance estimates, risk analyses and demographic estimates of population growth rate. WCSI Hector's dolphins: Probably declining, assuming ECSI estimates of capture rate and productivity are applied to this area via risk analyses. There has been a substantial reduction in commercial set net effort on the WCSI since 2008 which may have resulted in a reduction in captures. SCSI Hector's dolphins: Unknown. Inconsistent evidence from abundance estimates and risk analyses.
Threat status	Māui dolphins: NZ: Nationally Critical, Criterion A(1), Conservation Dependent in 2010 IUCN: Critically Endangered, Criteria A4c,d and C2a(ii) in 2013 Hector's dolphins: NZ: Nationally Endangered, Criterion C(1/1), Conservation Dependent in 2010 IUCN: Endangered, Criterion A4d in 2013
Number of interactions[17]	Māui dolphins: <1 per annum (Davies et al 2008), 4.97 per annum (95% CI: 0.28–8.04; Currey et al 2012) ECSI Hector's dolphins: 35 to 50 per annum (Davies et al 2008) WCSI Hector's dolphins: 70 to 100 per annum (Davies et al 2008) SCSI Hector's dolphins: about 2 per annum (Davies et al 2008)
Trends in interactions	Possible reduction from 35 to 50 per annum (Davies et al 2008) to about 23 for ECSI (Slooten & Davies 2012). No estimates for other areas.

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

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6 NEW ZEALAND SEABIRDS

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

Note: This Chapter has been partially updated (capture estimates) for the AEBAR 2015.

6.1 CONTEXT

Seabird names and taxonomy in this document generally follow that adopted by the Ornithological Society of New Zealand (OSNZ 2010) except where a different classification has been agreed by the parties to the Agreement for the Conservation of Albatrosses and Petrels, ACAP, or the New Zealand Threat Classification Scheme (NZTCS) classifies multiple taxa within a single OSNZ species (There are probably more than 10 000 bird species worldwide, but fewer than 400 are classified as seabirds (being specialised marine foragers). All but seven seabird taxa in New Zealand are absolutely protected under s.3 of the Wildlife Act 1953, meaning that it is an offence to hunt or kill them. Southern black-backed gull, *Larus dominicanus*, is the only species that is not protected. Black shag, *Phalacrocorax carbo*, and subantarctic skua, *Catharacta antarctica lonnbergi*, are partially protected, and sooty shearwater, *Puffinus griseus*, grey-faced petrel, *Pterodroma macroptera*, little shag, *Phalacrocorax melanoleucos brevirostris*, and pied shag, *Phalacrocorax varius*, may be hunted or killed subject to Minister's notification. Of the 85 seabird taxa that breed in New Zealand waters, 47 are considered threatened (by far the largest number in the world). For albatrosses and petrels, a key threat is injury or death in fishing operations, although the Wildlife Act provides defences if the accidental or incidental death or injury took place in the course of fishing pursuant to a permit, licence, authority, or approval issued, granted, or given under the Fisheries Act 1996, as long as the interaction is reported. Commercial fishers are required to complete a Non-Fish and Protected Species Catch Return (NFPSCR, s11E of the Fisheries (Reporting) Regulations 2001).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Common name	Scientific name	DOC category	IUCN category
Wandering albatross	*Diomedea exulans*	Non-Resident Native: Migrant	Vulnerable
Antipodean albatross	*Diomedea antipodensis*	Threatened: Nationally Critical	#Vulnerable
Gibson's albatross	*Diomedea antipodensis gibsonii*	Threatened: Nationally Critical	#Vulnerable
Southern royal albatross	*Diomedea epomophora*	At Risk: Naturally Uncommon	Vulnerable
Northern royal albatross	*Diomedea sanfordi*	At Risk: Naturally Uncommon	Endangered
Black-browed albatross	*Thalassarche melanophris*	Non-Resident Native: Coloniser	#Endangered
Campbell black-browed albatross	*Thalassarche impavida*	At Risk: Naturally Uncommon	#Endangered
Southern Buller's albatross	*Thalassarche bulleri*	At Risk: Naturally Uncommon	#Near
Northern Buller's albatross	*Thalassarche bulleri platei.*	At Risk: Naturally Uncommon	#Near
White-capped albatross	*Thalassarche steadi**	At Risk: Declining	Near Threatened
Salvin's albatross	*Thalassarche salvini*	Threatened: Nationally Critical	Vulnerable
Chatham Island albatross	*Thalassarche eremita*	At Risk: Naturally Uncommon	Vulnerable
Indian yellow-nosed albatross	*Thalassarche carteri*	Non-Resident Native: Coloniser	Endangered
Grey-headed albatross	*Thalassarche chrysostoma*	Threatened: Nationally	Vulnerable
Light mantled sooty albatross	*Phoebetria palpebrata*	At Risk: Declining	Near Threatened
Flesh-footed shearwater	*Puffinus carneipes*	Threatened: Nationally	Least Concern
Wedge-tailed shearwater	*Puffinus pacificus*	At Risk: Relict	Least Concern
Buller's shearwater	*Puffinus bulleri*	At Risk: Naturally Uncommon	Vulnerable
Sooty shearwater	*Puffinus griseus*	At Risk: Declining	Near Threatened
Short-tailed shearwater	*Puffinus tenuirostris*	Non-Resident Native: Migrant	Least Concern
Fluttering shearwater	*Puffinus gavia*	At Risk: Relict	Least Concern
Hutton's shearwater	*Puffinus huttoni*	At Risk: Declining	Endangered
Kermadec little shearwater	*Puffinus assimilis kermadecensis*	At Risk: Relict	#Least Concern
North Island little shearwater	*Puffinus assimilis haurakiensis*	At Risk: Declining	#Least Concern
Subantarctic little shearwater	*Puffinus elegans*	At Risk: Naturally Uncommon	#Least Concern
Northern diving petrel	*Pelecanoides urinatrix urinatrix*	At Risk: Relict	#Least Concern
Southern diving petrel	*Pelecanoides urinatrix*	At Risk: Relict	#Least Concern
Subantarctic diving petrel	*Pelecanoides urinatrix exsul*	Non-Resident Native: Coloniser	#Least Concern
South Georgian diving petrel	*Pelecanoides georgicus* †	Threatened: Nationally Critical	Least Concern
Grey petrel	*Procellaria cinerea*	At Risk: Naturally Uncommon	Near Threatened
Black petrel	*Procellaria parkinsoni*	Threatened: Nationally	Vulnerable
Westland petrel	*Procellaria westlandica*	At Risk: Naturally Uncommon	Vulnerable
White-chinned petrel	*Procellaria aequinoctialis*	At Risk: Declining	Vulnerable
Kerguelen petrel	*Lugensa brevirostris*	Non-Resident Native: Migrant	Least Concern
Southern Cape petrel	*Daption capense capense*	Non-Resident Native: Migrant	#Least Concern
Snares Cape petrel	*Daption capense australe*	At Risk: Naturally Uncommon	#Least Concern
Antarctic fulmar	*Fulmarus glacialoides*	Non-Resident Native: Migrant	Least Concern
Southern giant petrel	*Macronectes giganteus*	Non-Resident Native: Migrant	Least Concern
Northern giant petrel	*Macronectes halli*	At Risk: Naturally Uncommon	Least Concern
Fairy prion	*Pachyptila turtur*	At Risk: Relict	Least Concern
Chatham fulmar prion	*Pachyptila crassirostris*	At Risk: Naturally Uncommon	#Least Concern
Lesser fulmar prion	*Pachyptila crassirostris flemingi*	At Risk: Naturally Uncommon	#Least Concern

Table 6.1 [Continued]:

Common name	Scientific name	DOC category	IUCN category
Thin-billed prion	*Pachyptila belcheri*	Non-Resident Native: Migrant	Least Concern
Antarctic prion	*Pachyptila desolata*	At Risk: Naturally Uncommon	Least Concern
Salvin's prion	*Pachyptila salvini*	Non-Resident Native: Migrant	–
Broad-billed prion	*Pachyptila vittata*	At Risk: Relict	Least Concern
Blue petrel	*Halobaena caerulea*	Non-Resident Native: Migrant	Least Concern
Pycroft's petrel	*Pterodroma pycrofti*	At Risk: Declining	Vulnerable
Cook's petrel	*Pterodroma cookii*	At Risk: Relict	Vulnerable
Cook's petrel	*Pterodroma cookii*	At Risk: Relict	Vulnerable
Black-winged petrel	*Pterodroma nigripennis*	Not Threatened	Least Concern
Chatham petrel	*Pterodroma axillaris*	Threatened	Endangered
Mottled petrel	*Pterodroma inexpectata*	At Risk: Relict	Near Threatened
White-naped petrel	*Pterodroma cervicalis*	At Risk: Relict	Vulnerable
Kermadec petrel	*Pterodroma neglecta*	At Risk: Relict	Least Concern
Grey-faced petrel	*Pterodroma macroptera gouldi*	Not Threatened	Least Concern
Chatham Island taiko	*Pterodroma magentae*	Threatened: Nationally Critical	Critically
White-headed petrel	*Pterodroma lessonii*	Not Threatened	Least Concern
Soft-plumaged petrel	*Pterodroma mollis*	Non-Resident Native: Coloniser	Least Concern
Wilson's storm petrel	*Oceanites oceanicus*	Non-Resident Native: Migrant	Least Concern
Kermadec storm petrel	*Pelagodroma albiclunis*	Threatened: Nationally Critical	–
New Zealand storm petrel	*Pealeornis maoriana*	Threatened: Nationally	Critically
Grey-backed storm petrel	*Garrodia nereis*	At Risk: Relict	Least Concern
New Zealand white-faced storm	*Pelagodroma marina maoriana*	At Risk: Relict	#Least Concern
Black-bellied storm petrel	*Fregetta tropica*	Not Threatened	Least Concern
White-bellied storm petrel	*Fregetta grallaria grallaria*	Threatened: Nationally	Least Concern
Yellow-eyed penguin	*Megadyptes antipodes*	Threatened: Nationally	Endangered
Northern blue penguin**	*Eudyptula minor iredalei***	At Risk: Declining	#Least Concern
Southern blue penguin**	*Eudyptula minor minor***	At Risk: Declining	#Least Concern
Chatham Island blue penguin**	*Eudyptula minor*	At Risk: Naturally Uncommon	#Least Concern
White-flippered blue penguin**	*Eudyptula minor albosignata***	Threatened: Nationally	#Least Concern
Eastern rockhopper penguin	*Eudyptes filholi*	Threatened: Nationally Critical	#Vulnerable
Fiordland crested penguin	*Eudyptes pachyrhynchus*	Threatened: Nationally	Vulnerable
Snares crested penguin	*Eudyptes robustus*	At Risk: Naturally Uncommon	Vulnerable
Erect-crested penguin	*Eudyptes sclateri*	At Risk: Declining	Endangered

* OSNZ (2010) classify New Zealand white-capped albatross as a subspecies *Thalassarche cauta steadi*. Full species status is used here following ACAP.
** OSNZ (2010) classify a single species, little penguin *Eudyptula minor*. Multiple taxa are included here to reflect classification in the New Zealand Threat Classification Scheme.
*** OSNZ (2010) classify a single species, white-fronted tern *Sterna striata*. Multiple taxa are included here to reflect classification in the New Zealand Threat Classification Scheme.
# indicates that the IUCN classification is based on a broader definition of the species than listed in this table.
† Taxonomically Indeterminate in the New Zealand Threat Classification Scheme.

6.2 BIOLOGY

Taylor (2000) provided an excellent summary of the characteristics, ecology, and life history traits of seabirds (defined for the purpose of this document by the list in

Table 6.1) which is further summarised here.

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

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

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

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

6.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

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

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

change were listed as threats for some taxa or areas where understanding was particularly poor.

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

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

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

Seabirds are ranked by the International Union for the Conservation of Nature (IUCN) as the world's most threatened bird grouping (Croxall et al 2012). Globally they face a number of threats to their long term viability, both at their breeding sites and while foraging at sea. Work at the global level on reducing threats at breeding sites is a major focus of the Agreement on the Conservation of Albatrosses and Petrels (ACAP) and DOC is the lead New Zealand lead agency. However, the key threat to seabirds at sea, especially albatrosses and petrels, is incidental capture and death in fisheries managed by MPI.

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

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

6.4 STATE OF KNOWLEDGE IN NEW ZEALAND

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

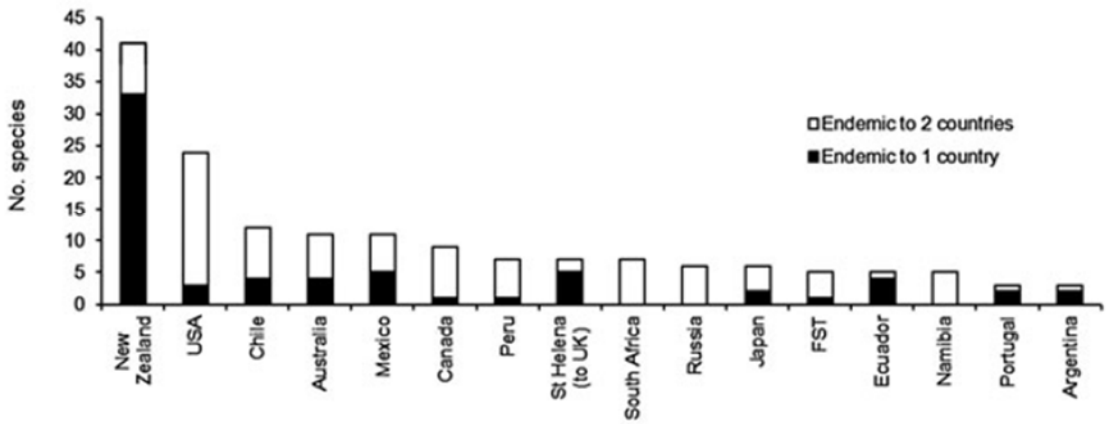


Figure 6.1: (from Croxall et al 2012). Number of endemic breeding seabird taxa by country.

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

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

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

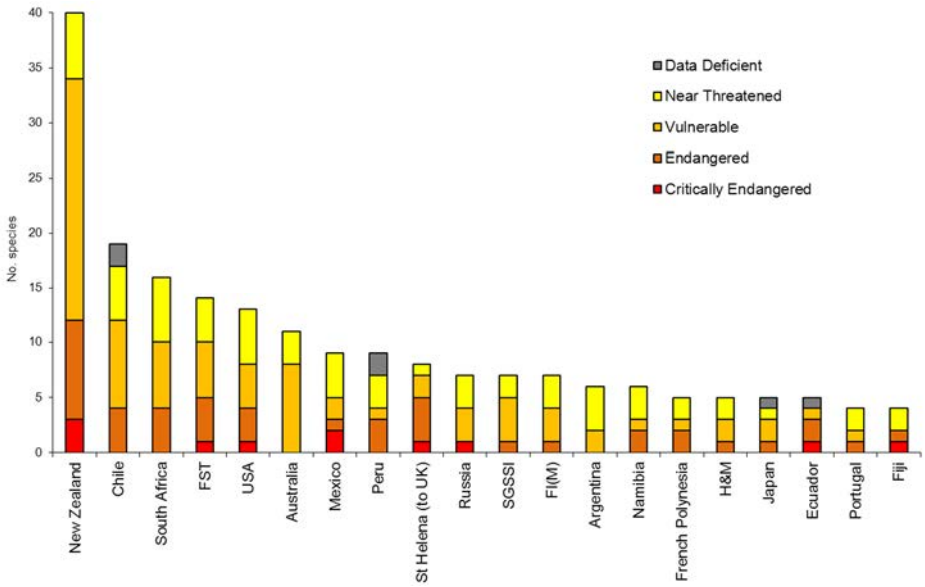


Figure 6.2: (from Croxall et al 2012, supplementary material): The number of breeding and resident seabird species by country in each IUCN category (excluding Least Concern). FST, French Southern Territories; SGSSI, South Georgia and South Sandwich Islands; FI(M), Falkland Islands (Malvinas); H&M, Heard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

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

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

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

with commercial, recreational or artisanal fishing operations in waters under the jurisdiction of other states.

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

6.4.1 SEABIRD DEMOGRAPHIC AND DISTRIBUTION STUDIES

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

6.4.1.1 CHATHAM ISLAND ALBATROSS

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

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

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

To determine foraging movements and behaviour of Chatham Island albatross during the incubation and early chick rearing stages of the breeding season, GPS loggers were applied to breeding birds for the duration of one foraging trip. Where possible, birds were also tagged with a geolocator logger to record activity (i.e. salt water immersion) during foraging trips. The resulting distributional range of Chatham Islands albatross during incubation and early chick rearing from these tracking studies from November to December 2007–2009 are given in Figure 6.3 (Fraser et al 2010b).

To track the birds on a longer time- scale during the non-breeding season, geolocation loggers (GLS) were used. These devices have a life span of up to about 6 years and are intended to remain on the birds for at least one year. They were applied to each banded bird's leg using a plastic band to which the loggers were attached with glue and a cable tie.

Table 6.3: (from Fraser et al 2011) Counts of Chatham Island albatross nest sites for the years: 2007 (19–29 November); 2008 (22 November – 7 December); 2009 (9–12 December); and 2010 (24–30 December).

	2007	2008	2009	2010
Total nests counted	5 247	5 407	5 194	5 245

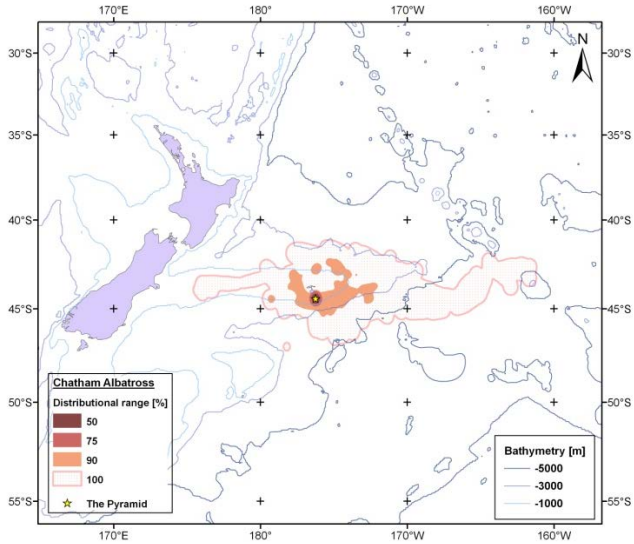


Figure 6.3: (from Fraser et al 2010b) Distributional range of Chatham Island albatross during incubation and early chick rearing as derived from tracking studies in November/December 2007–2009 (n=51 tracks).

6.4.1.2 NORTHERN BULLER'S ALBATROSS AND NORTHERN GIANT PETREL AT THE FORTY -FOURS, CHATHAM ISLANDS

The Forty-Fours, a small group of islands, are located about 35 km east of Chatham Island. They are home to the main breeding populations of northern royal albatross (*Diomedea sanfordi*) and northern Buller's albatross (*Thalassarche nov* sp.). A large colony of northern giant petrel (*Macronectes halli*) also breeds at the Forty-Fours. The northern Buller's albatross nest estimate on the Forty-Fours for 2007 was 15 238 (Scofield et al 2008b), for 2008 was 14 674 (Fraser et al 2009a), and for 2009 was 14 185 (Fraser et al 2010a). Fixed grids sampled each year also confirmed the consistent population count (Fraser et al 2010a). Northern giant petrels nest mainly in the north-eastern part of the island along the cliff tops, interspersed with the northern royal albatross. Estimates of nests with chicks in them (both alive and dead) were: 430 in November 2007 (Scofield et al 2008b); 349 in November 2008 (Fraser et al 2009a); and 270 in December 2009 (Fraser et al 2010a). Ten geolocators were placed on five incubating pairs of northern royal albatross in November 2007 (Scofield et al 2008b). Some of the geolocators have not yet been removed from the birds and data are still to be presented.

6.4.1.3 NORTHERN ROYAL ALBATROSS

The main breeding populations of northern royal albatross are on the Forty-Fours and The Sisters which are small island groups off the main Chatham Island. There is also a small colony at Taiaroa Head, South Island. The islands where northern royal albatross nest at the Chatham Islands are privately-owned, and landing there is weather-dependent. In order to monitor populations effectively, counts are required immediately following egg-laying (because this provides the most reliable estimates of the numbers of breeding pairs), and at fledging but prior to any chick departing each year (because this allows breeding success to be estimated each year). Aerial photography is the most cost-effective method of making these counts at these times and locations. Aerial counts of nesting northern royal albatross were made during each of the four breeding seasons 2006–07 to 2009–10.

Three trips to the Chatham Islands were planned each year during this study, with the primary objectives of each trip being to take aerial photographs for population counts on both the Forty-Fours and The Sisters. Trips were timed to coincide with key events in the breeding seasons and were planned for:

- Late November or early December (to count the number of northern royal albatrosses at the completion of egg laying);
- April (to count northern royal albatross chicks shortly after hatching); and
- September (to count northern royal albatross chicks just prior to fledging).

The November 2007 aerial survey was made just before the field team arrived on the Forty-Fours to study northern Buller's albatross and northern giant petrels. A ground count of breeding northern royal albatross was made at about the same time of day as the aerial photography was completed. This one-off exercise showed that aerial and ground counts are broadly comparable and there is probably little bias caused by birds being obscured to aerial counting or the counting of non-breeding birds. Aerial counts suggested that the estimated total number of breeding pairs ranged from 5 388 to 5 744 (Table 6.4). These estimates do not differ markedly from an estimate made in the 1970s (Robertson 1998, cited in Scofield 2011).

At the small population that self-established on the mainland of New Zealand at Taiaroa Head, banding as well as monitoring of individuals has been carried out since 1938. Richard and Abraham (2013) estimated the overall annual adult survival rate at 0.95 (95% c.i.: 0.941–0.959). Estimates of other demographic rates were also obtained during the estimation process. The mean age at first return of juveniles to the colony was estimated at 4.81 years (95% c.i.: 4.63–5.06), and the mean age at first breeding as 8.85 years (95% c.i.: 8.53–9.29).

Table 6.4: (from Scofield 2011) Aerial counts of northern royal albatross eggs and chicks at their key Chatham Islands nesting sites, 2006–07 to 2009–10.

	2006–07		2007–08		2008–09		2009–10	
	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks
Forty-Fours	1 879	1 018	2 212	1 093	2 055	1 036	2 692	1 083
Big Sister	2 128	871	2 018	288	2 081	496	1 893	665
Middle Sister	1 381	670	1 371	435	1 316	483	1 159	569
Total	5 388	2 559	5 601	1 816	5 452	2 015	5 744	2 317

6.4.1.4 SALVIN'S ALBATROSS ON BOUNTY ISLANDS

Salvin's albatross (*Thalassarche salvini*) is endemic to New Zealand, breeding only on the Bounty Islands and the Western Chain of The Snares. The Bounty Islands are a group of bare rocky islands/islets situated 659 km south-east of New Zealand's South Island. In October 2010, Baker et al (2010a) completed an aerial survey of the Bounty Islands to photograph all albatross colonies. This was the first complete population survey of Salvin's albatross on the Bounty Islands. Photo montages were created from the aerial photography and the number of nesting birds was counted. From these data, Baker et al (2010a) estimated the total count of nesting Salvin's albatrosses in the Bounty Islands in October 2010 to be 41 101 (95%c.i.: 40 696–41 506).

This estimate may be biased high by the presence of "loafers" (non-breeding birds) as it was not possible to ground truth the aerial photography or detect the proportion of loafers within the colony from close-up photography (because of the general lack of nest pedestals resulting from low availability of nesting material on the island). Conversely, the estimate maybe biased low because aerial photography was not possible on some small areas of steep cliff where albatross nests may have been missed (Baker et al 2012).

A review of existing ground counts was reported by Amey & Sagar (2013). To estimate population trends and examine the accuracy of ground counts, whole-island surveys of Salvin's albatross breeding at Proclamation Island, Bounty Islands, were undertaken during November in 1997, 2004, and 2011. These counts suggest that the numbers of Salvin's Albatross nests on Proclamation Island declined by 14% between 1997, and 2004, by 13% between 2004 and 2011, and overall by 30% between 1997 and 2011. Counts of nests on Depot Island decreased by 10% between 2004 and 2011.

Baker et al (2014a) conducted a repeat aerial survey of the Bounty Islands in October 2013. Using the same correction factor applied to the 2010 counts, they estimated the total annual breeding pairs at 39 995 (95% c.i.: 39 595 - 40 395) compared to the corrected estimate for 2010 of 31 786 (95% c.i: 31 430 – 32 143).

6.4.1.5 SALVIN'S ALBATROSS ON SNARES WESTERN CHAIN

In 2008, a 3-year study of Salvin's albatrosses was initiated at the Snares Western Chain. The three main objectives of the Salvin's albatross field work were:

- to estimate the breeding population size from counts of occupied nests;
- to determine foraging locations and activity by retrieving geolocator tracking devices deployed in 2008; and
- to estimate annual survival rates of banded adult birds from recapture analyses.

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

Table 6.5: (from Sagar et al 2011) Numbers of Salvin's albatross pairs breeding on Toru and Rima Isles, Western Chain, The Snares, 2008–2010. Failed nests are those assessed to contain fresh egg fragments. No count was made on Rima Islet in 2010.

Islet	Date	Adult + egg	Obvious failed nest	Total
Toru	6–7 October 2008	828	70	898
	2 October 2009	783	51	834
	28–29 September 2010	780	49	829
Rima	16 October 2008	279	18	297
	30 September 2009	265	17	282

In order to estimate the adult survival of Salvin's albatross, a total of 257 occupied nests were counted within a clearly-defined study area established in October 2008 (Charteris et al 2009). Within this area, 116 birds banded in previous years were recaptured, and a further 20 breeding birds were banded in the study area during October 2010. Among the recaptured birds were 13 that had been banded as chicks on Toru Islet during 1986, and 23 of the 123 birds banded as breeding adults in 1995. These recapture rates lead to an estimated adult survival probability of 0.967 for Salvin's albatross, one of the highest estimates for any species of annual-breeding albatross (Sagar et al 2011).

Twenty-four of the 35 geolocation loggers deployed on breeding birds during October 2008 were retrieved. Data were processed by the British Antarctic Survey and a preliminary assessment of the distribution of Salvin's albatrosses during the entire year is presented in Figure 6.4. None of the 24 birds tracked was within the New Zealand EEZ during April; 23 were in South American waters between Tierra del Fuego and northern Peru and one was in eastern Bass Strait and along the eastern coast of Tasmania (Figure 6.4a). Birds began to return to New Zealand waters during May and this continued throughout June and July. The tracks of birds exiting South American waters originated from either the Peruvian or southern Chilean coasts. During this period, birds recently arrived in New Zealand waters occurred primarily east of the Chatham Islands, off Puysegur and on the Stewart- Snares Shelf (Figure 6.4b). Eggs are laid starting in August and all of the birds occurred within Australasian waters throughout August to October, primarily on the Challenger Plateau, off Puysegur, the Stewart-Snares Shelf, and Campbell Plateau (Figure 6.4c). During this period these birds from the Snares Western Chain occupy a relatively narrow longitudinal range between 160°E and 175°E and appear to avoid, or be excluded from, the area around the Bounty Islands, where there is another colony of Salvin's albatross. Beginning in mid-October chicks hatch and, between November and March, presumed successful breeders foraged primarily on the Challenger Plateau, off Puysegur, the Stewart- Snares Shelf, and Campbell Plateau (Figure 6.4d). There was some movement across the Pacific in each of the months between November and March with presumed failed breeders leaving the New Zealand EEZ during the earlier part of this period and presumed successful breeders migrating east during March (Sagar et al 2011).

Further research has been recently conducted on the Salvin's albatross on the Snares Western Chain, under DOC CSP project PRO2014-02. This research included a ground based census, aerial survey (including ground truthing) and collection of information on tagged birds. The final reports for this research were not available at time of printing.

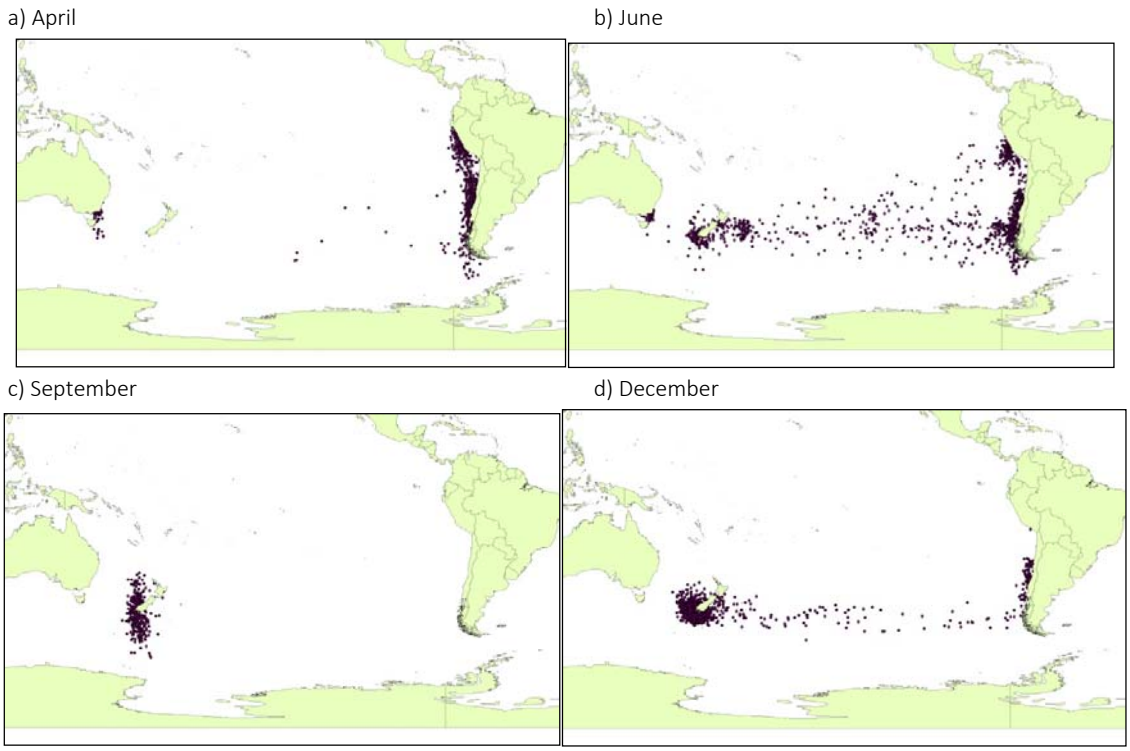


Figure 6.4: (from Sagar et al 2011) Distribution of Salvin's albatrosses Thalassarche salvini from the Snares Western Chain tagged with geolocators at four times of the year: a) April, after the completion of their breeding season, b) June, showing their return tracks from South American waters to New Zealand waters prior to egg laying, c) September, when their partners were incubating an egg, and d) December, the birds around New Zealand are presumed to be foraging for food for themselves and their chick, whilst the birds crossing the Pacific and in South American waters are presumed to be failed breeders.

6.4.1.6 WHITE CAPPED ALBATROSS

Repeated population censuses of the white-capped albatrosses breeding in the Auckland Islands were conducted in the month of December between 2006 and 2010, and the month of January in 2012 and 2013, using aerial photography (Baker et al 2007b, 2008a, 2009a, 2011a, 2013). These population censuses were carried out to estimate population size and track population trends. Photo montages were created from the aerial photography and counted by an observer. Counts of photo montages in all years except 2006 were undertaken by one observer only. Multiple counts of photomontages from the December 2006 census to estimate counter variability associated with miscounting and misidentifying white spots on the ground as birds. Ground truthing was conducted to determine the number of birds sitting or standing on nests, the number of pairs (partners accompanying an incubating bird), and the number of loafers present in the colony.

2006–2010: In 2010, the total count of nesting white-capped albatrosses was estimated to be 72 635 (95%CI 72 096–73 174), 4370 (4238–4502) and 117 (95–139) annual breeding pairs, respectively, at Disappointment Island, South West Cape and Adams Island, giving a total for these sites of 76 913 (76 358–77 468) breeding pairs (Table 6.6). The counts of nesting white-capped albatross over the previous four years were significantly lower than the counts taken in 2006, when a total of 117 197 breeding pairs were present at the Auckland Islands. These differences in counts may represent normal inter-annual variation in breeding rather than indicating a decline in numbers due to fisheries mortalities (Baker et al 2011a).

2011–13: Surveys suggested 99 776 breeding pairs in 2011 and 118 098 breeding pairs in 2012 and 95 278 in 2013. However, evidence from a series of 'close-up' photographs taken each year over the entire series indicates that the number of non-breeding birds present in the colonies differed somewhat between December and January. The proportion was very low in December counts (1–2% of birds present) to 7 and 15% for the January counts taken in 2012 and 2013, respectively. Estimated annual counts for all three breeding sites in the Auckland Islands were adjusted to account for the presence of non-breeding birds (Table 6.6). These adjusted figures were used as inputs into models used for assessment of population trend. The population size estimates computed from a TRIM model indicate an average growth rate of - 3.16% per year (λ = 0.9684 ± 0.001); assessed by TRIM as moderate decline. However, a simple linear trend analysis, as performed by TRIM is not well suited to a data set with high inter-annual

variability. Trend analysis using smoothing splines is more appropriate to such data sets, and showed no evidence for systematic monotonic decline over the 8 years of the study, therefore providing support to the null hypotheses of no trend (stability) in the total population. Full details are provided by Baker et al (2013, 2014b).

Table 6.6: (after Baker et al 2013, 2014b) Aerial-photographic counts of breeding pairs of white-capped albatrosses on three islands in the Auckland Islands group in December 2006–2013.

Year	Adams	Disappointment	SW Cape	Total	95% limits	Adjusted for loafers
2006	–	110 649	6 548	117 197	116 570–117 823	116 025
2007	79	86 080	4 786	90 945	90 342–91 548	90 036
2008	131	91 694	5 264	97 089	96 466–97 712	96 118
2009	132	70 569	4 161	74 862	74 315–75 409	73 838
2010	117	72 635	4 370	77 122	76 567–77 677	76 119
2011	178	93 752	5 846	99 776	99 144–100 408	92 692
2012	215	111 312	6 571	118 098	117 411–118 785	102 273
2013	184	89 552	5 542	95 278	94 661-95 895	74 031

6.4.1.7 WHITE-CHINNED PETREL ON ANTIPODES ISLANDS

In 2007, a 5-year study of white-chinned petrels (*Procellaria aequinoctialis*) was initiated on Antipodes Island. Four seasons of fieldwork have been completed (Sommer et al 2008, 2009, 2010). The objectives of the white-chinned petrel field work were:

- to estimate the population trend from mark-recapture in the three study areas;
- to determine foraging locations and activity; and
- to estimate burrow occupancy in a range of habitats in order to increase the accuracy of a total island population estimate.

Three study areas were established and all white-chinned petrel burrows in each were checked at least three times during each field trip to identify both birds. Identifying white-chinned petrel burrows can involve a degree of subjectivity because white-headed petrels, *Pterodroma lessoni*, also nest on Antipodes Island. Although many white-chinned petrel burrows have very large entrances, and many white-headed petrel burrows have much smaller entrances with steep tunnels, white-chinned petrel have been found in burrows with entrances that have characteristics somewhere between the two. Estimated occupancy rates were similar in the years studied (Table 6.7). Overall, the number of burrows fluctuates between years as new burrows are dug and the number of burrows with unidentified eggshell remains varies (Sommer et al 2010).

Table 6.7: (from Sommer et al 2010) White-chinned petrel (WCP) study burrow occupancy between years.

Year	Timing	Total "WCP" burrows counted	"WCP" burrows with breeding WCP	% with breeding WCP
2008	mid Jan to end Feb	280	71	25.4
2009	late Jan to end Feb	285	77	27.0
2010	mid Dec to early Jan	295	81	27.5

To determine the foraging area of breeding white chinned petrels, 34 dataloggers (30 British Antarctic Survey, 4 Lotek) were deployed on breeding white-chinned petrels in 2008 (Sommer et al 2008). Seventeen and 13 of these birds were recaptured during the 2009 and 2010 field trips and their dataloggers were removed (Sommer et al 2009, 2010). Data from the 17 geolocators recovered during 2009 have been processed and enable initial conclusions to be made of the foraging movements of white-chinned petrels from the Antipodes. In summary, these are:

- During the breeding season, the birds foraged within the EEZ, mostly north of Antipodes Island and to the east of the mainland (Figure 6.5a).

- There was movement of birds across the Pacific to the coasts of Chile and Peru during February, presumably by failed breeders (Figure 6.5b).
- In the latter part of the breeding season (April and May) the birds tended to forage south of Antipodes Island.
- In May, after breeding, all birds migrated across the Pacific to forage off the west coast of South America, remaining there until August (Figure 6.5c).
- In September, the birds returned across the Pacific to Antipodes Island from the coast of Peru for the start of the new breeding season.

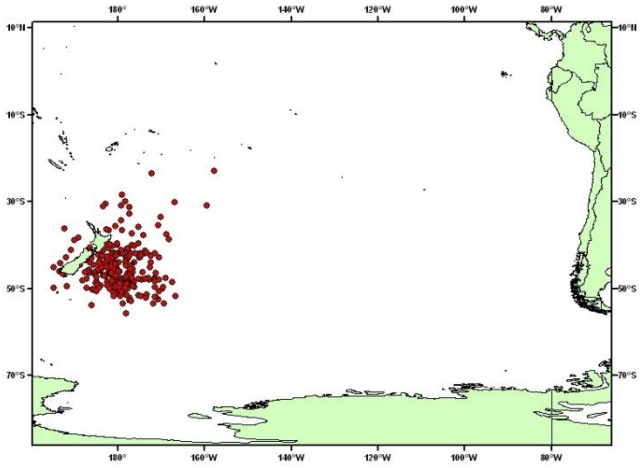
Occupancy was also estimated across a range of habitats throughout the island using transects. These transects varied in length and were measured by saving tracks on a handheld GPS. All white-chinned petrel burrows within 1 m either side of the transect (i.e., a 2 m-wide strip in total) were recorded (Table 6.8) and occupancy determined using a stick or burrowscope. Habitat type and slope were also recorded for each burrow (Sommer et al 2008, 2009, 2010).

Between December 2009 and January 2010, breeding white-chinned petrels were estimated to have an average density across all sampled habitats of 45 occupied burrows.ha^{-1}. The total area of Antipodes Island is 2 025 ha (Bell 2002) and, assuming all of this area is similarly suitable to the sampled areas, a preliminary estimate of the total population is 91 125 breeding pairs (Sommer et al 2010), compared with 100 000 pairs estimated by Taylor (2000). Habitat information (slope, aspect, vegetation) has been recorded for each transect and a quantitative survey of the extent of different habitat types over the entire area were completed during the 2011 field season to allow a more robust population estimate to be calculated, based on burrow densities in different habitat types.

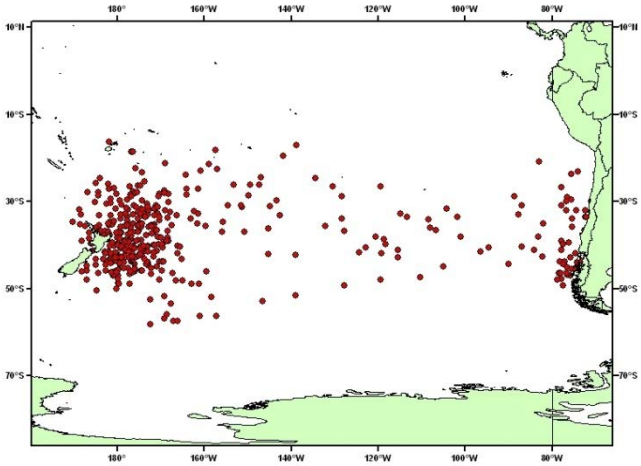
Table 6.8: (from Sommer et al 2010) Results of white-chinned petrel occupancy transects in various habitats spread throughout Antipodes Island.

No. transects	Total burrows	No. containing white-chinned petrel breeding (non-breeding)	No. containing white-headed petrel	No. empty	No. not used for occupancy estimate	% burrows with breeding white-chinned petrel
20	247	59 (10)	21	144	13	25.2

a) December



b) February



c)June-August

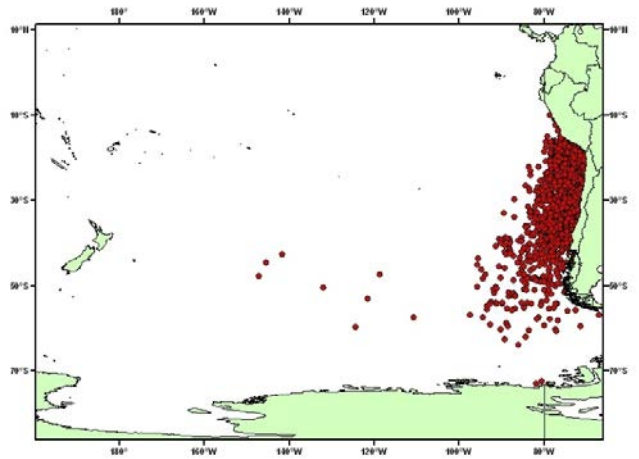


Figure 6.5: (from Sommer et al 2010) Foraging locations of white-chinned petrels from the Antipodes, in a) December, b) February and in c) June-August, after the end of the breeding season.

6.4.1.8 GREY PETREL ON ANTIPODES ISLANDS

A 2-year study of grey petrels (*Procellaria cinerea*) on Antipodes Island commenced during 2009 and was completed during the period 19 March – 30 April 2010. The objectives of the grey petrel field work were:

- to estimate the population trend from mark-recapture analysis in the study areas;
- to determine foraging location and activity; and
- to estimate the total island population by examining burrow occupancy in a range of habitats.

In 2009, a total of 69 burrows in Alert Bay, the Crater and Crater Ridge containing grey petrels were marked as study burrows (Sommer et al 2009). In addition, 64 grey petrel burrows within the white-chinned petrel study areas were used as study burrows (Sommer et al 2010).

To establish the foraging distribution of grey petrels, 27 geolocation dataloggers were deployed on breeding grey petrels in 2009 (Sommer et al 2009). Eighteen of the 27 geolocators deployed were subsequently retrieved, although one datalogger had dislodged from the attachment to the petrel. Data from the geolocators are being processed by the British Antarctic Survey (Sommer et al 2010).

Occupancy transects were carried out after peak egg-laying in the study burrows. Because of the short daylight hours at this time of year transects were limited to the northern half of the island. Transects were conducted in all habitat types on the coastal and inland slopes. A few transects were also done on the flatter ground more usually associated with white-chinned petrels. Transects were mapped and measured by recording the position of the start and end of each transect as well as each burrow with a hand held GPS.

Sommer et al (2010) estimated a breeding population of 48 960 pairs (96 pairs.ha^{-1} over 510 ha of suitable habitat). Although two seasons of field work on grey petrels is insufficient to allow an assessment of population trend over this period, a comparison of population trend is possible with reference to the earlier study of Bell (2002) who reported a mean of 104 occupied grey petrel burrows ha^{-1} from a survey completed during April-June 2001. Assuming the same 510 ha of suitable habitat on Antipodes Island, Bell estimated a breeding population of 53 040 pairs, similar to Sommer et al's (2010) estimate.

6.4.1.9 FLESH-FOOTED SHEARWATER

Flesh-footed shearwaters, *Puffinus carneipes*, breed around Australia and New Zealand and migrate to the northern hemisphere in the non-breeding season. In New Zealand, they nest in burrows on islands around the North Island and in Cook Strait. Of the breeding sites identified by DOC staff (G. Taylor unpublished, cited in Baker et al in prep) eight major breeding islands for the flesh-footed shearwater were chosen for re-survey: Lady Alice, West Chicken, Whatupuke and Coppermine (Hen and Chickens Group); Green (Mercury Group), Ohinau (Ohena Sub Group of Mercury Group), Karewa (Bay of Plenty) and Titi (Cook Strait). In addition, it is estimated that Middle Island (Mercury Group) held approximately 3000 pairs in 2003 (Waugh & Taylor 2012).

Baker & Double (2007) designed a survey methodology for estimating population size and assessing long-term trends for the flesh-footed shearwater. Surveys using this design were undertaken at the eight major breeding areas by Baker et al (2008b, 2009b, 2010b, in prep.). Field work was focussed on visiting all of the eight sites at least once during the 5 years of the study to estimate the number of pairs breeding at each site. A few sites were visited annually to estimate population trends. Baker et al (2008b, 2009b, 2010b, in prep.) searched these sites by locating ridgelines and systematically searching from the ridgeline to the sea or, where unsuitable terrain such as a cliff was encountered, using a series of 2 m-wide search transects. These search transects were established by following a compass bearing downhill from the ridgeline. When potential burrows were located, their location of that colony from the start point of the search transect was recorded, and the number of potential burrows subsequently found 1 m either side of the transect line counted. At some sites, colony transects were well marked to permit follow-up surveys in future years. The origin points for transects were randomly located along a central line or 'backbone' which was run through the colony. In practice, most colonies were centred on ridgelines or located on steep slopes, and the backbone was located along a ridgeline.

All colony areas, with the exception of those on Karewa, were mapped by using transect data and a hand-held GPS. On Karewa Island, the sensitive nature of the substrate meant that sampling was curtailed to working from boards laid on the surface along a sandy track used by DOC for park management purposes. This access point was used as a long

transect, with other shorter transects established either side as permitted by the terrain encountered.

The density of potential burrows was scaled up to the estimated area of each colony to derive an estimate of the number of burrows for each colony (Table 6.9). Baker et al (in prep) estimate the total count of burrows on the eight islands surveyed to be 20 945 (95% c.i., 19 019 – 22 871), notably fewer than Taylor's (2000) estimate of 25 000–50 000 pairs. Baker et al (in prep) state that their estimates generally accord with the indicative population estimates developed by Graeme Taylor (cited in Baker et al in prep.) with the exception of that for Coppermine and Ohinau Islands. Baker et al's (in prep.) estimate of 1425 occupied burrows (1059–1791) for Coppermine is much lower than Taylor's indicative estimate of 10 000 (presumably breeding pairs). In contrast, Baker et al's (in prep.) estimate of 2071 occupied burrows (943–3200) for Ohinau greatly exceeds Taylor's indicative estimate.

Waugh et al (2014) assessed the feasibility of gaining improved estimates of key flesh-footed shearwater population parameters and investigated the at-sea distribution of flesh-footed shearwaters. Study plots were established at Lady Alice/Mauimua, Titi Island and Ohinau Island, with burrow mapping by GPS and hand-drawn maps. The occupancy of burrows and size of breeding population at each colony was assessed. Occupancy as assessed by burrow-scoping and through inspection of burrow contents through study hatches.

Table 6.9: (from Baker et al in prep.) Estimated number of potential and occupied burrows for eight New Zealand islands surveyed 2007/08 to 2010/11. Note that some colonies on Lady Alice and Coppermine were visited in all years, and for these colonies the highest estimate was used to derive the island total. The number of occupied burrows can reasonably be considered an estimate of annual breeding pairs for each island.

Island	No. Potential burrows	Lower 95% CI	Upper 95% CI	No. Occupied burrows	Lower 95% CI	Upper 95% CI
West Chicken	193	-2	388	15	0	210
Lady Alice	2 763	2 079	3 447	921	237	1 605
Whatupuke	2 941	1 767	4 115	1 210	36	2 384
Coppermine	2 290	1 924	2 656	1 425	1 059	1 791
Titi	2 814	2 201	3 427	337	0	950
Green	132	82	182	74	24	124
Ohinau	3 883	2 755	5 011	2 071	943	3 200
Karewa	5 929	4 420	7 438	2 561	1 052	4 070
Total	20 945	19 019	22 871	8 614	6 689	10 540

Analysis of island-wide population survey information, collected from 2011-12 to 2013-14 compared with previous surveys conducted from 2007-2010 (Baker et al 2008b, 2009b, 2010b, in prep) indicated a probable decline for the population on Ohinau Island, and stable populations on Lady Alice Island/Mauimua and Titi Island. Adult annual survival was within the range reported for other shearwaters, at 0.93 for Kauwahaia Island and 0.94 for burrow-caught birds at Lady Alice/Mauimua (Waugh et al 2014).

Tracking of flesh-footed shearwaters using GPS loggers showed that birds were foraging several hundreds of kilometres from their breeding site over deep oceanic waters to the east of the New Zealand region during incubation. During early chick-rearing period, the flesh-footed shearwaters contracted their range with a higher concentration of activity in waters near the breeding site and at zones of upwelling and relative high productivity within 400 km of the breeding site. The overlap of foraging activity with trawl, longline and gillnet fisheries indicated highest intensity of overlap when the breeding birds were foraging close to the breeding site during early chick rearing (Waugh et al 2014).

6.4.1.10 WESTLAND PETREL

The Westland petrel, *Procellaria westlandica*, is endemic to New Zealand and nests in burrows in dense rainforest near Punakaiki, Westland. This species is poorly studied, probably largely because they nest in burrows, inhabit dense forest, and attend their nests only at night. As for the flesh-footed shearwater a survey methodology for estimating population size and assessing long-term trends for the Westland petrel was designed (Baker & Double 2007). Once a colony was located, Baker et al (2007b, 2008c, 2011b) estimated population size through a three stage process. First, burrow densities were determined in each colony by using 2 m-wide strip 'colony transects', and mapped burrows along each transect. These transects

differed from search transects in that they were confined to identified colonies and were randomly placed within the colonies. Second, the proportion of active nests per burrow was estimated using burrow scopes and 'inspection by hand' (inserting an arm down burrows to determine occupancy and feel for eggs, chicks, adult birds or nesting material). Finally, the area of each colony was measured by exploring the approximate boundaries on foot and mapping the densely-inhabited area and this area multiplied by the density to arrive at a population estimate for each colony.

Although Westland petrels breed throughout a 16 square kilometre area near Punakaiki, which has been designated as a Special Conservation Area, sampling effort was concentrated on estimating the population in high density areas, noting the challenges posed by the rugged terrain and often adverse weather conditions (Baker et al 2007b, 2008c, 2011b). Baker et al (2007b, 2008c, 2011b) estimated the number of potential burrows in all Westland petrel colonies to total 6846 (95% c.i. 6389 – 7302) during the period 2007 to 2011. Of these, an estimated 2827 (2143–3510) were occupied. The rugged terrain and inclement weather made it difficult to ensure that the permanent transects were replicated exactly each year and hence raises some doubts about the comparability of counts.

6.4.2 QUANTIFYING FISHERIES INTERACTIONS

Information with which to characterise seabird interactions with fisheries comes from a variety of sources. Some is opportunistically collected, whilst other information collection is targeted at specifically describing the nature and extent of seabird captures in fisheries. This section is focussed on the targeted information collection.

Many New Zealand commercial fisheries have MPI observer coverage, much of which is funded by DOC's CSP programme (e.g., Rowe 2009, 2010, Ramm 2011, 2012). Observers collect independent data on the number of captures of seabirds, the number of fishing events observed, and at-sea identification of the seabirds for these fisheries. Commercial fishers are legally required to provide effort data allowing estimation of the total number of fishing events in a fishery. In combination these data have been used for many years to assess the nature and extent of seabird captures in fisheries (e.g., Abraham et al 2010b, Abraham & Thompson 2009a, 2010, 2011a, b, Ayers et al 2004, Baird 1994, 1995, 1996, 1997, 1999, 2000a, b, 2001a, b, 2003, 2004 a–c, 2005, Baird et al 1998, 1999, Baird & Griggs 2004, Thompson & Abraham 2009)[1]. In this context, "captures" include all seabirds observed by an observer to be brought on-board a fishing vessel, whether reported as live or dead, but exclude non-fishing-related events (e.g., birds striking the superstructure and landing on deck) and decomposed carcasses. Specimens and photographs (especially for birds released alive) are also collected allowing verification of at-sea identifications (from carcasses or photographs) and description of biological characters (sex, age, condition, etc., available only from carcasses).

In some fisheries observer data are temporally and spatially well stratified, whilst in others data are only available from a spatially select part of the fishery, or a limited part of the year. Where sufficient observer data are available, estimates of total seabird captures in the fishery are calculated. The methods currently used in estimating seabird captures in New Zealand fisheries are described in Abraham & Thompson (2011a). In this context, captures include all seabirds recovered on a fishing vessel except birds that simply land on the deck or collide with a vessel's superstructure, decomposing animals, records of tissue fragments, and birds caught during trips carried out under special permit (e.g., for trials of mitigation methods). Observer coverage has been highly heterogeneous in that some fisheries and areas have had much higher coverage than others. This complicates estimation of the total

[1] As part of its data reconciliation processes, MPI has identified that less than 2% of observed protected species captures between 2002 and 2015 were not recorded in Centralised Observer Database (COD). Steps are being taken to update the database and estimates of protected species captures and associated risks. Accordingly, some estimates of protected species captures or risk in this seabird chapter may have a small negative bias. Updated estimates will be reviewed by the Aquatic Environment Working Group in the second quarter of 2016.

number of seabirds captured, especially when estimates include more than one fishery, because the distribution of birds and captures is also heterogeneous (Figure 6.6).

Fisher-reported captures (on NFPSCR forms available since 1 October 2008) have not been used to estimate total captures because the reported capture rates are much lower than those reported by independent observers (Abraham & Thompson 2011b) and the species identification is less certain.

Abraham & Thompson (2011a) made model-based estimates of captures in New Zealand trawl and longline fisheries for the following taxa or groups: sooty shearwater (*Puffinus griseus*); white-chinned petrel (*Procellaria aequinoctialis*); white-capped albatross (*Thalassarche steadi*); Salvin's albatross (*Thalassarche salvini*); southern Buller's albatross (*Thalassarche bulleri*); other albatrosses; and all other birds. The five individual species were chosen because they are the most frequently caught in trawl and longline fisheries. Captures of other albatrosses are mostly Gibson's or Antipodean wandering albatrosses or Campbell Island albatrosses. The 'other birds' category includes many taxa but grey, black, great-winged, and Cape petrels (both sub-species but mostly Southern Cape petrels, *Daption capense capense*), flesh-footed shearwater, and spotted shag are relatively common observed captures (the latter based on few observations that included 31 captures in one event). Estimated captures up to and including the 2013–14 year are shown in Table 6.10 to Table 6.15.

Observed captures of seabirds in trawl fisheries were most common off both coasts of the South Island, along the Chatham Rise, on the fringes of the Stewart-Snares shelf, and around the Auckland Islands (Figure 6.7). This largely reflects the distribution of the major commercial fisheries for squid, hoki, and middle-depth species which have tended to have relatively high observer coverage. White-capped, Salvin's, and southern Buller's have been the most frequently observed captured albatrosses, and sooty shearwater and white chinned petrel have been the other species most frequently observed (Table 6.16). About 41% of observed captures were albatrosses.

Observed captures of seabirds in surface longline fisheries were most common off the southwest coast of the South Island and the northeast coast of the North Island (Figure 6.8), again largely reflecting the distribution of the major commercial fisheries (for southern bluefin and other tunas). The charter fleet targeting tuna has historically had much higher observer coverage than the domestic fleet. Southern Buller's and white-capped have been the most frequently observed captured albatrosses, and grey, white-chinned, and black petrels have been the other species most frequently observed (Table 6.17). About 80% of observed captures were albatrosses.

Observed captures of seabirds in bottom longline fisheries were most common off the south coast of the South Island, along the Chatham Rise, scattered throughout the Sub-Antarctic, and off the northeast coast of the North Island, especially around the Hauraki Gulf (Figure 6.9). This distribution largely reflects the distribution of the ling and snapper longline fisheries that have received most observer coverage; other bottom longline fisheries have had much less coverage. Salvin's and Chatham have been the most frequently observed captured albatrosses, and white chinned petrel, grey petrel, sooty shearwater, and black petrels have been the other species most frequently observed (Table 6.18). Only about 15% of observed captures were albatrosses.

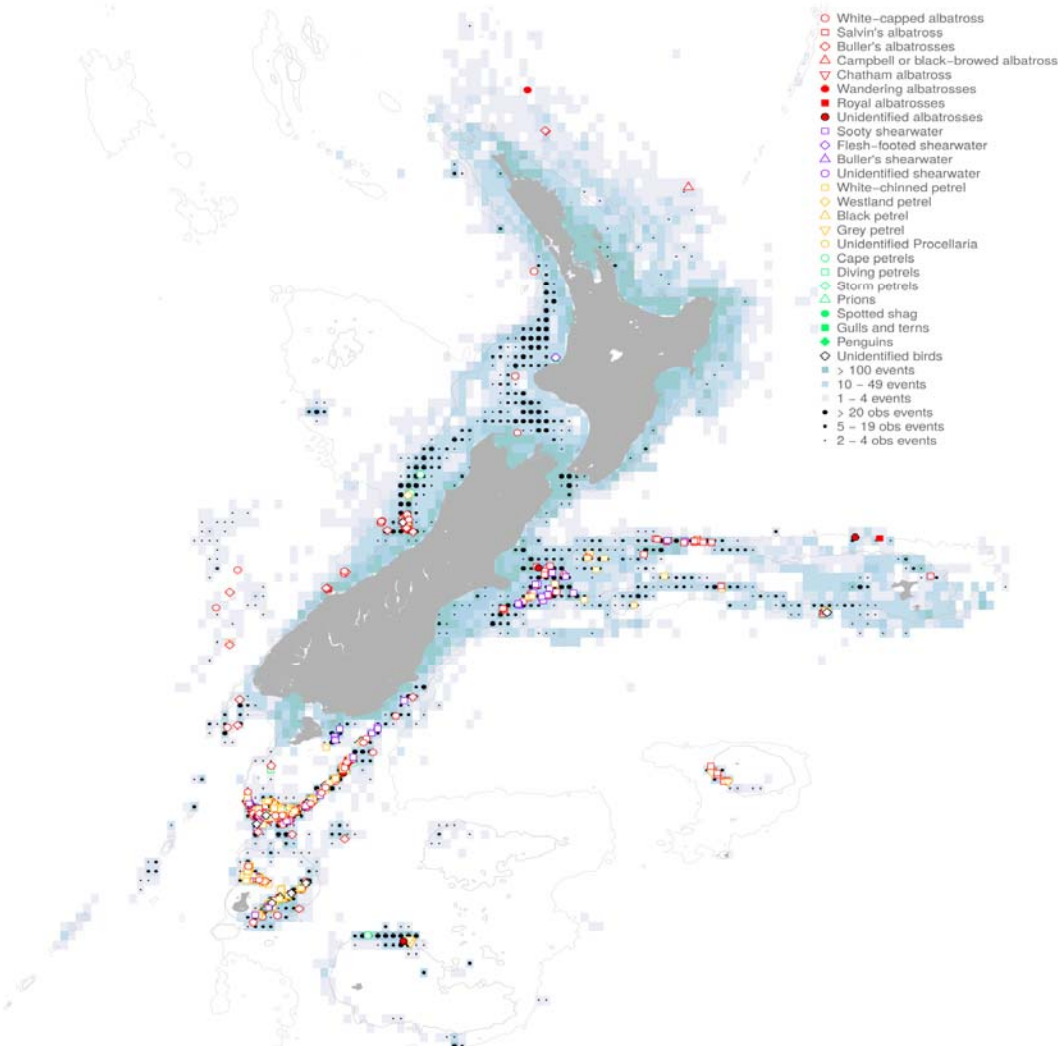


Figure 6.6: All observed seabird captures in trawl, surface longline, and bottom longline fishing within the New Zealand region, between October 2012 and September 2013. The colour within each 0.2 degree cell indicates the number of fishing events (tows and sets, darker colours indicate more fishing) and the black dots indicate the number of observed events (larger dots indicate more observations). The coloured symbols indicate the location of observed seabird captures, randomly jittered by 0.2 degrees. The 500 m and 1000 m depth contours are shown. http://data.dragonfly.co.nz/psc/ Data version v20140131. See footnote 1.

Table 6.10: Summary of observed and model-estimated total captures of all seabirds combined by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2013–14. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. http://data.dragonfly.co.nz/psc/ Data version v2015001. Some of these estimates may have a small negative bias, see footnote 1.

	Fishing effort			Seabirds		Model estimates		
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl
2002–03	130 173	6 840	5.3	269	3.93	3 935	3 508–4 400	100.0
2003–04	120 830	6 549	5.4	262	4.00	3 268	2 904–3 667	100.0
2004–05	120 448	7 714	6.4	483	6.26	4 172	3 771–4 605	100.0
2005–06	109 939	6 619	6.0	356	5.38	3 695	3 314–4 116	100.0
2006–07	103 318	7 933	7.7	211	2.66	2 659	2 335–3 018	100.0
2007–08	89 524	9 050	10.1	235	2.60	2 243	1 986–2 528	100.0
2008–09	87 553	9 805	11.2	469	4.78	2 750	2 481–3 047	100.0
2009–10	92 888	9 010	9.7	258	2.86	2 410	2 130–2 715	100.0
2010–11	86 089	7 445	8.6	380	5.10	2 642	2 391–2 922	100.0
2011–12	84 421	9 087	10.8	248	2.73	2 127	1 879–2 408	100.0
2012–13	83 839	12 398	14.8	712	5.74	2 534	2 293–2 817	100.0
2013–14	85 091	13 096	15.4	512	3.91	2 277	2 041–2 542	100.0
Surface longline								
2002–03	10 770 488	2 195 152	20.4	115	0.052	2 235	1 828–2 776	100.0
2003–04	7 386 884	1 607 304	21.8	71	0.044	1 683	1 351–2 255	100.0
2004–05	3 679 965	783 812	21.3	41	0.052	785	629–989	100.0
2005–06	3 690 709	705 945	19.1	37	0.052	844	674–1 068	100.0
2006–07	3 739 882	1 040 948	27.8	187	0.180	827	696–990	100.0
2007–08	2 246 339	421 900	18.8	37	0.088	539	429–676	100.0
2008–09	3 115 633	937 496	30.1	57	0.061	650	526–813	100.0
2009–10	2 995 264	665 883	22.2	147	0.221	831	696–989	100.0
2010–11	3 188 179	674 572	21.2	47	0.070	793	633–1 008	100.0
2011–12	3 099 977	728 190	23.5	65	0.089	853	682–1 079	100.0
2012–13	2 876 932	560 333	19.5	27	0.048	769	612–973	100.0
2013–14	2 546 764	773 527	30.4	37	0.048	660	523–835	100.0
Bottom longline								
2002–03	37 761 953	10 774 720	28.5	265	0.025	3 015	2 534–3 602	100.0
2003–04	43 214 066	5 060 025	11.7	54	0.011	2 433	1 996–3 005	100.0
2004–05	41 839 578	2 883 725	6.9	30	0.010	2 779	2 205–3 639	100.0
2005–06	37 145 583	3 802 951	10.2	41	0.011	2 121	1 686–2 766	100.0
2006–07	38 126 940	2 315 772	6.1	58	0.025	2 720	2 088–3 732	100.0
2007–08	41 499 499	3 593 511	8.7	40	0.011	2 251	1 785–2 934	100.0
2008–09	37 444 720	4 029 546	10.8	33	0.008	2 095	1 666–2 732	100.0
2009–10	40 438 801	2 271 123	5.6	56	0.025	2 292	1 825–2 949	100.0
2010–11	40 899 106	1 732 775	4.2	29	0.017	2 583	2 055–3 401	100.0
2011–12	37 876 333	2 100 831	5.5	10	0.005	2 137	1 695–2 814	100.0
2012–13	32 510 529	398 388	1.2	3	0.008	1 935	1 558–2 494	100.0
2013–14	40 697 435	2 750 416	6.8	106	0.039	2 138	1 723–2 745	100.0

Table 6.11: Summary of observed and model-estimated total captures of white-capped albatross by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2013–14. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. http://data.dragonfly.co.nz/psc/ Data version v2015001. Some of these estimates may have a small negative bias, see footnote 1.

	Fishing effort			Seabirds		Model estimates		
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl
2002–03	130 173	6 840	5.3	85	1.24	761	622–917	100.0
2003–04	120 830	6 549	5.4	148	2.26	935	790–1 096	100.0
2004–05	120 448	7 714	6.4	243	3.15	1 225	1 064–1 395	100.0
2005–06	109 939	6 619	6.0	69	1.04	581	471–706	100.0
2006–07	103 318	7 933	7.7	57	0.72	468	369–584	100.0
2007–08	89 524	9 050	10.1	42	0.46	339	262–427	100.0
2008–09	87 553	9 805	11.2	96	0.98	479	392–576	100.0
2009–10	92 888	9 010	9.7	48	0.53	382	293–485	100.0
2010–11	86 089	7 445	8.6	40	0.54	371	286–468	100.0
2011–12	84 421	9 087	10.8	67	0.74	392	312–491	100.0
2012–13	83 839	12 398	14.8	126	1.02	415	330–516	100.0
2013–14	85 091	13 096	15.4	71	0.54	345	264–439	100.0
Surface longline								
2002–03	10 770 488	2 195 152	20.4	2	0.001	75	36–130	100.0
2003–04	7 386 884	1 607 304	21.8	17	0.011	141	79–234	100.0
2004–05	3 679 965	783 812	21.3	3	0.004	33	15–62	100.0
2005–06	3 690 709	705 945	19.1	2	0.003	31	13–59	100.0
2006–07	3 739 882	1 040 948	27.8	28	0.027	48	36–65	100.0
2007–08	2 246 339	421 900	18.8	4	0.009	39	18–71	100.0
2008–09	3 115 633	937 496	30.1	3	0.003	43	19–82	100.0
2009–10	2 995 264	665 883	22.2	31	0.047	81	54–122	100.0
2010–11	3 188 179	674 572	21.2	3	0.004	53	24–95	100.0
2011–12	3 099 977	728 190	23.5	8	0.011	157	82–271	100.0
2012–13	2 876 932	560 333	19.5	11	0.020	140	76–242	100.0
2013–14	2 546 764	773 527	30.4	6	0.008	114	59–207	100.0
Bottom longline								
2002–03	37 761 953	10 774 720	28.5	0	0.000	29	5–74	100.0
2003–04	43 214 066	5 060 025	11.7	1	0.000	24	5–60	100.0
2004–05	41 839 578	2 883 725	6.9	0	0.000	31	6–79	100.0
2005–06	37 145 583	3 802 951	10.2	1	0.000	23	5–56	100.0
2006–07	38 126 940	2 315 772	6.1	0	0.000	33	6–86	100.0
2007–08	41 499 499	3 593 511	8.7	0	0.000	31	6–81	100.0
2008–09	37 444 720	4 029 546	10.8	0	0.000	31	6–78	100.0
2009–10	40 438 801	2 271 123	5.6	0	0.000	27	5–69	100.0
2010–11	40 899 106	1 732 775	4.2	0	0.000	37	7–97	100.0
2011–12	37 876 333	2 100 831	5.5	2	0.001	34	8–86	100.0
2012–13	32 510 529	398 388	1.2	0	0.000	28	5–73	100.0
2013–14	40 697 435	2 750 416	6.8	0	0.000	32	6–83	100.0

Table 6.12: Summary of observed and model-estimated total captures of Salvin's albatross by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2013–14. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. http://data.dragonfly.co.nz/psc/ Data version v2015001. Some of these estimates may have a small negative bias, see footnote 1.

	Fishing effort			Seabirds		Model estimates		
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl
2002–03	130 173	6 840	5.3	24	0.35	579	434–752	100.0
2003–04	120 830	6 549	5.4	11	0.17	436	306–594	100.0
2004–05	120 448	7 714	6.4	37	0.48	691	522–892	100.0
2005–06	109 939	6 619	6.0	9	0.14	449	322–602	100.0
2006–07	103 318	7 933	7.7	14	0.18	403	290–538	100.0
2007–08	89 524	9 050	10.1	11	0.12	280	197–386	100.0
2008–09	87 553	9 805	11.2	37	0.38	336	250–446	100.0
2009–10	92 888	9 010	9.7	40	0.44	397	297–517	100.0
2010–11	86 089	7 445	8.6	20	0.27	370	272–487	100.0
2011–12	84 421	9 087	10.8	24	0.26	340	252–445	100.0
2012–13	83 839	12 398	14.8	48	0.39	383	291–498	100.0
2013–14	85 091	13 096	15.4	45	0.34	407	308–530	100.0
Surface longline								
2002–03	10 770 488	2 195 152	20.4	1	0.000	62	27–112	100.0
2003–04	7 386 884	1 607 304	21.8	0	0.000	47	19–88	100.0
2004–05	3 679 965	783 812	21.3	1	0.001	20	8–37	100.0
2005–06	3 690 709	705 945	19.1	0	0.000	24	9–46	100.0
2006–07	3 739 882	1 040 948	27.8	1	0.001	21	8–38	100.0
2007–08	2 246 339	421 900	18.8	1	0.002	14	5–26	100.0
2008–09	3 115 633	937 496	30.1	3	0.003	20	8–35	100.0
2009–10	2 995 264	665 883	22.2	1	0.002	21	8–39	100.0
2010–11	3 188 179	674 572	21.2	0	0.000	14	5–28	100.0
2011–12	3 099 977	728 190	23.5	1	0.001	11	4–21	100.0
2012–13	2 876 932	560 333	19.5	0	0.000	10	3–21	100.0
2013–14	2 546 764	773 527	30.4	0	0.000	7	2–16	100.0
Bottom longline								
2002–03	37 761 953	10 774 720	28.5	15	0.001	88	47–158	100.0
2003–04	43 214 066	5 060 025	11.7	10	0.002	92	51–160	100.0
2004–05	41 839 578	2 883 725	6.9	0	0.000	97	42–195	100.0
2005–06	37 145 583	3 802 951	10.2	1	0.000	78	30–174	100.0
2006–07	38 126 940	2 315 772	6.1	22	0.010	132	59–314	100.0
2007–08	41 499 499	3 593 511	8.7	0	0.000	95	40–201	100.0
2008–09	37 444 720	4 029 546	10.8	1	0.000	100	48–183	100.0
2009–10	40 438 801	2 271 123	5.6	0	0.000	123	47–310	100.0
2010–11	40 899 106	1 732 775	4.2	2	0.001	114	56–216	100.0
2011–12	37 876 333	2 100 831	5.5	0	0.000	134	54–306	100.0
2012–13	32 510 529	398 388	1.2	0	0.000	125	59–237	100.0
2013–14	40 697 435	2 750 416	6.8	6	0.002	209	97–450	100.0

Table 6.13: Summary of observed and model-estimated total captures of Buller's albatross by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2013–14. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. http://data.dragonfly.co.nz/psc/ Data version v2015001. Some of these estimates may have a small negative bias, see footnote 1.

	Fishing effort			Seabirds		Model estimates		
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl
2002–03	130 173	6 840	5.3	6	0.09	116	58–197	100.0
2003–04	120 830	6 549	5.4	9	0.14	131	73–218	100.0
2004–05	120 448	7 714	6.4	24	0.31	187	124–274	100.0
2005–06	109 939	6 619	6.0	9	0.14	115	65–185	100.0
2006–07	103 318	7 933	7.7	5	0.06	94	46–165	100.0
2007–08	89 524	9 050	10.1	18	0.20	125	79–191	100.0
2008–09	87 553	9 805	11.2	18	0.18	106	64–171	100.0
2009–10	92 888	9 010	9.7	11	0.12	95	53–161	100.0
2010–11	86 089	7 445	8.6	20	0.27	114	75–172	100.0
2011–12	84 421	9 087	10.8	36	0.40	150	107–212	100.0
2012–13	83 839	12 398	14.8	59	0.48	133	98–188	100.0
2013–14	85 091	13 096	15.4	36	0.27	112	75–167	100.0
Surface longline								
2002–03	10 770 488	2 195 152	20.4	41	0.019	390	248–605	100.0
2003–04	7 386 884	1 607 304	21.8	39	0.024	347	217–554	100.0
2004–05	3 679 965	783 812	21.3	22	0.028	124	78–191	100.0
2005–06	3 690 709	705 945	19.1	15	0.021	130	78–213	100.0
2006–07	3 739 882	1 040 948	27.8	49	0.047	138	98–192	100.0
2007–08	2 246 339	421 900	18.8	21	0.050	97	63–143	100.0
2008–09	3 115 633	937 496	30.1	30	0.032	117	77–176	100.0
2009–10	2 995 264	665 883	22.2	69	0.104	168	128–226	100.0
2010–11	3 188 179	674 572	21.2	28	0.042	128	83–188	100.0
2011–12	3 099 977	728 190	23.5	32	0.044	179	113–278	100.0
2012–13	2 876 932	560 333	19.5	10	0.018	130	77–209	100.0
2013–14	2 546 764	773 527	30.4	23	0.030	128	82–201	100.0
Bottom longline								
2002–03	37 761 953	10 774 720	28.5	1	0.000	47	18–92	100.0
2003–04	43 214 066	5 060 025	11.7	0	0.000	44	18–84	100.0
2004–05	41 839 578	2 883 725	6.9	0	0.000	70	28–136	100.0
2005–06	37 145 583	3 802 951	10.2	0	0.000	59	22–119	100.0
2006–07	38 126 940	2 315 772	6.1	0	0.000	72	27–140	100.0
2007–08	41 499 499	3 593 511	8.7	6	0.002	95	41–177	100.0
2008–09	37 444 720	4 029 546	10.8	0	0.000	56	23–106	100.0
2009–10	40 438 801	2 271 123	5.6	0	0.000	64	26–126	100.0
2010–11	40 899 106	1 732 775	4.2	0	0.000	76	31–148	100.0
2011–12	37 876 333	2 100 831	5.5	3	0.001	68	28–133	100.0
2012–13	32 510 529	398 388	1.2	0	0.000	50	20–101	100.0
2013–14	40 697 435	2 750 416	6.8	3	0.001	59	26–112	100.0

Table 6.14: Summary of observed and model-estimated total captures of white-chinned petrel by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2013–14. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. http://data.dragonfly.co.nz/psc/ Data version v2015001. Some of these estimates may have a small negative bias, see footnote 1.

	Fishing effort			Seabirds		Model estimates		
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl
2002–03	130 173	6 840	5.3	13	0.19	130	83–191	100.0
2003–04	120 830	6 549	5.4	18	0.27	112	75–160	100.0
2004–05	120 448	7 714	6.4	55	0.71	254	198–323	100.0
2005–06	109 939	6 619	6.0	70	1.06	396	312–494	100.0
2006–07	103 318	7 933	7.7	29	0.37	149	107–200	100.0
2007–08	89 524	9 050	10.1	60	0.66	233	183–293	100.0
2008–09	87 553	9 805	11.2	104	1.06	344	284–413	100.0
2009–10	92 888	9 010	9.7	74	0.82	286	226–357	100.0
2010–11	86 089	7 445	8.6	121	1.63	380	313–459	100.0
2011–12	84 421	9 087	10.8	56	0.62	189	148–239	100.0
2012–13	83 839	12 398	14.8	276	2.23	426	386–475	100.0
2013–14	85 091	13 096	15.4	105	0.80	185	158–217	100.0
Surface longline								
2002–03	10 770 488	2 195 152	20.4	4	0.002	144	54–361	100.0
2003–04	7 386 884	1 607 304	21.8	2	0.001	168	39–653	100.0
2004–05	3 679 965	783 812	21.3	3	0.004	36	14–86	100.0
2005–06	3 690 709	705 945	19.1	1	0.001	49	15–166	100.0
2006–07	3 739 882	1 040 948	27.8	5	0.005	29	14–54	100.0
2007–08	2 246 339	421 900	18.8	4	0.009	22	11–38	100.0
2008–09	3 115 633	937 496	30.1	3	0.003	22	10–39	100.0
2009–10	2 995 264	665 883	22.2	3	0.005	27	13–47	100.0
2010–11	3 188 179	674 572	21.2	6	0.009	29	15–50	100.0
2011–12	3 099 977	728 190	23.5	4	0.005	30	14–54	100.0
2012–13	2 876 932	560 333	19.5	1	0.002	34	14–67	100.0
2013–14	2 546 764	773 527	30.4	1	0.001	25	10–49	100.0
Bottom longline								
2002–03	37 761 953	10 774 720	28.5	132	0.012	487	313–797	100.0
2003–04	43 214 066	5 060 025	11.7	15	0.003	214	94–510	100.0
2004–05	41 839 578	2 883 725	6.9	11	0.004	700	319–1 469	100.0
2005–06	37 145 583	3 802 951	10.2	13	0.003	322	124–870	100.0
2006–07	38 126 940	2 315 772	6.1	12	0.005	728	303–1 599	100.0
2007–08	41 499 499	3 593 511	8.7	10	0.003	441	181–1 016	100.0
2008–09	37 444 720	4 029 546	10.8	1	0.000	388	148–904	100.0
2009–10	40 438 801	2 271 123	5.6	1	0.000	354	138–832	100.0
2010–11	40 899 106	1 732 775	4.2	24	0.014	570	275–1 164	100.0
2011–12	37 876 333	2 100 831	5.5	1	0.000	342	122–934	100.0
2012–13	32 510 529	398 388	1.2	0	0.000	347	133–822	100.0
2013–14	40 697 435	2 750 416	6.8	34	0.012	444	210–919	100.0

Table 6.15: Summary of observed and model-estimated total captures of sooty shearwaters by October fishing year in trawl (effort in tows), surface longline (effort in hooks) and bottom longline (effort in hooks) fisheries between 2002–03 and 2013–14. Observed and modelled rates are per 100 trawl tows or 1000 longline hooks. Caps, observed captures; % obs, percentage of effort observed; % incl, percentage of total effort included in the model. http://data.dragonfly.co.nz/psc/ Data version v2015001. Some of these estimates may have a small negative bias, see footnote 1.

	Fishing effort			Seabirds		Model estimates		
Year	All effort	Observed	% obs	Caps	Rate	Mean	95% c.i.	% incl
2002–03	130 173	6 840	5.3	120	1.75	1 176	934–1 462	100.0
2003–04	120 830	6 549	5.4	54	0.82	574	430–748	100.0
2004–05	120 448	7 714	6.4	74	0.96	613	469–793	100.0
2005–06	109 939	6 619	6.0	169	2.55	1 183	959–1 452	100.0
2006–07	103 318	7 933	7.7	84	1.06	626	482–813	100.0
2007–08	89 524	9 050	10.1	82	0.91	505	391–647	100.0
2008–09	87 553	9 805	11.2	152	1.55	679	555–824	100.0
2009–10	92 888	9 010	9.7	43	0.48	348	255–471	100.0
2010–11	86 089	7 445	8.6	106	1.42	528	416–656	100.0
2011–12	84 421	9 087	10.8	32	0.35	280	195–405	100.0
2012–13	83 839	12 398	14.8	104	0.84	318	243–426	100.0
2013–14	85 091	13 096	15.4	125	0.95	364	292–463	100.0
Surface longline								
2002–03	10 770 488	2 195 152	20.4	8	0.004	15	8–42	100.0
2003–04	7 386 884	1 607 304	21.8	3	0.002	8	3–28	100.0
2004–05	3 679 965	783 812	21.3	0	0.000	2	0–9	100.0
2005–06	3 690 709	705 945	19.1	0	0.000	2	0–9	100.0
2006–07	3 739 882	1 040 948	27.8	2	0.002	4	2–10	100.0
2007–08	2 246 339	421 900	18.8	0	0.000	1	0–4	100.0
2008–09	3 115 633	937 496	30.1	0	0.000	1	0–4	100.0
2009–10	2 995 264	665 883	22.2	0	0.000	1	0–5	100.0
2010–11	3 188 179	674 572	21.2	0	0.000	1	0–5	100.0
2011–12	3 099 977	728 190	23.5	0	0.000	0	0–3	100.0
2012–13	2 876 932	560 333	19.5	0	0.000	1	0–5	100.0
2013–14	2 546 764	773 527	30.4	0	0.000	1	0–4	100.0
Bottom longline								
2002–03	37 761 953	10 774 720	28.5	23	0.002	72	48–108	100.0
2003–04	43 214 066	5 060 025	11.7	17	0.003	102	51–196	100.0
2004–05	41 839 578	2 883 725	6.9	3	0.001	49	15–113	100.0
2005–06	37 145 583	3 802 951	10.2	3	0.001	24	8–51	100.0
2006–07	38 126 940	2 315 772	6.1	1	0.000	30	5–83	100.0
2007–08	41 499 499	3 593 511	8.7	6	0.002	35	14–74	100.0
2008–09	37 444 720	4 029 546	10.8	0	0.000	40	3–119	100.0
2009–10	40 438 801	2 271 123	5.6	7	0.003	84	29–191	100.0
2010–11	40 899 106	1 732 775	4.2	0	0.000	34	2–99	100.0
2011–12	37 876 333	2 100 831	5.5	0	0.000	31	2–92	100.0
2012–13	32 510 529	398 388	1.2	0	0.000	30	3–94	100.0
2013–14	40 697 435	2 750 416	6.8	0	0.000	20	1–57	100.0

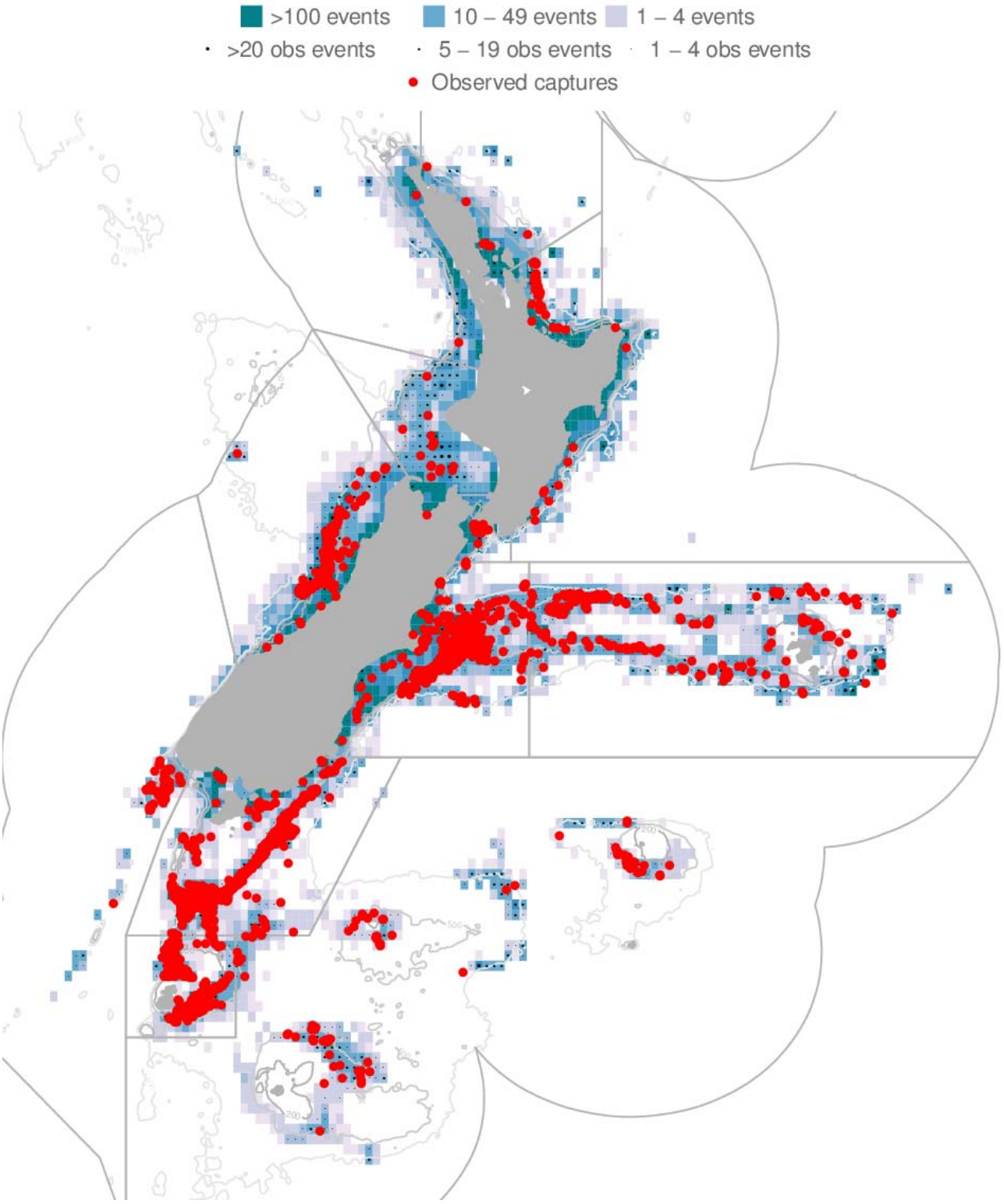


Figure 6.7: Map of trawl fishing effort and all observed seabird captures in trawls, October 2002 to September 2014. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is shown only if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. http://data.dragonfly.co.nz/psc/ Data version v2015001. See footnote 1.

Table 6.16: Summary of seabirds observed captured in trawl fisheries 2002–03 to 2013-14. Declared target species are: SQU, arrow squid; HOK+, hoki, hake, ling; Mid., other middle depth species silver, white, and common warehou, barracouta, alfonsinos, stargazer; SCI, scampi; ORH+, orange roughy and oreos; SBW, southern blue whiting; JMA, Jack mackerels; Ins., other inshore species for which one or more captures have been observed; tarakihi, red cod, spiny dogfish, John dory, snapper; FLA, flatfishes. http://data.dragonfly.co.nz/psc/ Data version v2015001. See footnote 1.

	Declared target species									
Species or group	SQU	HOK+	Mid.	SCI	ORH+	SBW	JMA	Ins.	FLA	Total
White-capped albatross	834	104	88	20	4		11	28	3	1092
Salvin's albatross	22	144	63	35	19	13		24	0	320
Southern Buller's albatross	97	104	32	8	3	1	2	1	0	248
Campbell albatross	2	8	0	1	0	2		0	0	13
Southern royal albatross	8	1	1		1	1		0	0	12
Chatham Island albatross	0	1	1	1	8			0	0	11
Southern black-browed	1	2	0	0	0	1	0	2	0	6
Gibson's albatross	0	0	0		1			0	0	1
Sooty albatross	1	0	0		0			0	0	1
Northern royal albatross	0	0	0		1			0	0	1
Albatross indet.	20	21	8	12	2	3	0	0	0	66
All albatrosses	**985**	**385**	**193**	**77**	**39**	**21**	**13**	**55**	**3**	**1771**
Sooty shearwater	659	278	156	37	3		11	1	0	1145
White-chinned petrel	706	83	85	75	1		26	5	0	981
Cape petrels	1	42	2	3	19	3	2	0	0	72
Flesh-footed shearwater	0	3	0	45	0			9	0	57
Grey petrel	1	1	0		3	42		0	0	47
Spotted shag	0	0	0		0			0	32	32
Westland petrel	2	19	3		0		1	2	0	27
Common diving petrel	5	11	2	2	2		2	0	0	24
Antarctic prion	17	0	0		0			0	0	17
Fairy prion	3	4	0		0		7	0	0	14
Giant petrel spp.	3	6	1	1	1	0	0	0	0	12
Black petrel	0	0	0	4	0			7	0	11
Grey-backed storm petrel	3	1	1		0	1		0	0	6
Fulmar prion	0	0	0		0		3	0	0	3
White-faced storm petrel	2	1	0		0			0	0	3
Black-bellied storm petrel	0	2	1		0			0	0	3
Short-tailed shearwater	0	0	0		1		1	0	0	2
Black-backed gull	0	0	0		0			0	1	1
White-headed petrel	1	0	0		0			0	0	1
Double-banded plover	0	1	0		0			0	0	1
Other bird indet.	110	26	10	2	3	5	2	7	0	165
All other birds	**854**	**200**	**105**	**132**	**30**	**51**	**44**	**30**	**33**	**1479**
All observed birds	1839	585	298	209	69	72	57	85	36	3250
Approx. proportion obs.	0.28	0.18	0.08	0.08	0.24	0.49	0.38	0.01	0.01	0.09

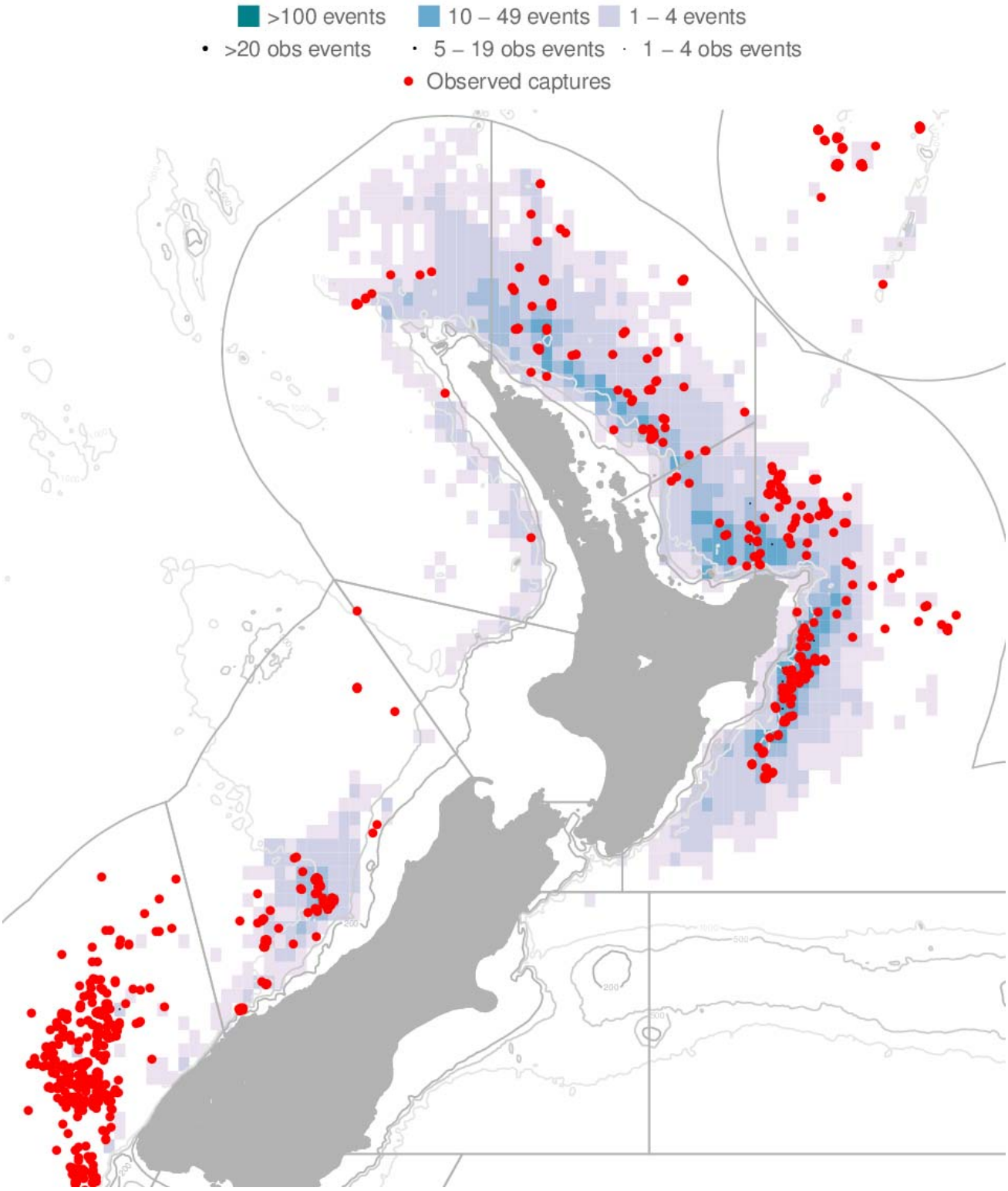


Figure 6.8: Map of surface longline fishing effort and all observed seabird captures by surface longlines, October 2002 to September 2013. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is shown only if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell (here, 89.4% of effort is displayed). http://data.dragonfly.co.nz/psc/ Data version v2015001. See footnote 1.

Table 6.17: Summary of seabirds observed captured in surface longline fisheries 2002–03 to 2013-14. Declared target species are: SBT, southern bluefin tuna; BIG, bigeye tuna; SWO, broadbill swordfish; ALB, albacore tuna. http://data.dragonfly.co.nz/psc/ Data version v2015001. See footnote 1.

	Declared target species				
Species or group	SBT	BIG	SWO	ALB	Total
Southern Buller's albatross	359	10	1	8	378
White-capped albatross	114	1	3		118
Campbell albatross	22	3	3	17	45
Gibson's albatross	10	10	10	7	37
Antipodean albatross	6	8	15	3	32
Salvin's albatross	4	4		1	9
Southern royal albatross	6	1			7
Wandering albatross	1	2			3
Black-browed albatrosses	3	1	2		6
Southern black-browed	2				2
Sooty albatross	2				2
Northern Buller's	1				1
Northern royal albatross		1			1
Albatross indet.	9	4	38	0	51
All albatrosses	**539**	**45**	**72**	**36**	**692**
Grey petrel	41		2	5	48
White-chinned petrel	24	6	5	2	37
Grey-faced petrel		3	3	17	23
Black petrel		22	2	1	25
Sooty shearwater	4		1	8	13
Flesh-footed shearwater		11	1		12
Westland petrel	6		1	2	9
Cape petrels	2				2
Southern giant petrel	2				2
White-headed petrel				2	2
Gadfly petrels		1			1
Other bird indet.	2	0	0	0	2
All other birds	**81**	**43**	**15**	**37**	**176**
All observed birds	**620**	**88**	**87**	**73**	**868**
Approx. proportion obs.	**0.42**	**0.03**	**0.09**	**0.38**	**0.22**

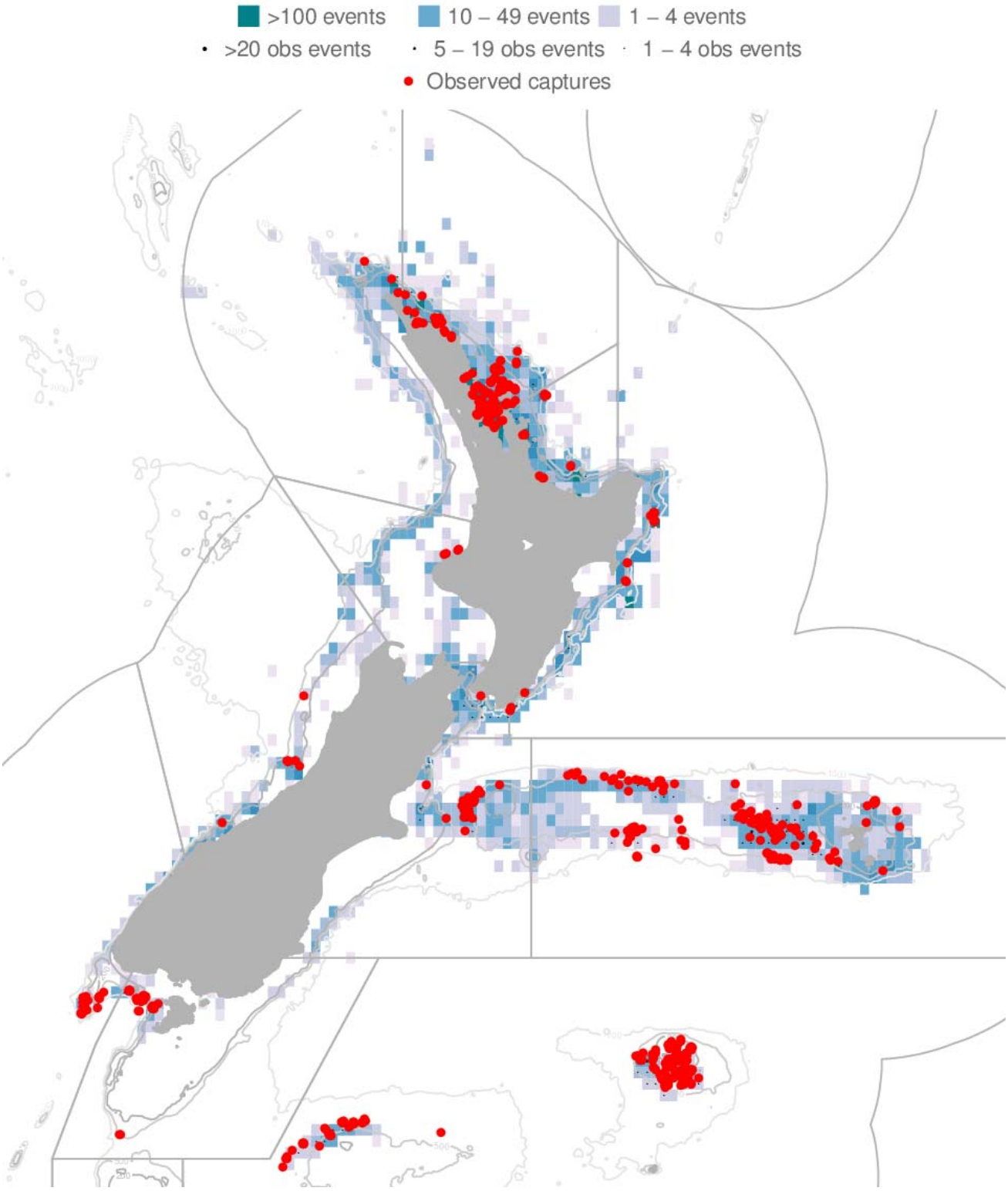


Figure 6.9: Map of bottom longline fishing effort and all observed seabird captures by bottom longlines, October 2002 to September 2014. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort (events). Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is shown only if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell (here, 95.8% of effort is displayed). http://data.dragonfly.co.nz/psc/ Data version v2015001. See footnote 1.

Table 6.18: Summary of seabirds observed captured in bottom longline fisheries 2002–03 to 2012–13. Declared target species are: LIN, ling; SNA, snapper; BNS, bluenose; HPB, hapuku or bass. http://data.dragonfly.co.nz/psc/ Data version v2015001. See footnote 1.

Species or group	Declared target species					
	LIN	SNA	BNS	HPB	Other	Total
Salvin's albatross	55	0		0	2	57
Chatham Island albatross	18	0		0	0	18
Southern Buller's	10	0	3	0	0	13
White-capped albatross	4	0		0	0	4
Campbell albatross		0	2	1	1	4
Southern royal albatross	4	0		0	0	4
Yellow-nosed albatross	1	0		0	0	1
Black-browed albatrosses	1	0		0	0	1
Albatross indet.	7	0	1	0	0	8
All albatrosses	**100**	**0**	**6**	**1**	**3**	**110**
White-chinned petrel	235	0	2	0	17	254
Grey petrel	79	0		0	0	79
Flesh-footed shearwater		65		3	3	71
Sooty shearwater	59	0		1	0	60
Black petrel		35	20	5	0	60
Cape petrels	25	0	0	0	0	25
Fluttering shearwater		8		0	1	9
Buller's shearwater		9		0	0	9
Grey-faced petrel		0		6	0	6
Fairy prion	5	0		0	0	5
Southern black-backed gull		2		0	3	5
Giant petrel spp.	5	0	0	0	0	5
Common diving petrel	3	0		0	0	3
Pied shag		2		0	0	2
Australasian gannet		2		0	0	2
Crested penguins	1	0		0	0	1
Red-billed gull		1		0	0	1
Short-tailed shearwater	1	0		0	0	1
Westland petrel		0		0	1	1
Other bird indet.	7	9	0	0	0	16
All other birds	**420**	**133**	**22**	**15**	**25**	**615**
All observed birds	**520**	**133**	**28**	**16**	**28**	**725**
Approx. proportion obs.	**0.17**	**0.02**	**0.01**	**0.01**	**0.05**	**0.09**

Model-based estimates of captures can be combined across trawl and longline fisheries (Figure 6.10). Summed across all bird taxa, trawl, surface longline, and bottom longline fisheries account for 45%, 13%, and 42% of captures, respectively, but there are substantial differences in these proportions among seabird taxa. A high proportion (85% between 2003-04 and 2013-14) of white-capped albatross captures are taken in trawl fisheries with most of the remainder taken in surface longline fisheries. The trawl fishery also accounts for 92% of sooty shearwaters captured, with most of the remainder taken by bottom longliners. The proportion captured by trawl fisheries reduces to 26% for all other albatrosses combined, with 48% and 26% taken in surface and bottom longline fisheries, respectively. Bottom longline and trawl take similar proportions of the white-chinned petrels captured (42% and 51%, respectively).

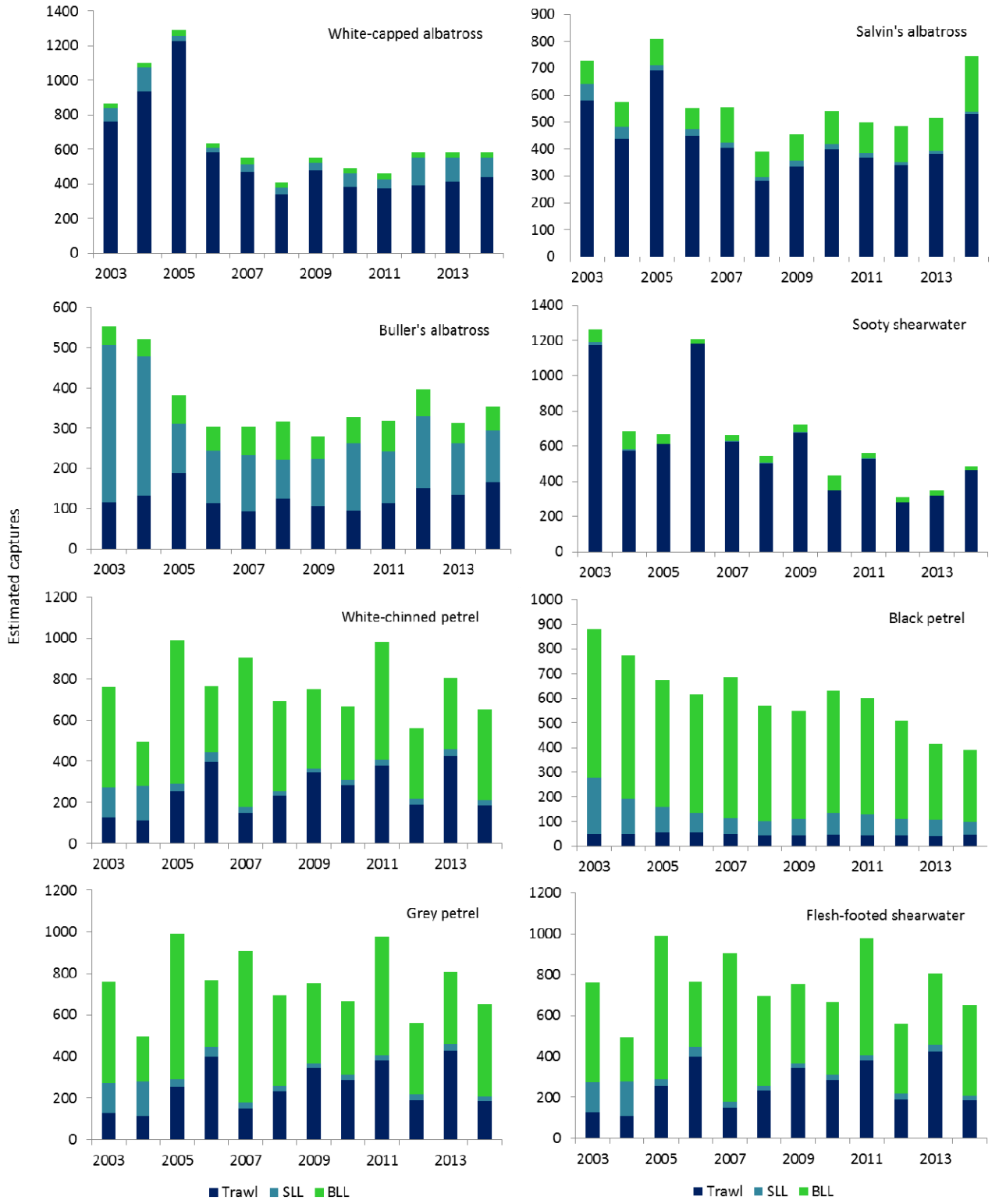


Figure 6.10: Model-based estimates of captures of the most numerous seabird taxa observed captured in trawl, surface longline, and bottom longline fisheries between 2002–03 and 2013-14. For confidence limits see Table 6.10 to Table 6.15. Note that this level of aggregation conceals any different trends within a fishing method (e.g., deepwater vs. inshore and flatfish trawl or large vs. small longliners). http://data.dragonfly.co.nz/psc/ Data version v2015001. These estimates may have a small negative bias, see footnote 1.

Over the 2003-04 to 2013-14 period, there appear to have been downward trends (across all fisheries) in the estimated captures of white-capped albatross, and non-albatross taxa other than white-chinned petrel (Figure 6.10). Estimated captures of other albatrosses and white-chinned petrel appear to have fluctuated without much trend, although there is some evidence for an increasing trend for white-chinned petrel, especially in trawl fisheries.

Because fishing effort often changes with time, estimates of total captures may not be the only index required for comprehensive monitoring. The number of captures (with certain caveats, see later) is clearly more biologically relevant for birds, but capture rates by fishery may be more useful measures to assess fishery performance and the effectiveness of mitigation approaches. Dividing modelled catch estimates by the number of tows or hooks set in a particular fishery in each year provides catch rate indices by fishery. These are typically reported as the number of birds captured per 100 trawl tows or per 1000 longline hooks (Figure 6.11 to Figure 6.15).

For white-capped albatross, captures rates in the major offshore trawl fisheries for squid and hoki declined after 2004–05 (Figure 6.11) but showed no trend for inshore trawlers and increased for surface longliners targeting southern bluefin tuna. Together, these fisheries account for 71% of all estimated captures of white-capped albatross in these years.

For Salvin's albatross, captures rates have fluctuated without trend or increased in all fisheries taking substantial numbers of this species between 2002–03 and 2013-14, especially after 2006–07 (Figure 6.12). Capture rates were unusually high in all trawl fisheries in 2004–05. Together, these fisheries account for 85% of all estimated captures of Salvin's albatross in these years.

For Buller's albatross, estimated captures decreased in bigeye tuna target surface longline fisheries between 2002-03 and 2013-14, while capture rates increased. Captures and capture rates fluctuated with no trend in southern bluefin tuna target fisheries and displayed no apparent trend in longline bottom longline and hoki trawl fisheries (Figure 6.13). Together these fisheries account for 57% of all estimated captures of Southern Buller's albatross in these years.

For white-chinned petrel, captures rates increased between 2002–03 and 2013-14 in squid trawlers (Figure 6.14) but showed little trend for bottom longliners targeting ling and bluenose, and scampi trawl. Together, these fisheries account for 67% of all estimated captures of white-chinned petrel in these years.

For sooty shearwaters, captures rates decreased between 2002–03 and 2013-14 for bottom longliners targeting ling with 2009-10 higher than other subsequent years, but fluctuated without apparent trend in squid, middle-depth, and hoki trawlers (Figure 6.15). High capture rates of this species occur across all three trawl fisheries in some years. Together, these fisheries account for 85% of all estimated captures of sooty shearwaters in these years.

On-board captures recorded by observers represent the most reliable source of information for monitoring trends in total captures and capture rates, but these data have three main deficiencies with respect to estimating total fatalities, especially to species level. First, some captured seabirds are released alive (26% in trawl fisheries between 2002–03 and 2012–13, 27% in surface longline fisheries, and 27% in bottom longline fisheries), meaning that, all else being equal, estimates of captures may overestimate total fatalities, depending on the survival rate of those released. There is a trend in the percentage of albatross observed caught on trawl vessels that were released alive with an general increase from 2009-10, this trend is less apparent for across all birds or in other methods (Table 6.19). Second, identifications by observers are not completely reliable and sometimes use generic codes rather than species codes. While a proportion of dead captures are returned for necropsy and photographs taken for confirmation of identification, there remains uncertainty about the identity of 24% of observed captures in trawl fisheries between 2002–03 and 2012–13, 32% from surface longline fisheries, and 30% from bottom longline fisheries. The number of uncertain identifications is always higher than the number of birds released alive in previous years, but in the last 3 years, photo identification has been quite common, including for birds captured and released alive. Third, not all birds killed or mortally wounded by fishing gear are recovered on a fishing vessel. Some birds caught on longline hooks fall off before being recovered, and birds that collide with trawl warps may be dragged under the water and drowned or injured to the extent that they are unable to fly or feed. Excluding this "cryptic" mortality means that, all

else being equal, estimates of captures will underestimate total fatalities, and the extent of underestimation will vary among taxa and fisheries. These deficiencies do not greatly affect the suitability of estimates of captures and capture rates for monitoring purposes, but they have necessitated the development of alternative methods for assessing risk and population consequences.

Table 6.19: Percentage of observed captures that were released alive (http://data.dragonfly.co.nz/psc/ Data version v20140131)

	All birds			Albatross spp only		
	Trawl	SLL	BLL	Trawl	SLL	BLL
2002-03	24	18	20	7	28	11
2003-04	9	30	28	4	31	82
2004-05	20	41	37	11	48	100
2005-06	18	38	49	7	40	43
2006-07	18	22	12	13	24	0
2007-08	18	38	10	13	38	30
2008-09	26	26	36	19	34	50
2009-10	34	30	54	31	32	N/A
2010-11	30	45	31	38	51	88
2011-12	25	16	70	24	18	30
2012-13	40	26	0	35	27	N/A

6.4.3 MANAGING FISHERIES INTERACTIONS

New Zealand had taken steps to reduce incidental captures of seabirds before the advent of the IPOA in 1999 and the NPOA in 2004. For example, regulations were put in place under the Fisheries Act to prohibit drift net fishing in 1991 and prohibit the use of netsonde monitoring cables ("third wires") in trawl fisheries in 1992. The use of tori lines (streamer lines designed to scare seabirds away from baited hooks) was made mandatory in all tuna longline fisheries in 1992.

The fishing industry also undertook several initiatives to reduce captures, including funding research into new or improved mitigation measures, and adopting voluntary codes of practice and best practice fishing methods. Codes of practice have been in place in the joint venture tuna longline fishery since 1997–98, requiring, among other things, longlines to be set at night and a voluntary upper limit on the incidental catch of seabirds. That limit was steadily reduced from 160 "at risk" seabirds in 1997–98, to 75 in 2003–04. Most vessels in the domestic longline tuna fishery had also voluntarily adopted night setting by 2004. A code of practice was in place for the ling auto-line fishery by 2002–03. Other early initiatives included reduced deck lighting, the use of thawed rather than frozen baits, sound deterrents, discharging of offal away from setting and hauling, weighted branch lines, different gear hauling techniques and line shooters. Current regulated and voluntary initiatives are summarised by fishery in Table 6.20.

In 2002, MFish, DOC, and stakeholders began working with other countries to reduce the incidental catch of seabirds. As a result, a group called Southern Seabird Solutions was formed and formally established as a Trust in 2003 (http://www.southernseabirds.org/) and received royal patronage in 2012. Southern Seabird Solutions exists to promote responsible fishing practices that avoid the incidental capture of seabirds in New Zealand and the southern ocean. Membership includes representatives from the commercial fishing industry, environmental and conservation groups, and government departments. The Trust's vision is that: *All fishers in the Southern Hemisphere avoid the capture of seabirds*, and this is underpinned by the strategic goals on: Culture Change; Supporting Collaboration; Mitigation Development and Knowledge Transfer; Recognising Success; and Strengthening the Trust.

Building on these initiatives, New Zealand's 2004 NPOA established a more comprehensive framework to reducing incidental captures approach across all fisheries (because focussing on longline fisheries like the IPOA was considered neither equitable nor sufficient).

It included two goals that set the overall direction:

1. To ensure that the long-term viability of protected seabird species is not threatened by their incidental catch in New Zealand fisheries waters or by New Zealand flagged vessels in high seas fisheries; and
2. To further reduce incidental catch of protected seabird species as far as possible, taking into account advances in technology, knowledge and financial implications.

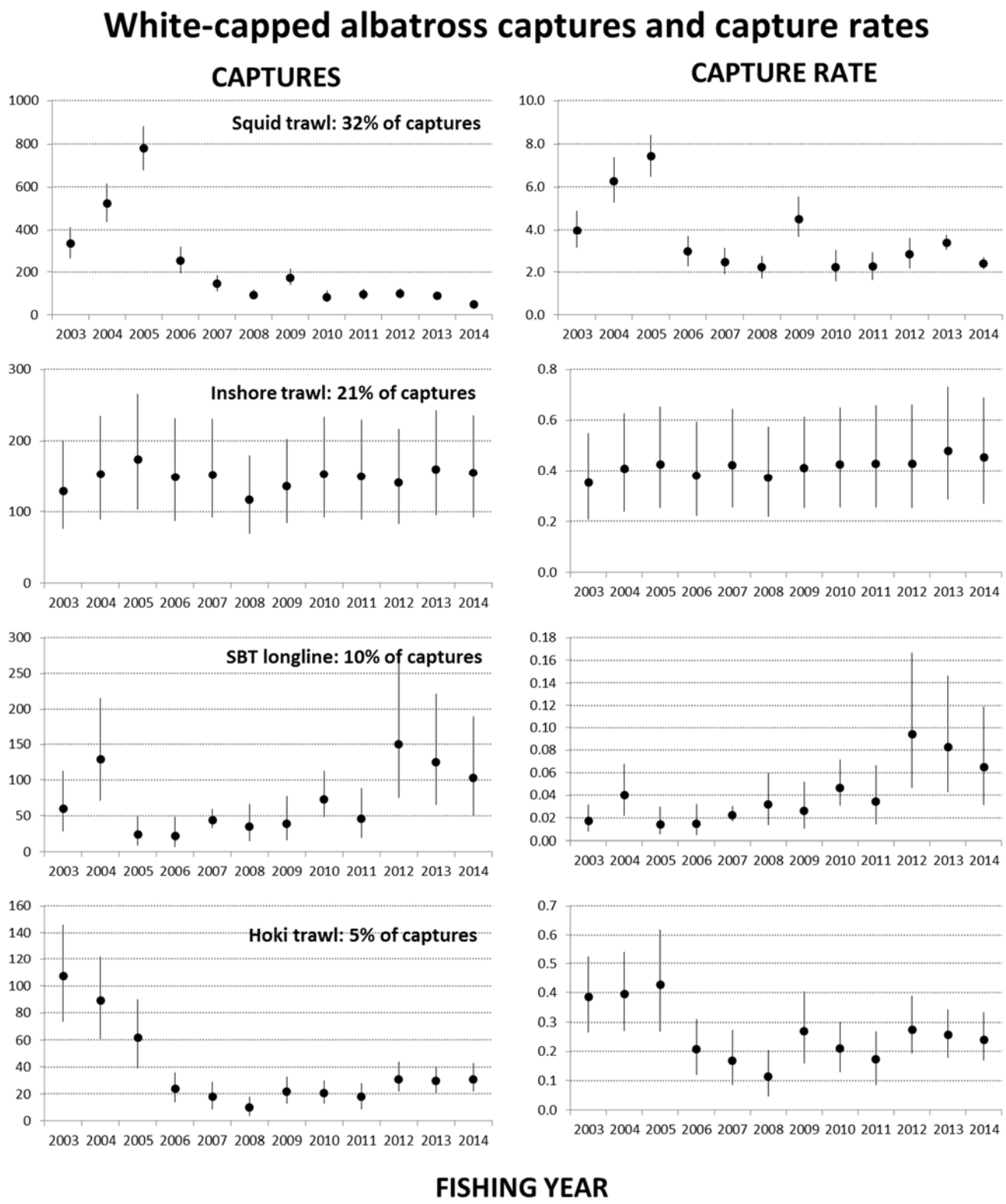


Figure 6.11: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of white capped albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2013–14 (cumulatively, 71% of all white-capped albatross captures). http://data.dragonfly.co.nz/psc/ Data version v2015001. These estimates may have a small negative bias, see footnote 1.

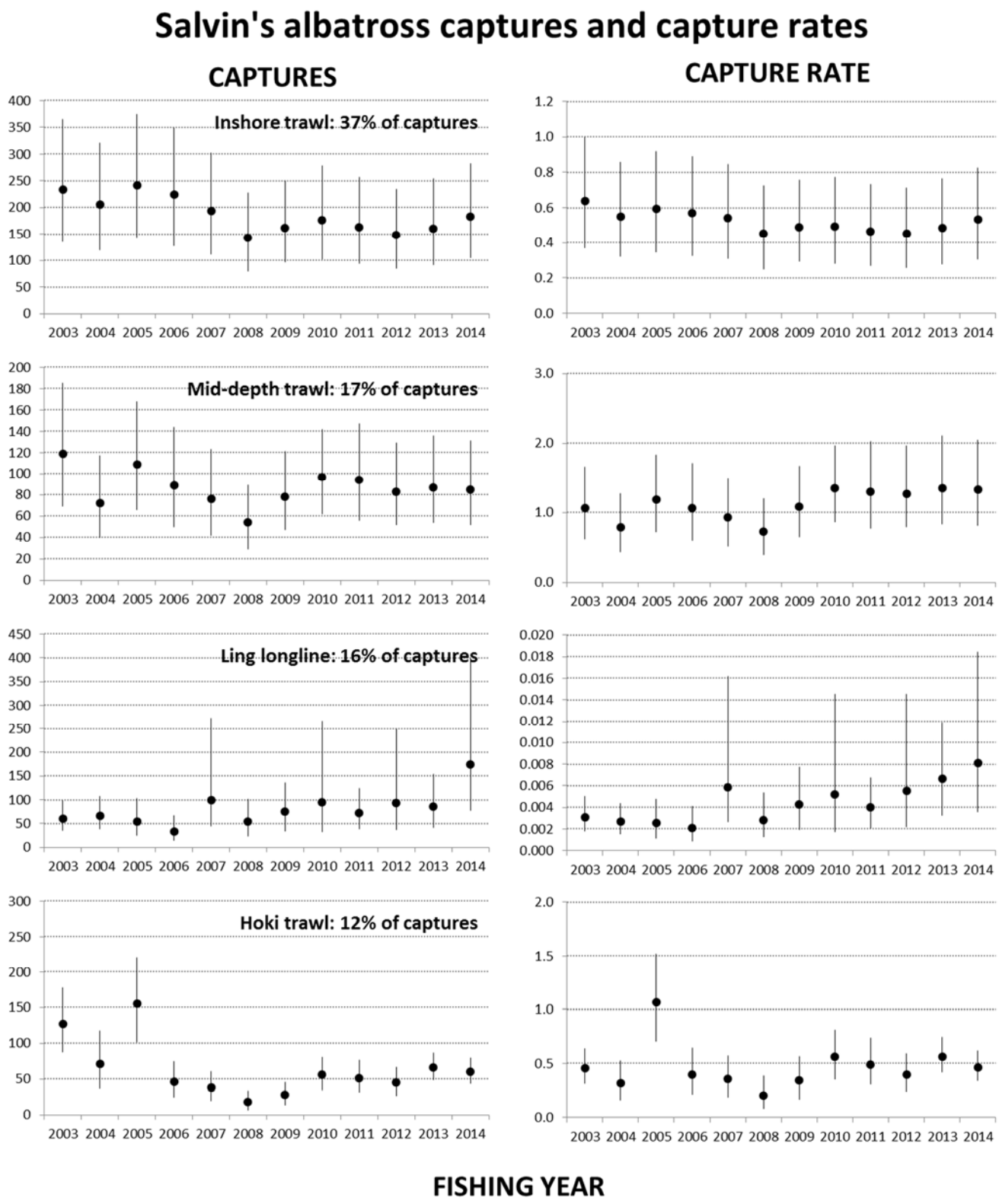


Figure 6.12: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of Salvin's albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2013–14 (cumulatively, 82% of all Salvin's albatross captures). http://data.dragonfly.co.nz/psc/ Data version v2015001. These estimates may have a small negative bias, see footnote 1.

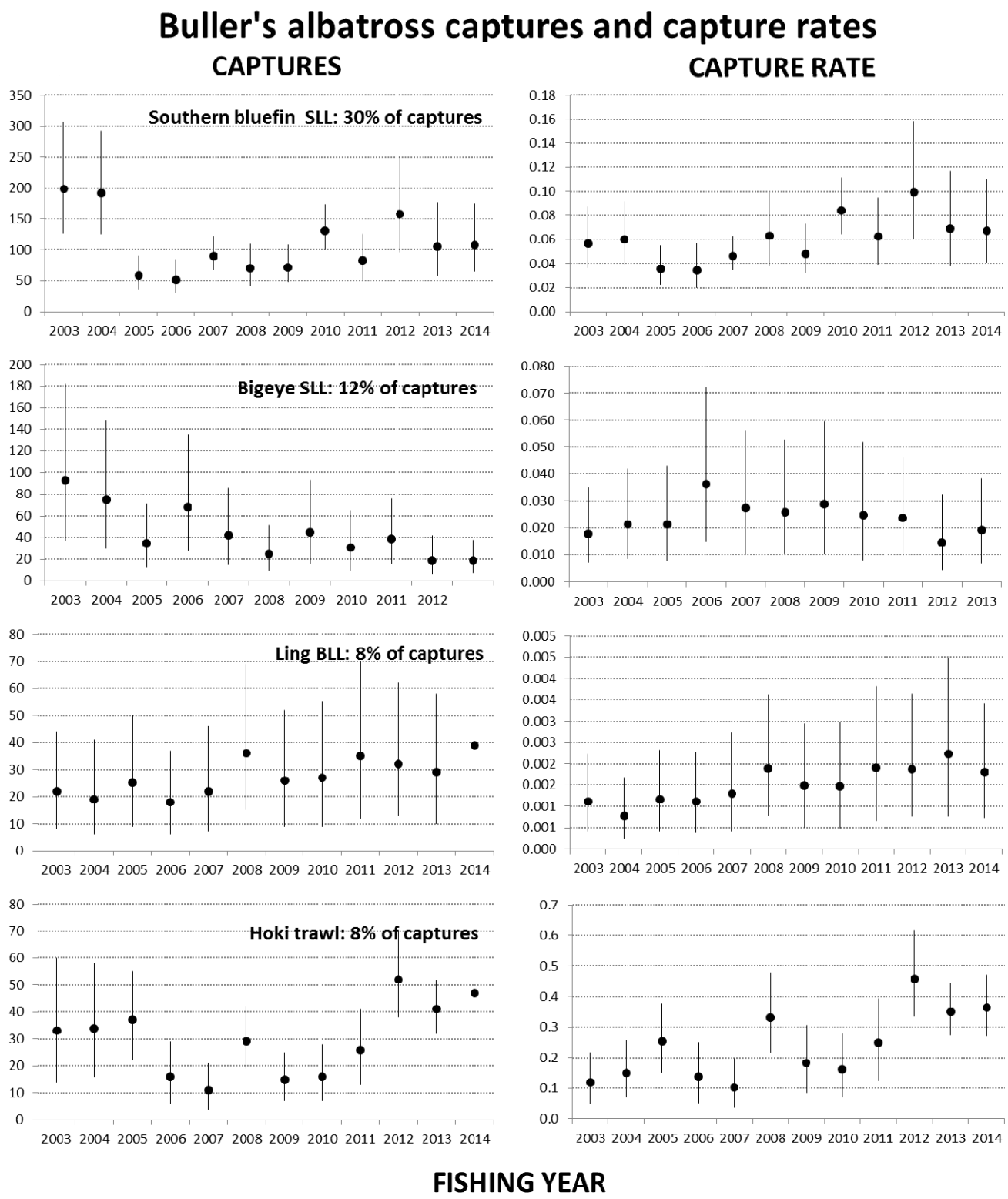


Figure 6.13: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of Buller's albatross in the four fisheries estimated to have taken the most captures between 2002–03 and 2013–14 (cumulatively, 57% of all Buller's albatross captures). http://data.dragonfly.co.nz/psc/ Data version v20150001. These estimates may have a small negative bias, see footnote 1.

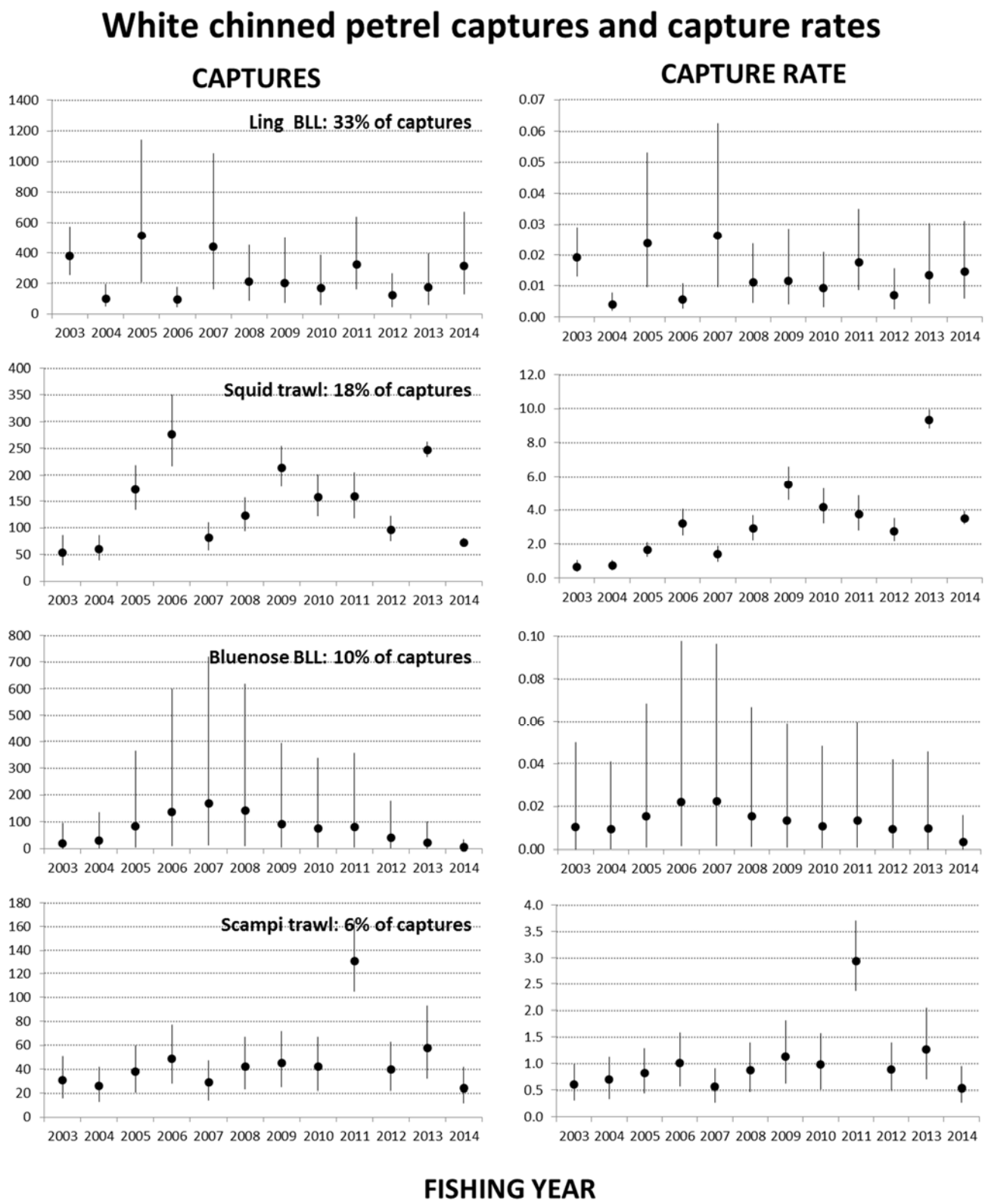


Figure 6.14: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of white chinned petrels in the four fisheries estimated to have taken the most captures between 2002–03 and 2013–14 (cumulatively, 67% of all white-chinned petrel captures). http://data.dragonfly.co.nz/psc/ Data version v20150001. These estimates may have a small negative bias, see footnote 1.

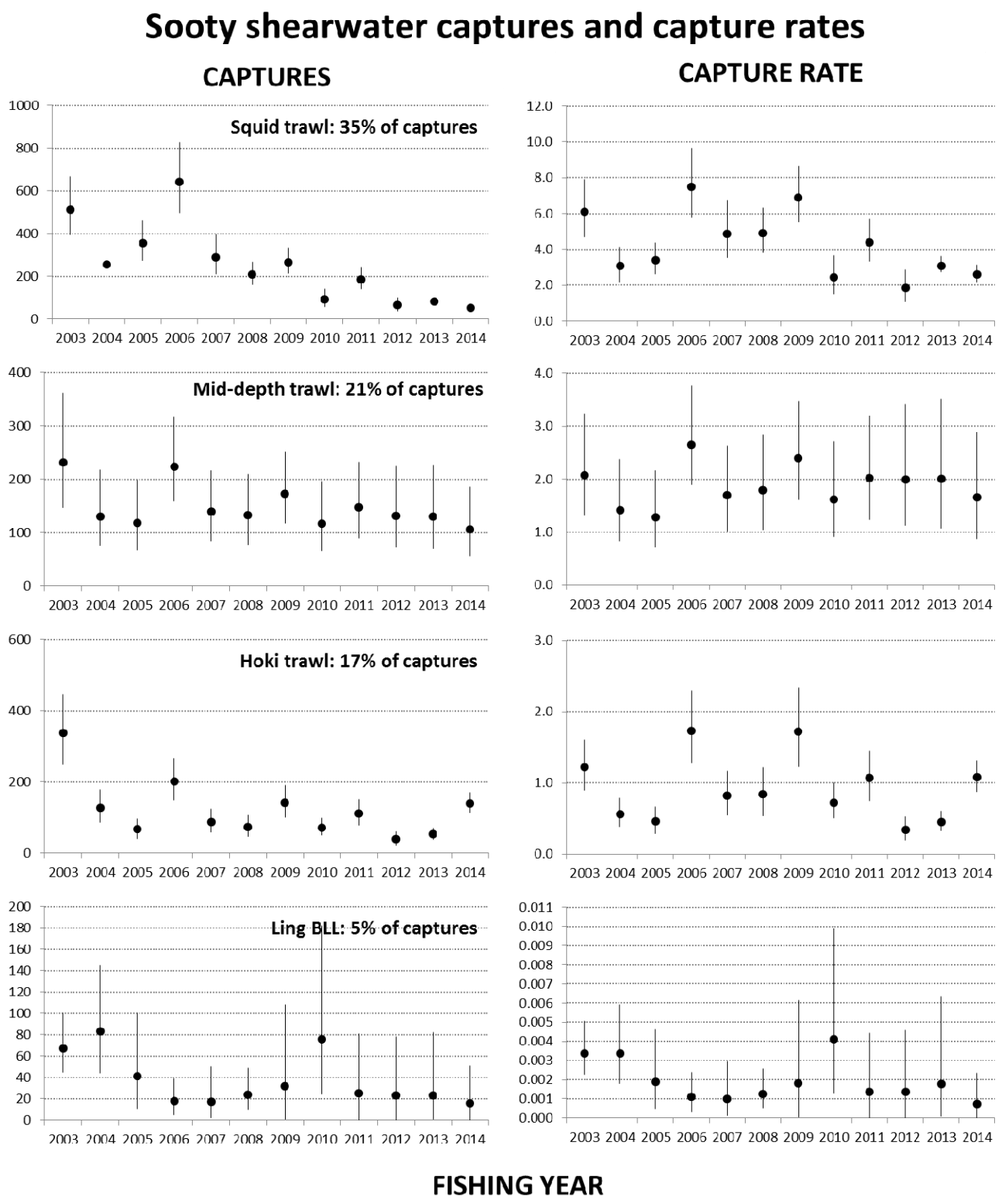


Figure 6.15: Model-based estimates of captures (left panels) and capture rates (right panels, captures per 100 trawl tows or 1000 longline hooks) of sooty shearwaters in the four fisheries estimated to have taken the most captures between 2002–03 and 2013–14 (cumulatively, 85% of all sooty shearwater captures). http://data.dragonfly.co.nz/psc/ Data version v2015001. These estimates may have a small negative bias, see footnote 1.

Together the two goals established the NPOA as a long-term strategy. The second goal was designed to build on the first goal by promoting and encouraging the reduction of incidental catch beyond the level that is necessary to ensure long term viability. The goals recognised that, although seabird deaths may be accidentally caused by fishing, most seabirds are absolutely protected under the Wildlife Act. The second goal balances the need to continue reducing incidental catch against the factors that influence how this can be achieved in practice (e.g., advances in technology and the costs of mitigation). The scope of the 2004 NPOA included:

- all seabird species absolutely or partially protected under the Wildlife Act;
- commercial and non-commercial fisheries;
- all New Zealand fisheries waters; and
- high seas fisheries in which New Zealand flagged vessels participate, or where foreign flagged vessels catch protected seabird species.

Specific objectives were established in the 2004 NPOA as follows:

1. Implement efficient and effective management measures to achieve the goals of the NPOA, using best practice measures where possible.
2. Ensure that appropriate incentives and penalties are in place so that fishers comply with management measures.
3. Establish mandatory bycatch limits for seabird species where they are assessed to be an efficient and effective management measure and there is sufficient information to enable an appropriate limit to be set.
4. Ensure that there is sufficient, reliable information available for the effective implementation and monitoring of management measures.
5. Establish a transparent process for monitoring progress against management measures.
6. Ensure that management measures are regularly reviewed and updated to reflect new information and developments, and to ensure the achievement of the goals of the NPOA.
7. Encourage and facilitate research into affected seabird species and their interactions with fisheries.
8. Encourage and facilitate research into new and innovative ways to reduce incidental catch.
9. Provide mechanisms to enable all interested parties to be involved in the reduction of incidental catch.
10. Promote education and awareness programmes to ensure that all fishers are aware of the need to reduce incidental catch and the measures available to achieve a reduction.

The 2004 NPOA-seabirds set out the mix of voluntary and mandatory measures that would be used to help reduce incidental captures of seabirds, noted research into the extent of the problem and the techniques for mitigating it, and outlined mechanisms to oversee, monitor and review the effectiveness of these measures. It was not within the scope of the NPOA to address threats to seabirds other than fishing. Such threats are identified in DOC's Action Plan for Seabird Conservation in New Zealand (Taylor 2000) and their management is undertaken by DOC.

Since publication of the NPOA in 2004, more progress has been made in the commercial fishing sector, including:

- in the deepwater fishing sector;
  - industry has implemented vessel specific risk management plans (VMPs) comprising non-mandatory seabird scaring devices, offal management, and other measures to reduce risks to seabirds,
  - the government has implemented mandatory measures to reduce risk to seabirds (e.g., use and deployment of seabird scaring devices), and
  - industry has taken a proactive stance in resourcing a 24/7 liaison officer to undertake incident response actions, mentoring, VMP and regime development and reviewing, and fleet wide training;
- in the bottom and surface long-line sectors, the government has implemented mandatory measures including tori lines, night setting, line weighting and offal management;
- a number of research projects have been or are currently being undertaken by government and industry into offal discharge, efficacy of seabird scaring devices, line weighting and longline setting devices; and
- workshops organised by both industry bodies and Southern Seabird Solutions are being held for the inshore trawl and longline sectors.

Mitigation has developed substantially since FAO's IPOA was published and a number of recent reviews consider the effectiveness of different methods (Bull 2007, 2009) and summarise currently accepted best practice (ACAP 2011). In December 2010, FAO held a Technical Consultation where International Guidelines on bycatch management and reduction of discards were adopted (FAO 2010). The text included an agreement that the guidelines should complement appropriate bycatch measures addressed in the IPOA-Seabirds and its Best Practice Technical Guidelines (FAO 2009). The Guidelines were subsequently adopted by FAO in January 2011.

In 2013 the Ministry for Primary Industries released a revised and updated version of the NPOA-Seabirds. This revision seeks to address recommendations from the IPOA/NPOA Seabirds Best Practice Technical Guidelines (FAO 2009). The scope of the revised New Zealand NPOA-Seabirds 2013 is as follows:

- all seabird species absolutely or partially protected under the New Zealand Wildlife Act 1953;
- commercial, recreational and customary non-commercial fisheries in waters under New Zealand fisheries jurisdiction;
- all fishing methods which capture seabirds, including longlining, trawling, set netting, hand lining, trolling, purse seining and potting;
- all waters under New Zealand fisheries jurisdiction;
- high seas fisheries in which New Zealand flagged vessels participate, and, as appropriate and relevant, where foreign flagged vessels catch New Zealand seabirds; and
- other areas in which New Zealand seabirds are caught.

The long term objective of the 2013 NPOA-Seabirds is: *"New Zealand seabirds thrive without pressure from fishing related mortalities, New Zealand fishers avoid or mitigate against seabird captures and New Zealand fisheries are globally recognised as seabird friendly."*

The high level subsidiary objectives of the NPOA-Seabirds 2013 are:

i. Practical objective: All New Zealand fishers implement current best practice mitigation measures relevant to their fishery and aim through continuous improvement to reduce and where practicable eliminate the incidental mortality of seabirds.
ii. Biological risk objective: Incidental mortality of seabirds in New Zealand fisheries is at or below a level that allows for the maintenance at a favourable conservation status or recovery to a more favourable conservation status for all New Zealand seabird populations.
iii. Research and Development objectives:
    a. the testing and refinement of existing mitigation measures and the development of new mitigation measures results in more practical and effective mitigation options that fishers readily employ;
    b. research and development of new observation and monitoring methods results in improved cost effective assurance that mitigation methods are being deployed effectively; and
    c. research outputs relating to seabird biology, demography and ecology provide a robust basis for understanding and mitigating seabird incidental mortality.
iv. International objective: In areas beyond the waters under New Zealand jurisdiction, fishing fleets that overlap with New Zealand breeding seabirds use internationally accepted current best practice mitigation measures relevant to their fishery.

Areas identified in the NPOA-Seabirds 2013 which clearly require additional progress include:

i. mitigation measures for, and education, training and outreach in commercial set net fisheries and inshore trawl fisheries;
ii. implementation of spatially and temporally representative at sea data collection in inshore and some Highly Migratory Species (HMS) fisheries;
iii. mitigation measures for net captures for deepwater trawl fisheries;
iv. the extent of any cryptic mortality (seabird interactions which result in mortality but are unobserved or unobservable); and
v. mitigation measures for, education, training and outreach in, and risk assessment of non-commercial fisheries (in particular the set net and hook and line fisheries).

The most important factor influencing contacts between seabirds and trawl warp cables is the discharge of offal (Wienecke & Robertson 2002; Sullivan et al 2006b, ACAP 2011). Offal management methods used to reduce the attraction of seabirds to vessels include mealing, mincing, and batching. ACAP recommends (ACAP 2011) full retention of all waste material where practicable because this significantly reduced the number of seabirds feeding behind vessels compared with the discharge of unprocessed fish waste (Wienecke & Robertson 2002, Abraham 2009, Favero et al 2010) or minced waste (Melvin et al 2010). Offal management has been found to be a key driver of seabird bycatch in New Zealand trawl fisheries (Abraham 2007, Abraham & Thompson 2009b, Abraham et al 2009, Abraham 2010b, Pierre et al 2010, 2012a, b). Other best practice recommendations (ACAP 2011) are the use of bird-scaring lines to deter birds from foraging near the trawl warps, use of snatch blocks to reduce the aerial extent of trawl warps, cleaning fish and benthic material from nets before shooting, minimising the time the trawl net is on the surface during hauling, and binding of large meshes in pelagic trawl before shooting.

In New Zealand, the three legally permitted devices used for mitigation by trawlers are tori lines (e.g., Sullivan et al 2006a), bird bafflers (Crysel 2002), and warp scarers (Carey 2005). Middleton & Abraham (2007) reported experimental trials of mitigation devices designed to reduce the frequency of collisions between seabirds and trawl warps on 18 observed vessels in the squid trawl fishery in 2006. The frequencies of birds striking either warps or one of three mitigation devices (tori lines, 4-boom bird bafflers, and warp scarers) were assessed using standardised protocols during commercial fishing. Different warp strike mitigation treatments were used on different tows according to a randomised experimental design. Middleton & Abraham (2007) confirmed that the discharge of offal was the main factor influencing seabird strikes; almost no strikes were recorded when there was no discharge, and strike rates were low when only sump water was discharged (see also Abraham et al 2009). In addition to this effect, tori lines were shown to be most effective mitigation approach and reduced warp strikes by 80–95% of their frequency without mitigation. Other mitigation approaches were only 10–65% effective. Seabirds struck tori lines about as frequently as they did the trawl warps in the absence of mitigation but the consequences are unknown.

Recommended best practice for surface (pelagic) longline fisheries and bottom (demersal) longlines (ACAP 2011) includes weighting of lines to ensure rapid sinking of baits (including integrated weighted line for bottom longlines), setting lines at night when most vulnerable birds are less active, and the proper deployment of bird scaring lines (tori lines) over baits being set, and offal management (especially for bottom longlines). A range of other measures are offered for consideration.

6.4.4 MODELLING FISHERIES INTERACTIONS AND ESTIMATING RISK

6.4.4.1 HIERARCHICAL STRUCTURE OF RISK ASSESSMENTS

Hobday et al (2007) described a hierarchical framework for ecological risk assessment in fisheries (see Figure 6.16). The hierarchy included three levels: Level 1 qualitative, expert-based assessments (often based on a Scale, Intensity, Consequence Analysis, SICA); Level 2 semi-quantitative analysis (often using some variant of Productivity Susceptibility Analysis, PSA); and Level 3 fully quantitative modelling including uncertainty analysis. The hierarchical structure is designed to “screen out” potential effects that pose little or low risk for the least investment in data collection and analysis, escalating to risk treatment or higher levels in the hierarchy only for those potential effects that pose non-negligible risk. This structure relies for its effectiveness on a low potential for false negatives at each stage, thereby identifying and screening out activities that are ‘low risk’ with high certainty. This focuses effort on remaining higher risk activities. In statistical terms, risk assessment tolerates Type I errors (false positives, i.e. not screening out activities that may actually present a low risk) in order to avoid Type II errors (false negatives, i.e. incorrectly screening out activities that actually constitute high risk), and it is important to distinguish this approach from normal estimation methods. Whereas normal estimation strives for a lack of bias and a balance of Type I and Type II errors, risk assessment is designed to answer the question “how bad could it be?” The divergence between the risk assessment approach and normal, unbiased estimation approaches should diminish at higher levels in the risk assessment hierarchy, where the assessment process should be informed by good data that support robust estimation. seabird taxa (Table 6.25 shows the results for all 26 fishery groups).

Table 6.20: (from MPI 2013, the revised NPOA-seabirds): summary of current mitigation measures applied to New Zealand vessels fishing in New Zealand waters to avoid incidental seabird captures. R, regulated; SM, required via a self-managed regime (non-regulatory, but required by industry organisation and audited independently by government); V, voluntary with at least some use known; N/A, measure not relevant to the fishery; years in parentheses indicate year of implementation; *, part of a vessel management plan (VMP). Note, this table may not capture all voluntary measures adopted by fishers.

Mitigation Measure	Surface longline	Bottom longline	Trawl >=28 m	Trawl <28 m	Set net	Notes
Netsonde cable prohibition	N/A	N/A	R (1992)	R (1992)	N/A	Netsonde cables also called third wires
Streamer (tori) lines	R	R	N/A	N/A	N/A	
Additional streamer line	–	–	N/A	N/A	N/A	
Night setting	R (or line weighting)	R (or line weighting)	–	–	–	} Longlines must use night setting if not line weighting, or *vice-versa*
Line weighting	R (or night setting)	R (or night setting)	N/A	N/A	N/A	
Seabird scaring device	N/A	N/A	R (2006)	R?	N/A	To prevent warp captures and collisions
Additional bird scaring device	N/A	N/A	SM (2008)*	–	N/A	
Dyed bait	V	–	N/A	N/A	N/A	
Offal management	V	R	SM (2008)*	–	–	
VMPs			SM (2008)	V	–	Some VMPs developed for vessels < 28m
Code of Practice	V	–	VMP	–	–	

Note: A vessel management plan (VMP) is a vessel-specific seabird risk management plan which specifies seabird mitigation devices to be used, operational management requirements to minimise the attraction of seabirds to vessels, and incident response requirements and other techniques or processes in place to minimise risk to seabirds from fishing operations.

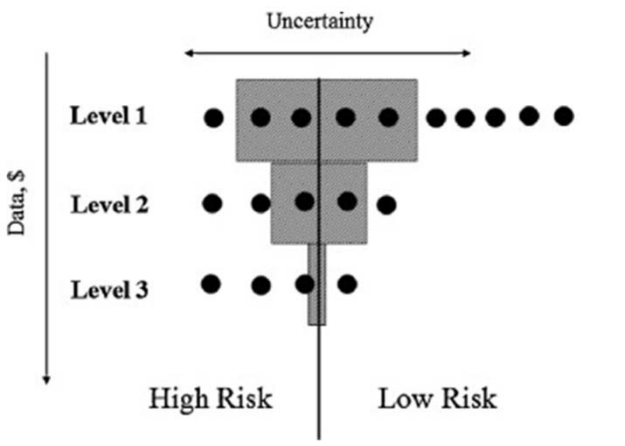


Figure 6.16: (from Hobday et al 2007): Diagrammatic representation of the hierarchical risk assessment process where activities that present low risk are progressively screened out by assessments of increasingly high data content, sophistication, and cost.

6.4.5 QUALITATIVE (LEVEL 1) RISK ASSESSMENT

Rowe (2013) summarised an expert-based, qualitative (Level 1) risk assessment, commissioned by DOC, for the incidental mortality of seabirds caused by New Zealand fisheries. The main focus was on fisheries operating within the NZ EEZ and on all seabirds absolutely or partially protected under the Wildlife Act 1953. New Zealand flagged vessels fishing outside the EEZ were included, but risk from non-NZ fisheries and other human causes were not included.

The panel of experts who conducted the Level 1 risk assessment assessed the threat to each of 101 taxa posed by 26 fishery groups, scoring exposure and consequence independently according to the schemas in Table 6.21 and Table 6.22 (details in Rowe 2013). The risk for a given taxon posed by a given fishery was calculated as the product of exposure and consequence scores. Potential risk was estimated as the risk posed by a fishery assuming no mitigation was in place, and residual risk (called "optimum risk" by Rowe 2013) was estimated assuming that mitigation was in place throughout a given fishery and deployed correctly. The panel also agreed a confidence score for each taxon-fishery interaction using the schema in Table 6.23.

Total potential and residual risk for a seabird taxon was estimated by summing the scores across all fisheries (Table 6.24 shows taxa with an aggregate score of 30 or higher), and total potential and residual risk posed by a fishery group was estimated by summing the scores across all

Table 6.21: Exposure scores used by Rowe (2013) (modified from Fletcher 2005, Hobday et al 2007).

Score	Descriptor	Description
0	Remote	The species will not interact directly with the fishery
1	Rare	Interactions may occur in exceptional circumstances
2	Unlikely	Evidence to suggest interactions possible
3	Possible	Evidence to suggest interactions occur, but are uncommon
4	Occasional	Interactions likely to occur on occasion
5	Likely	Interactions are expected to occur

Table 6.22: Consequence scores used by Rowe (2013) (modified from Fletcher 2005, Campbell & Gallagher 2007, Hobday et al 2007).

Score	Descriptor	Description
1	Negligible	Some or one individual/s impacted, no population impact
2	Minor	Some individuals are impacted, but minimal impact on population structure or dynamics. In the absence of further impact, rapid recovery would occur
3	Moderate	The level of interaction / impact is at the maximum acceptable level that still meets an objective. In the absence of further impact, recovery is expected in years
4	Major	Wider and longer term impacts; loss of individuals; potential loss of genetic diversity. Level of impact is above the maximum acceptable level. In the absence of further impact, recovery is expected in multiple years
5	Severe	Very serious impacts occurring, loss of seabird populations causing local extinction; decline in species with single breeding population, measurable loss of genetic diversity. In the absence of further impact, recovery is expected in years to decades
6	Intolerable	Widespread and permanent / irreversible damage or loss occurring; local extinction of multiple seabird populations; serious decline of a species with a single breeding population, significant loss of genetic diversity. Even in the absence of further impact, long-term recovery period to acceptable levels will be greater than decades or may never occur

Table 6.23: Confidence scores used by Rowe (2013) (after Hobday et al 2007).

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

Table 6.24: Potential and residual risk scores for each seabird taxon with a potential risk score of 30 or more in Rowe (2013). Residual risk ("optimal risk" in Rowe 2013, not tabulated therein for grey-faced petrel or light-mantled albatross) is estimated assuming mitigation is deployed and correctly used throughout all interacting fisheries.

Taxon	Potential score	Residual score	Percent reduction
White-chinned petrel	159	123	23
Sooty shearwater	126	108	14
Black petrel	139	106	24
Salvin's albatross	161	106	34
White-capped albatross	141	94	33
Flesh-footed shearwater	117	92	21
Southern Buller's albatross	123	85	31
Grey petrel	123	84	32
Black-browed albatross	114	80	30
Northern Buller's albatross	107	72	33
Chatham albatross	114	71	38
Campbell albatross	97	66	32
Westland petrel	89	59	34

Antipodean albatross	89	55	38
Gibson's albatross	89	55	38
Wandering albatross	89	55	38
Southern royal albatross	79	49	38
King shag	48	48	0
Pitt Island shag	46	46	0
Chatham Island shag	45	45	0
Hutton's shearwater	37	35	5
Northern giant petrel	62	35	44
Pied shag	35	35	0
Indian yellow-nosed albatross	58	34	41
Southern giant petrel	61	34	44
Fluttering shearwater	34	32	6
Spotted shag	31	31	0
Stewart Island shag	31	31	0
Yellow-eyed penguin	30	30	0
Grey-faced petrel	31	–	–
Light-mantled albatross	30	–	–

White-chinned petrel, sooty shearwater, black petrel, Salvin's albatross, white-capped albatross, and flesh-footed shearwater were all estimated by this procedure to have an aggregate risk score of 90 or higher (range 92 to 123) even if mitigation was in place and deployed properly across all fisheries. Of the 101 seabird taxa considered, the aggregate risk score was less than 30 for 70 taxa with respect to potential risk and for 72 taxa with respect to residual risk.

Setnet and inshore trawl fisheries groups posed the greatest residual risk to seabirds (summed across all taxa); both had aggregate scores of over 200 and had no substantive mitigation. Surface and bottom longline fisheries and middle-depth trawl fisheries for finfish and squid also had aggregate risk scores of 100 or more. These risk scores were substantially reduced if mitigation was assumed to be deployed throughout these fisheries (reductions of 24 to 56%), but all remained above 100. Trawling for southern blue whiting and deep-water species, inshore drift net, various seine methods, ring net, diving, dredging, and hand gathering all had aggregate risk scores of 40 or less if mitigation was assumed to be deployed throughout these fisheries. Diving, dredging, and hand gathering were all judged by the panel to pose essentially no risk to seabirds.

6.4.5.1 SEMI-QUANTITATIVE (LEVEL 2) RISK ASSESSMENT

The level 2 method developed by MPI is a generalisation of the spatial overlap approach described by Kirby & Hobday (2007) and arose initially from an expert workshop hosted by the then Ministry of Fisheries in 2008 and attended by experts with specialist knowledge of New Zealand fisheries, seabird-fishery interactions, seabird biology, population modelling, and ecological risk assessment. The overall framework is described in Sharp et al (2011) and has been variously applied and improved in multiple iterations (Waugh et al 2008a, b, developed further by Sharp 2009, Waugh & Filippi 2009, Filippi et al 2010, Richard et al 2011, Richard & Abraham 2013b). The method applies the "exposure-effects" approach where exposure refers to the number of fatalities arising from an activity and effect refers to the consequence of that exposure for the population. The relative encounter rate of each seabird taxon with each fishery group is estimated as a function of the spatial overlap between seabird distributions (e.g.,

Figure 6.17) and fishing effort distributions (e.g., see Figure 6.7 to Figure 6.9). These estimates are compared with observed captures in an integrated model including all seabird groups and fisheries to estimate vulnerability (capture rates per encounter) and total captures by taxon in each fishery group. All captures are assumed fatal because of the unknown survival rate of birds released alive. Potential fatality estimates also include scalars for cryptic mortality and are subsequently compared with population estimates and biological characteristics to yield estimates of population-level risk from fishing (see method diagram in Figure 6.18).

Table 6.25: Cumulative potential risk and residual risk scores across all seabird taxa for each fishery from Rowe (2013). Residual risk ("optimal risk" in Rowe 2013) is estimated assuming mitigation is deployed and correctly used throughout a given fishery.

Fishery group	No. taxa	Potential risk	Residual risk	Percent reduction
Setnet	42	374	374	0
Inshore trawl	44	225	225	0
Surface longline: charter	25	313	191	39
Surface longline: domestic	25	302	184	39
Bottom longline: small	33	354	154	56
Bottom longline: large	32	311	139	55
Mid-depth trawl: finfish	22	160	122	24
Mid-depth trawl: squid	21	156	118	24
Mid-depth trawl: scampi	23	94	94	0
Hand line	27	68	68	0
Squid jig	44	62	62	0
Dahn line	29	61	61	0
Pots, traps	17	61	61	0
Trot line	29	61	61	0
Pelagic trawl	27	63	51	19
Troll	23	50	50	0
Mid-depth trawl: southern blue whiting	21	53	40	25
Deep water trawl	21	46	35	24
Inshore drift net	12	33	33	0
Danish seine	15	32	32	0
Beach seine	16	29	29	0
Purse seine	11	22	22	0
Ring net	12	13	13	0
Diving	0	0	0	–
Dredge	0	0	0	–
Hand gather	0	0	0	–

For each taxon, the risk was assessed by dividing the estimated number of annual potential fatalities (APF) by an estimate of Potential Biological Removals (PBR, after Wade 1998). This index represents the amount of human-induced mortality a population can sustain without compromising its ability to achieve and maintain a population size above its maximum net productivity (MNPL) or to achieve rapid recovery from a depleted state. In the risk assessment, PBR was estimated from the best available information on the demography of each taxon, including the seasonality of the distribution of various species where applicable (

Figure 6.17). Because estimates of seabirds' demographic parameters and of fisheries related mortality are imprecise, the uncertainty around the demographic and mortality estimates was propagated through the analysis. This allowed uncertainty in the resulting risk to be calculated, and also allowed the identification of parameters where improved precision would reduce overly large uncertainties. However, not all sources of uncertainty could be included, and the results are best used as a guide in the setting of management and research priorities. In general, seabird demographics, the distribution of seabirds within New Zealand waters, and sources of cryptic mortality were poorly known.

Integral to Richard & Abraham's (2013b) update of the semi-quantitative risk assessment was a simulation study (Richard & Abraham 2013a) to assess the accuracy of the approximations used in PBR calculations used by Richard et al (2011) for seabird demographics. They showed that the PBR is typically overestimated, largely because r_{max} is overestimated by Niel & Lebreton's (2005) approximation. Richard & Abraham (2013a) therefore recommended that an additional calibration factor, ρ, be included in the calculation of the PBR to correct the approximation. The calibration factor varied between 0.17 and 0.61, depending on the seabird type; in general, the calibration factor was smaller for species with slower population growth rates, such as albatrosses, and higher for species with higher growth rates, such as shags and penguins. Previous estimates of the PBR using Niel & Lebreton's (2005) approximation for seabird populations that did not include this calibration factor are likely to have overestimated the human caused mortalities that the populations could support (Richard & Abraham 2013a).

The management criterion used for developing the seabird risk assessment was that seabird populations should have a 95% probability of being above half the carrying capacity after 200 years, in the presence of ongoing human-caused mortalities, and environmental and demographic stochasticity (Richard & Abraham 2013b). By simulating seabird populations, the factor ρ was calculated so that this criterion would be satisfied, provided human caused mortalities were less than the base PBR (the PBR with a recovery factor, f, of 1 and using the population size rather than a minimum population estimate). In calculation of the PBR during the simulations, the Neil & Lebreton (2005) method was used for estimating r_{max}, and the Gilbert (2009) method was used for estimating total population size. The simulations did not allow for any bias in the input parameters for individual populations.

Calculation of the PBR for a seabird species requires specification of the recovery factor, f. This factor is typically set between 0.1 and 0.5 and can be used for several purposes (e.g. Lonergan 2011). It can be used to "protect" against errors in the input data used to calculate the PBR for individual populations, to provide for faster recovery rates, and to reflect general risk aversion (especially for endangered species). For the 2013 update to the risk assessment, Richard & Abraham (2013a b, 2014) set the recovery factor to f = 1 and suggested that appropriate values for each species should be determined at a later stage.

Following the completion of the 2013 iteration of the level two seabird risk assessment (Richard & Abraham 2013b), the Ministry for Primary Industries convened an expert workshop in November 2013 to review the level two seabird risk assessment inputs and results (Walker et al 2015). This workshop systematically reviewed input data and other available information for the 26 seabird taxa with the highest risk ratios as assessed by the level two risk assessment. In summary, the results of the workshop are that:

- risk appeared to be overestimated for fourteen taxa, including black petrel;
- risk appeared to be reasonably estimated for nine taxa;
- risk appeared to be underestimated for three taxa: New Zealand king shag and Gibson's and Antipodean albatrosses.

A general preponderance of overestimated risk is acceptable in a risk assessment framework so long as results are used carefully. Risk assessments are generally designed to be conservative in order to highlight gaps in information to direct future research accordingly. In contrast, any persistent significant underestimation of risk across many species is more problematic as a species may then not be subject to the additional research or management intervention required. Note however that the spatially explicit risk assessment framework is used not only to identify which species are potentially at risk, but also to inform choices about the likely effectiveness of various management options to reduce that risk, and to prioritise further research. In this context over-estimated risk scores for a particular species, fishery group, or area may lead to sub-optimal prioritization, and ultimately delay risk reduction interventions for those species genuinely at risk. For this reason, modification to improve the level two risk assessment consistent with the recommendations of this workshop was considered a high priority for all at-risk species, regardless of whether those modifications are expected to produce a decrease or an increase in overall species-level risk.

Where current risk estimates were thought to be biased in either direction, this workshop did not seek to replace or modify the existing risk estimates for each taxon, but rather gave advice on how to improve the risk assessment at the next iteration under the existing framework, and made some recommendations for further research.

The 2014 iteration of the risk assessment (as described by Richard & Abraham 2014) estimated the risk posed to each of 70 seabird taxa by trawl, longline and set net fisheries within New Zealand's TS and EEZ. Substantial modifications to the 2013 iteration of the risk assessment (Richard & Abraham 2013b) were made in the 2014 iteration following the recommendations of the review workshop (Walker et al 2015), these included:

- Based on their location and season, 26 captures of southern Buller's albatross were changed to be of northern Buller's albatross. One capture previously identified as Kermadec storm petrel was changed to New Zealand white-faced storm petrel. Captures identified as southern Cape petrel were removed, as only the Snares Cape petrel subspecies breeds in New Zealand.
- The population size was changed for 11 species. It was decreased for Antipodean albatross, Gibson's

albatross, and Westland petrel, and increased for Salvin's albatross, New Zealand white capped albatross, black petrel, grey petrel, flesh-footed shearwater, pied shag, Stewart Island shag, and little black shag.

- The annual survival rate was increased for New Zealand white-capped albatross, Westland petrel, black petrel, and flesh-footed shearwater.
- The proportion of adults breeding was decreased for grey petrel and New Zealand white-capped albatross, and increased for pied shag.
- The breeding season was altered for 54 species.
- The royal albatrosses were separated from the Antipodean and Gibson's albatrosses for the estimation of vulnerability was amended. The grouping of shag species, depending on whether they forage in groups or not, was also amended. The two species of Buller's albatross were also disaggregated, although identification of these species was noted to be problematic and therefore an additional source of uncertainty.
- Swordfish target surface longline fishing was treated as a distinct fishery. The small vessel ling bottom-longline fishery was also treated as a separate fishery.
- The at-sea distribution was changed for black petrel, Salvin's albatross, Gibson's albatross, New Zealand white-capped albatross, yellow-eyed penguin, flesh-footed shearwater, Westland petrel, New Zealand storm petrel, and Kermadec storm petrel.
- A parameter was introduced to describe the proportion of birds that remain in New Zealand waters during the non-breeding season, instead of treating birds as absent during the non-breeding season.

Other changes included in the 2014 iteration of the risk assessment (Richard & Abraham 2014) were:

- The data on fishing effort and observed captures included two more years, and vulnerability was estimated using data between the 2006–07 and 2012–13 fishing years.
- The APFs were estimated on data between 2010–11 and 2012–13 fishing years to reflect the current level and spatial distribution of fishing effort.

While re-running the risk assessment, errors were found in the calculations used in the 2013 iteration of the risk assessment (Richard & Abraham 2013b). These affected both the calculation of the PBR_1, and the estimates of APF. An error during data preparation led to over-counting the effort observed in the poorly observed inshore trawl fishery. Also PBR_1 was not calculated using the lower quartile of the distribution of the number of annual breeding pairs as documented by Richard & Abraham (2013b).

In order to be confident in the integrity of the risk assessment, the PBR calculations were independently checked. A parser was written to read the input parameters, independently repeat the PBR calculations, and then confirm that the PBR_1 values could be reproduced. In repeating the calculation, the mean value of PBR_1 was calculated, by repeatedly drawing sets of 4000 samples from each of the distributions to derive a distribution of mean PBR_1 values. For each species, it was confirmed that the mean value lay within the 95% confidence interval of the resulting distribution (Richard & Abraham 2014). In addition, the code used for the calculations was reviewed and the PBR calculations were independently checked; no further errors were found (Webber 2014).

Richard & Abraham (2014) repeated the 2013 risk assessment before and after correcting these errors, the resulting risk ratios are given in. Fixing the error where PBR1 was calculated using the total number of annual breeding pairs, instead of the lower quartile of the distribution (N_{BPmin}) as was stated in the methods, resulted in a general increase in the estimated risk for all species.

The analyses by Richard & Abraham (2013a) used NBP, and adjustments in the calibration factor, ρ, were undertaken in order to meet the management objective. In the original form of the PBR approach evaluated by Wade (1998), it was proposed that allowance for various potential biases was made by adjusting the recovery factor, f. Calculating PBR_1 using N_{BPmin} rather than NBP yields a smaller PBR_1 than the base PBR (which assumes perfect knowledge of all input parameters) although the extent of bias accommodated through the substitution of N_{BPmin} for N_{BP} has not been evaluated.

Another error during data preparation led to over-counting the effort observed in the poorly observed inshore trawl fishery. Estimates of potential fatalities are large for New Zealand white-capped albatross and Salvin's albatross in this fishery, and fixing this error therefore led to a large increase in the estimate of APF for these species, with the

overall risk increasing from a median of 0.8 to almost 2 for New Zealand white-capped albatross, and from 3 to over 6 for Salvin's albatross. The impact of correcting the errors made in the 2013 iteration on the resulting risk ratios can be seen in Figure 6.19.

Following the recommendations from the review workshop (Walker et al 2015) to the risk assessment structure and inputs, the overall changes between the corrected 2013 risk assessment and the 2014 iteration can be seen in Figure 6.20 and Table 6.26. The progressive change in risk ratio to each successive change in the risk assessment structure and input parameters is given in Figure 6.21.

Amongst the 70 studied taxa, three species clearly stood out as at most risk from commercial fishing activities within New Zealand waters (Figure 6.20 and Table 6.26,). Even with the recovery factor set to 1, three species had a probability of more than 95% of the risk ratio exceeding 1 (estimated annual potential fishing-related fatalities being greater than the PBR_1), with black petrel having the highest risk ratio (estimated annual potential fishing-related fatalities over 15 times higher than PBR_1: median, 15.09; 95% c.i.: 9.65-23.26). Potential fatalities for Salvin's albatross were over three times PBR_1 (3.54; 95% c.i.: 1.81-6.47). Potential fatalities for southern Buller's albatross were nearly three times PBR_1 (2.82; 95% c.i.: 1.56-5.60). Another three species are classified as at "very high risk" because they have a risk ratio with a median above 1 or with the upper 95% confidence limit above 2: flesh-footed shearwater, Gibson's albatross, and New Zealand white-capped albatross (Richard & Abraham 2014).

Six species had a median risk ratio above 0.3 or the upper 95% confidence limit above 1 and are classified as at "high risk": Chatham Island albatross; Antipodean albatross; Westland petrel; northern Buller's albatross; Campbell black-browed albatross and Stewart Island shag. The risk ratio of seven species had a median above 0.1 or the upper 95% confidence limit above 0.3 and are classified as at "medium risk": white-chinned petrel; the mainland population of yellow-eyed penguin (assuming that all fisheries-related mortalities are of the mainland population); northern giant petrel; spotted shag; northern royal albatross; Chatham petrel; and Chatham Island taiko (Richard & Abraham 2014).In total, there were 16 200 (95% c.i.: 12 600 – 21 000) APF estimated across the four fishing methods (

Table 6.28 6.28). The highest number of APF was in trawl fisheries with 11 500 (8 070-16 300) potential fatalities, mainly of albatross, Procellaria petrels, and large shearwater species. Species with over 1000 estimated fatalities in trawl fisheries were New Zealand white-capped albatross, Salvin's albatross, white-chinned petrel, and sooty shearwater (Richard & Abraham 2014). In bottom-longline fisheries, there were a total of 2 900 (2 300-3 640) estimated APF (Table 6.28). The species with the highest number of estimated potential fatalities in these fisheries were: black petrel with 940 (685-1 240); flesh-footed shearwater with 492 (313-714); and Salvin's albatross with 398 (245-592) (Richard & Abraham 2014). Estimated APF for surface-longline fisheries totalled 1 440 (1 180-1 780) across all seabird species (Table 6.28), with bigeye tuna target and small vessel southern bluefin tuna target fisheries each contributing over 40% of these captures. The species with the highest number of APF in these fisheries were: southern Buller's albatross with 304 (201-436); Gibson's albatross with 187 (136-252); and NZ white-capped albatross with 150 (92-223) (Richard & Abraham 2014).

Estimated APF from set net fisheries were relatively low, with a total of 327 (95% c.i.: 226-453) across all species (Table 6.28). Although the total estimate was low, for some species, the highest number of estimated APF occurred in set-net fisheries. In particular, there were 33 (15-58) estimated annual potential fatalities of yellow-eyed penguin, assumed to come from the mainland population, and 47 (17-93) estimated APF of spotted shag in set-net fisheries.

Table 6.29 provides a comparison of the estimated number of annual observable captures of seabirds including and not including cryptic mortality in trawl, bottom-longline, surface-longline, and set-net fisheries. Excluding cryptic mortalities, the estimated mean number of observable black petrel captures was 544 (95% c.i. 425–675), exceeding PBR_1 (Richard & Abraham 2014).

(a) Breeding distribution (b) Non-breeding distribution

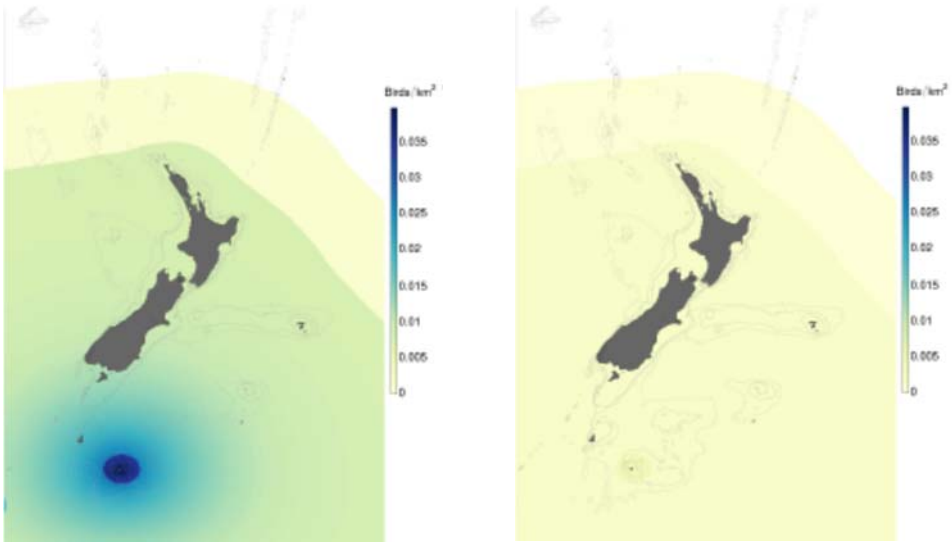


Figure 6.17: (from Richard & Abraham 2014 supplementary material) Relative density of white-chinned petrel. The base map for the distribution was obtained from the NABIS database. The breeding season runs from October to May. Also shown are incidental captures recorded by observers between 2006–07 and 2012–13 in trawl, surface-longline (SLL), bottom-longline (BLL), and set-net (SN) fisheries.

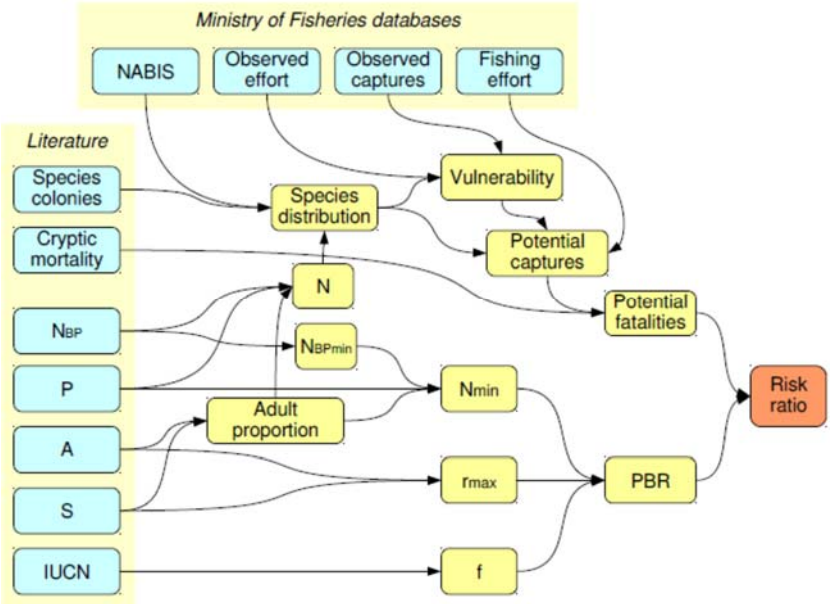


Figure 6.18: (reproduced from Richard et al 2011): Diagram of the modelling approach to calculate the risk index for each taxon. N_{BP}, number of annual breeding pairs; N, total number of birds over one year old; N_{BPmin}, lower 25% of the distribution of NBP; N_{min}, lower 25% of the distribution of the total number of birds over one year old; r_{max}, maximum population growth rate; *f*, recovery factor; PBR, Potential Biological Removal (set to 1.0 by Richard & Abraham 2013b); P, proportion of adults breeding in a given year; A, age at first reproduction; S, annual adult survival rate.

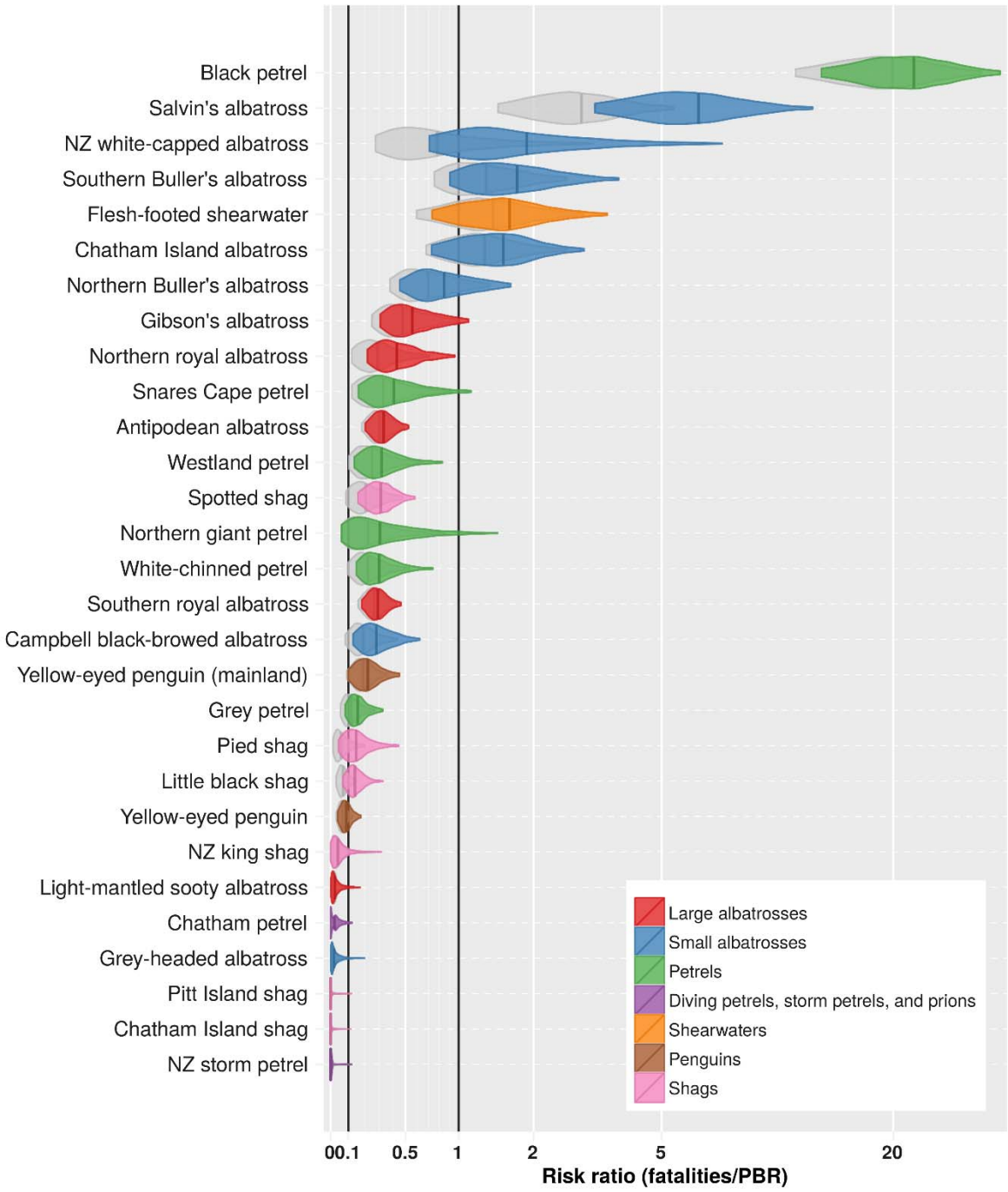


Figure 6.19: (reproduced from Richard & Abraham 2014) Risk ratio re-calculated on data from 2006–07 to 2013–14, after correcting errors in Richard & Abraham (2013b). The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential bird fatalities equalling the PBR with f = 0:1 and f = 1 indicated by the two vertical black lines, and the distribution of the corrected risk ratios within their 95% confidence interval indicated by the coloured shapes, including the median risk ratio (vertical line). The grey shapes indicate the risk ratios from the previous risk assessment report (Richard & Abraham 2013b). Seabird species are listed in decreasing order of the median risk ratio. Species with a risk ratio of almost zero were not included (95% upper limit with f = 1 less than 0.1). The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800.

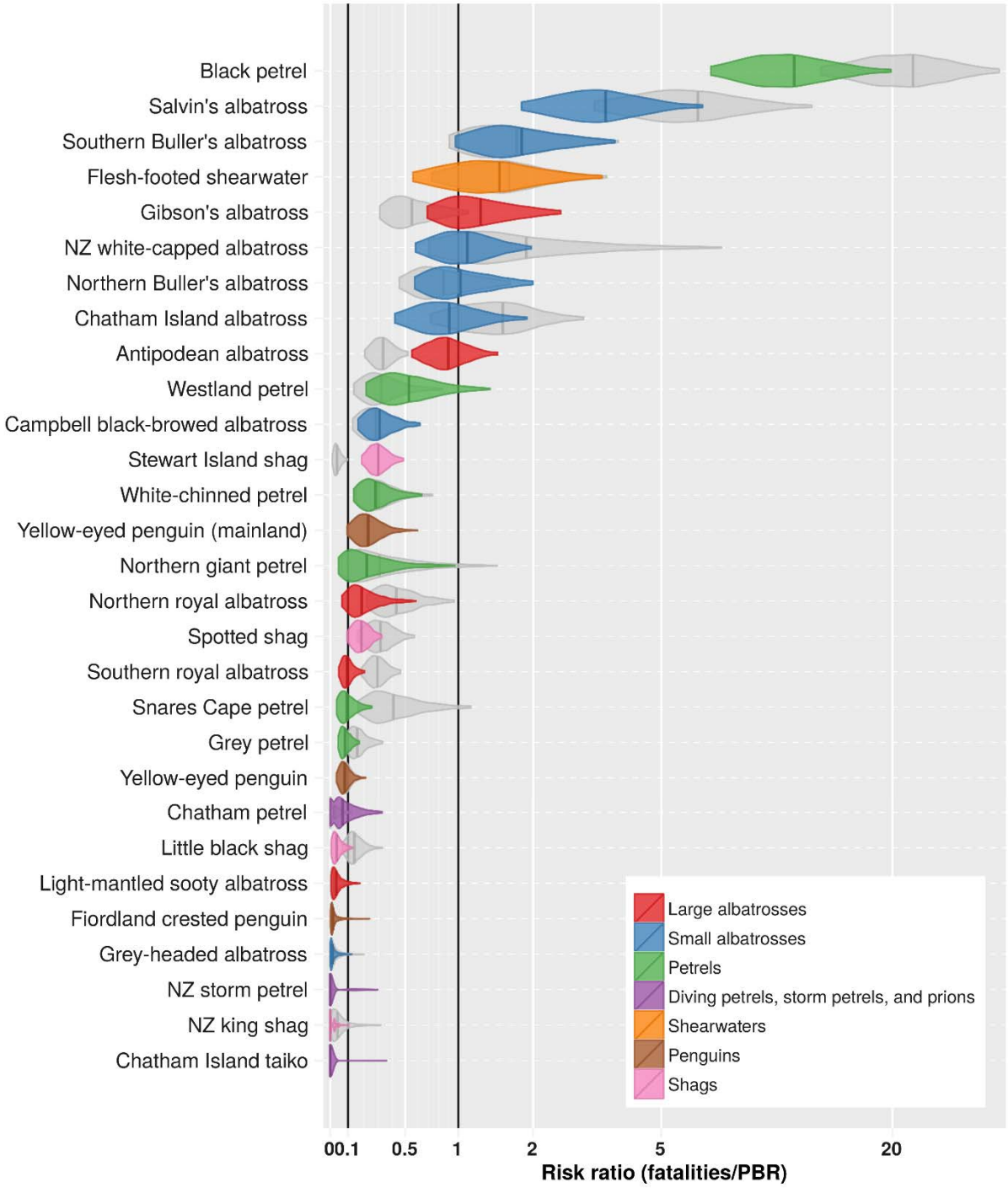


Figure 6.20: (reproduced from Richard & Abraham 2014) Risk ratio, updated to include data from the 2011–12 and 2013–14 fishing years. The risk ratio is displayed on a logarithmic scale, with the threshold of the number of potential bird fatalities equalling the PBR with f = 0:1 and f = 1 indicated by the two vertical black lines, and the distribution of the risk ratios within their 95% confidence interval indicated by the coloured shapes, including the median risk ratio (vertical line). Seabird species are listed in decreasing order of the median risk ratio. Species with a risk ratio of almost zero were not included (95% upper limit with f = 1 less than 0.1). The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800. The grey shapes indicate the risk ratios from the previous assessment (Richard & Abraham 2013b), corrected for errors, to show the change in risk since the 2010–11 fishing year.

Table 6.26: (reproduced from Richard & Abraham 2014) Comparison between the risk ratio reported by Richard & Abraham (2013b), after error correction, and in this study after updates. The table shows all species whose risk (in this study) had an upper 95% confidence limit greater than 0.1. Species names are coloured according to their risk category. Red: risk ratio with a median over 1 or upper 95% confidence limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1.

	Before updates		After updates	
	Median	95% c.i.	Median	95% c.i.
Black petrel	**22.46**	13.23–36.44	**11.34**	6.85–19.81
Salvin's albatross	**6.32**	3.18–12.57	**3.44**	1.82–6.50
Southern Buller's albatross	**1.74**	0.91–3.75	**1.82**	0.97–3.67
Flesh-footed shearwater	**1.63**	0.73–3.47	**1.5**	0.56–3.36
Chatham Island albatross	**1.55**	0.73–2.94	**0.91**	0.42–1.90
NZ white-capped albatross	**1.89**	0.71–7.32	**1.1**	0.59–1.97
Northern Buller's albatross	**0.85**	0.45–1.65	**1.02**	0.58–2.00
Gibson's albatross	**0.56**	0.31–1.11	**1.26**	0.69–2.49
Antipodean albatross	**0.33**	0.21–0.52	**0.89**	0.56–1.47
Westland petrel	**0.32**	0.14–0.83	**0.53**	0.21–1.37
Northern royal albatross	**0.43**	0.22–0.96	**0.19**	0.07–0.59
Snares Cape petrel	**0.41**	0.16–1.14	**0.09**	0.03–0.25
White-chinned petrel	**0.3**	0.15–0.74	**0.28**	0.14–0.64
Campbell black-browed albatross	**0.28**	0.13–0.62	**0.31**	0.16–0.63
Southern royal albatross	**0.29**	0.18–0.46	**0.1**	0.05–0.20
Northern giant petrel	**0.31**	0.06–1.47	**0.22**	0.05–0.96
Spotted shag	**0.31**	0.16–0.58	**0.18**	0.10–0.32
Grey petrel	**0.16**	0.08–0.33	**0.08**	0.04–0.17
Stewart Island shag	0.04	0.01–0.10	**0.3**	0.19–0.49
Little black shag	**0.14**	0.07–0.33	**0.04**	0.01–0.13
Yellow-eyed penguin	**0.09**	0.04–0.18	**0.08**	0.03–0.21
Chatham petrel	**0.02**	0.00–0.12	**0.07**	0.00–0.32
Light-mantled sooty albatross	**0.02**	0.00–0.17	**0.03**	0.01–0.17
NZ king shag	**0.04**	0.00–0.31	**0**	0.00–0.11
Grey-headed albatross	**0.02**	0.00–0.20	**0.01**	0.00–0.12
Fiordland crested penguin	0.01	0.00–0.06	**0.02**	0.00–0.24
NZ storm petrel	**0**	0.00–0.12	**0**	0.00–0.29
Chatham Island taiko	0	0.00–0.00	**0**	0.00–0.36

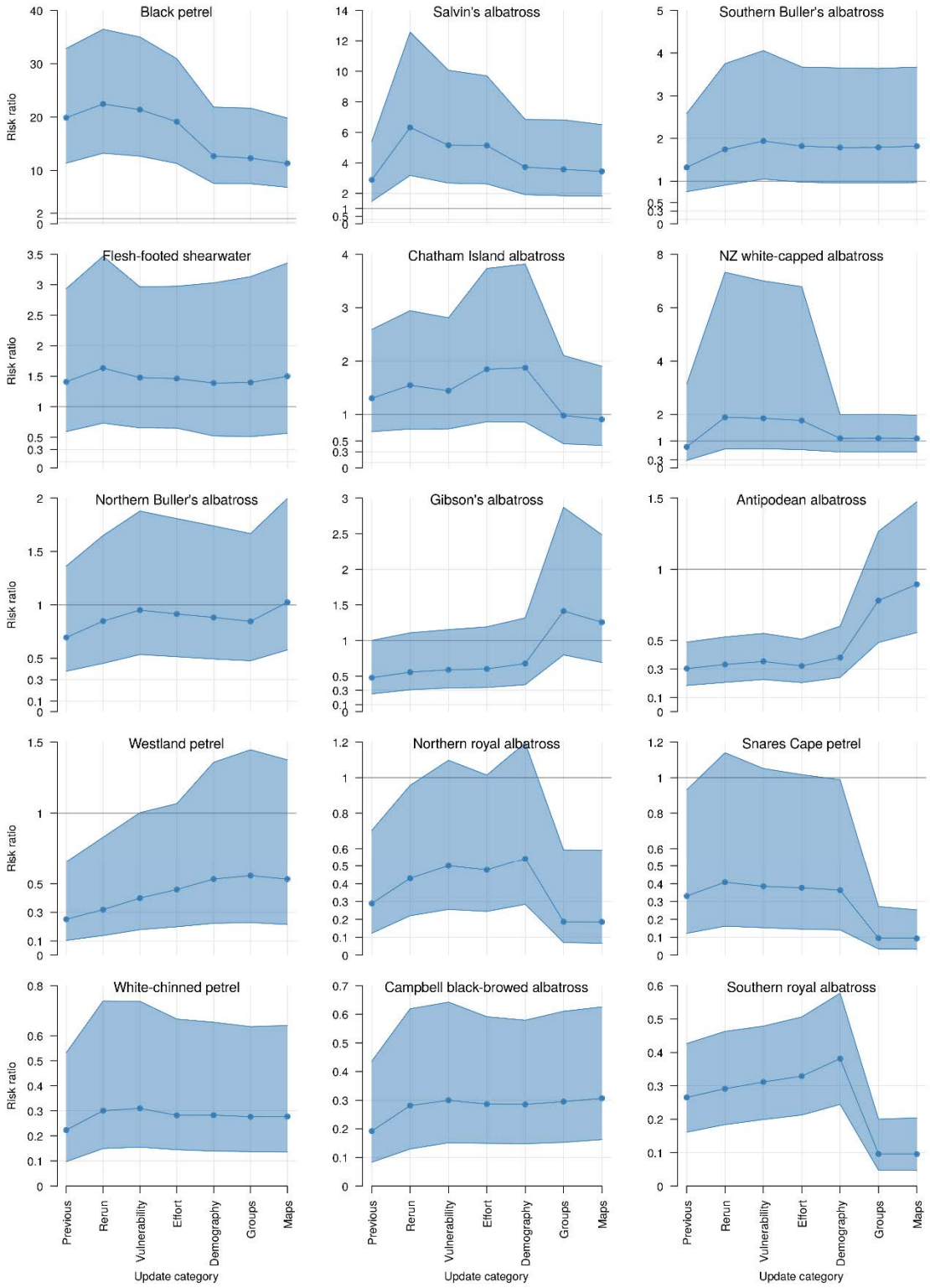


Figure 6.21: (reproduced from Richard & Abraham 2014) Progressive changes in the risk ratio. Previous: previous assessment (2013); Rerun: same years as 2013; Vulnerability: new fishing data, vulnerability estimated on 7 years, APFs on same 5 years as in previous assessment; Effort: effect of change in effort, vulnerability estimated on 7 years, APFs on last 3 years; Demography: updated demographic parameters; Groups: updated species and fishery groups; Maps: updated distribution maps. For the 15 species the most at risk.

Table 6.27: (reproduced from Richard & Abraham 2014) Potential Biological Removal (PBR_1, i.e., with a recovery factor f = 1), total annual potential fatalities (APF) in trawl, longline, and set-net fisheries, risk ratio with f = 1 (RR = APF/PBR_1), and the probability that APF > PBR with f = 1, f = 0:5, and f = 0:1 (P1, P0:5, and P0:1 respectively). Species are ordered in decreasing order of the median risk ratio. The risk ratio of yellow-eyed penguin refers to the mainland population only, based on the assumption that all estimated fatalities were of the mainland population, and the number of annual breeding pairs was between 600 and 800. Species names are coloured according to their risk category. Red: risk ratio with a median over 1 or upper 95% confidence limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1. PBR_1 and APF are rounded to three significant digits

	PBR_1		APF		Risk ratio		P_1	$P_{0.5}$	$P_{0.1}$
	Mean	95% c.i.	Mean	95% c.i.	Median	95% c.i.			
Black petrel	100	60–147	1 130	836–1 490	11.34	6.85–19.81	100.00	100.00	100.00
Salvin's albatross	1 020	638–1 650	3 480	2 250–5 200	3.44	1.82–6.50	100.00	100.00	100.00
Southern Buller's albatross	449	246–701	791	541–1 160	1.82	0.97–3.67	96.88	100.00	100.00
Flesh-footed shearwater	514	233–1 140	696	478–995	1.50	0.56–3.36	80.53	98.25	100.00
Gibson's albatross	181	98–281	222	161–301	1.26	0.69–2.49	73.90	100.00	100.00
NZ white-capped albatross	4 040	2 620–6 320	4 410	2 800–6 620	1.10	0.59–1.97	61.15	99.33	100.00
Northern Buller's albatross	540	296–845	549	409–723	1.02	0.58–2.00	52.62	99.67	100.00
Chatham Island albatross	139	85–228	127	70–226	0.91	0.42–1.90	39.12	93.65	100.00
Antipodean albatross	136	98–187	122	85–175	0.89	0.56–1.47	32.33	99.15	100.00
Westland petrel	157	89–234	88	37–181	0.53	0.21–1.37	9.82	54.48	100.00
Campbell black-browed albatross	673	437–937	213	121–359	0.31	0.16–0.63	0.05	8.90	100.00
Stewart Island shag	301	244–369	91	58–139	0.30	0.19–0.49	0.00	1.90	100.00
White-chinned petrel	5 200	2 670–8 170	1 440	906–2 540	0.28	0.14–0.64	0.32	8.62	99.92
Yellow-eyed penguin (mainland)	164	113–231	44	17–91	0.23	0.10–0.60	1.15	62.83	97.03
Northern giant petrel	164	57–352	37	9–99	0.22	0.05–0.96	2.27	14.00	82.85
Northern royal albatross	259	134–423	52	20–119	0.19	0.07–0.59	0.28	4.30	88.95
Spotted shag	2 400	1 580–3 890	426	285–628	0.18	0.10–0.32	0.00	0.00	96.45
Southern royal albatross	387	280–530	37	18–70	0.10	0.05–0.20	0.00	0.00	44.75
Snares Cape petrel	564	231–1 110	50	26–89	0.09	0.03–0.25	0.00	0.02	44.62
Grey petrel	2 150	1 220–3 200	177	110–274	0.08	0.04–0.17	0.00	0.00	32.00
Yellow-eyed penguin	465	321–659	44	17–90	0.08	0.03–0.21	0.35	0.78	29.40
Chatham petrel	9	4–19	1	0–2	0.07	0.00–0.32	0.05	0.57	36.15
Little black shag	215	123–366	9	1–23	0.04	0.01–0.13	0.00	0.00	6.20
Light-mantled sooty albatross	236	167–315	11	1–40	0.03	0.01–0.17	0.00	0.12	9.07
Pied shag	830	671–1 010	31	5–79	0.03	0.01–0.10	0.00	0.00	2.17
Fiordland crested penguin	322	210–427	12	0–72	0.02	0.00–0.24	0.10	0.52	8.97
Australasian gannet	2 730	1 210–5 450	41	3–129	0.01	0.00–0.06	0.00	0.00	0.20
Grey-headed albatross	221	130–328	5	0–24	0.01	0.00–0.12	0.00	0.05	4.03
Fluttering shearwater	1 800	1 040–2 850	25	3–90	0.01	0.00–0.05	0.00	0.00	0.30
Grey-faced petrel	11 900	5 540–26 300	101	43–187	0.01	0.00–0.02	0.00	0.00	0.00
Cook's petrel	2 250	1 070–4 960	16	6–32	0.01	0.00–0.02	0.00	0.00	0.00
Soft-plumaged petrel	60	25–133	0	0–2	0.01	0.00–0.04	0.00	0.00	0.00
Pycroft's petrel	93	43–208	1	0–2	0.01	0.00–0.03	0.00	0.00	0.00
Sooty shearwater	230 000	93 500–410 000	1 350	745–2 600	0.01	0.00–0.02	0.00	0.00	0.00
Northern little penguin	1 020	799–1 310	7	1–22	0.01	0.00–0.02	0.00	0.00	0.00
Mottled petrel	13 800	6 370–29 800	46	17–89	0.00	0.00–0.01	0.00	0.00	0.00
White-flippered little penguin	324	231–426	1	0–5	0.00	0.00–0.02	0.00	0.00	0.00
Hutton's shearwater	4 880	3 060–7 040	18	5–49	0.00	0.00–0.01	0.00	0.00	0.00
Southern little penguin	1 020	793–1 310	3	0–11	0.00	0.00–0.01	0.00	0.00	0.00
White-headed petrel	12 300	5 390–25 300	14	5–27	0.00	0.00–0.00	0.00	0.00	0.00
Common diving petrel	26 600	17 300–38 900	34	9–103	0.00	0.00–0.00	0.00	0.00	0.00
Snares crested penguin	3 220	2 090–4 280	5	0–20	0.00	0.00–0.01	0.00	0.00	0.00
Buller's shearwater	9 730	4 580–19 400	10	1–33	0.00	0.00–0.00	0.00	0.00	0.00
Black-bellied storm petrel	3 440	2 150–5 560	2	0–7	0.00	0.00–0.00	0.00	0.00	0.00
NZ white-faced storm petrel	55 900	32 400–92 400	51	8–223	0.00	0.00–0.00	0.00	0.00	0.00
Chatham Island little penguin	1 020	794–1 310	2	0–18	0.00	0.00–0.02	0.00	0.00	0.00
Southern black-backed gull	197 000	129 000–294 000	94	27–214	0.00	0.00–0.00	0.00	0.00	0.00
Fairy prion	85 000	53 700–133 000	41	10–122	0.00	0.00–0.00	0.00	0.00	0.00
Little shearwater	5 700	3 690–8 100	2	0–8	0.00	0.00–0.00	0.00	0.00	0.00
Eastern rockhopper penguin	6 400	5 280–7 880	3	0–12	0.00	0.00–0.00	0.00	0.00	0.00
Antarctic prion	13 900	7 940–24 200	3	0–7	0.00	0.00–0.00	0.00	0.00	0.00
Broad-billed prion	69 800	41 000–110 000	14	2–66	0.00	0.00–0.00	0.00	0.00	0.00
Erect-crested penguin	12 100	9 990–14 900	1	0–3	0.00	0.00–0.00	0.00	0.00	0.00
Auckland Island shag	163	122–216	0	0–1	0.00	0.00–0.01	0.00	0.00	0.00
Bounty Island shag	13	10–17	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Subantarctic skua	30	19–44	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Caspian tern	135	79–201	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Chatham Island shag	45	35–56	0	0–2	0.00	0.00–0.04	0.00	0.00	0.55
Campbell Island shag	196	128–261	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
White-bellied storm petrel	44	24–74	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
White tern	15	12–19	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
South Georgian diving petrel	3	2–4	0	0–0	0.00	0.00–0.00	0.00	0.00	0.68
NZ king shag	15	12–18	0	0–2	0.00	0.00–0.11	0.00	0.08	2.77
Kerm. storm petrel	2	1–3	0	0–0	0.00	0.00–0.00	0.00	0.00	0.02
Masked booby	35	23–51	0	0–0	0.00	0.00–0.01	0.00	0.00	0.00
NZ storm petrel	2	1–4	0	0–0	0.00	0.00–0.29	0.00	0.45	15.70
Pitt Island shag	66	43–89	0	0–3	0.00	0.00–0.04	0.00	0.00	0.57
Chatham Island taiko	1	0–2	0	0–0	0.00	0.00–0.36	0.05	1.35	3.52
Wedge-tailed shearwater	3 900	2 580–5 460	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00
Kerm. petrel	298	140–666	0	0–1	0.00	0.00–0.00	0.00	0.00	0.00
White-naped petrel	2 000	863–4 590	0	0–0	0.00	0.00–0.00	0.00	0.00	0.00

Table 6.28: Estimated of annual potential seabird fatalities by fishing method and target species/species group (from Richard & Abraham 2014, tables A-9 to A-16).

Fishing method	Target	Total annual potential seabird fatalities	95% c.i.
Trawl	Inshore	4 370	2 790-6 500
	Squid	1 950	1 330-2 980
	Hoki	1 420	989-2 020
	Scampi	1 200	786-1 880
	Middle depth	1 160	787-1 670
	Flatfish	928	571-1 460
	Ling	162	109-234
	Hake	117	76-172
	Deepwater	79	46-125
	Jack mackerel	77	48-125
	Southern blue whiting	64	39-105
Bottom longline	Snapper	759	535-1 020
	Small vessel, ling	706	484-978
	Bluenose	550	351-800
	Hapuka	434	268-671
	Minor targets	337	209-523
	Large vessel, ling	120	87-160
Surface longline	Bigeye	593	471-742
	Small vessel, southern bluefin	584	452-747
	Swordfish	206	146-282
	Large vessel, southern bluefin	39	23-57
	Minor targets	16	10-22
	Albacore	4	2-6
Setnet	Shark	136	97-184
	Flatfish	102	62-154
	Minor targets	75	51-105
	Grey mullet	14	7-23
Total		16 200	12 600-21 000

The method described by Richard et al (2011) and Richard & Abraham (2013b, 2014) offers the following advantages that make it particularly suitable for assessing risk to multiple seabird populations from multiple fisheries:

- risk is assessed separately for each seabird taxon; fisheries managers must assess risk to seabirds with reference to units that are biologically meaningful;
- the method does not rely on the existence of universal or representative fisheries observer data to estimate seabird mortality (fisheries observer coverage is generally too low and/or too spatially unrepresentative to allow direct impact estimation at the species or subspecies level); the method can be applied to any fishery for which at least some observer data exists;
- the method does not rely on detailed population models (the necessary data for which are unavailable for the great majority of taxa) because risk is estimated as a function of population-level potential fatalities and biological parameters that are generally available from published sources;
- the method assigns risk to each taxon in an absolute sense, i.e. taxa are not merely ranked relative to one another; this allows the definition of biologically meaningful performance standards and ability to track changes in performance over time and in relation to risk management interventions;

Table 6.29: (reproduced from Richard & Abraham 2014) Estimated number of annual observable captures of seabirds (not including cryptic mortality), and estimated number of annual potential fatalities (including cryptic mortality) in trawl, bottom-longline, surface-longline, and set-net fisheries in New Zealand's Exclusive Economic Zone. The species names are coloured according to their respective risk categories: Red: risk ratio with a median over 1 or upper 95% confidence limit (u.c.l.) over 2; dark orange: median over 0.3 or u.c.l. over 1; light orange: median over 0.1 or u.c.l. over 0.3; yellow: u.c.l. over 0.1.

Species	No cryptic mortality Mean	95% c.i.	With cryptic mortality Mean	95% c.i.
Gibson's albatross	95	71–125	223	163–307
Antipodean albatross	51	36–70	122	85–176
Southern royal albatross	12	7–21	38	19–69
Northern royal albatross	13	5–30	51	20–115
Campbell black-browed albatross	83	44–145	211	119–356
NZ white-capped albatross	633	525–751	4 420	2 820–6 540
Salvin's albatross	583	463–723	3 520	2 270–5 340
Chatham Island albatross	50	26–90	129	71–220
Grey-headed albatross	2	0–9	5	0–22
Southern Buller's albatross	330	256–421	1 260	901–1 730
Northern Buller's albatross	78	50–113	179	110–274
Light-mantled sooty albatross	3	0–12	11	1–38
Northern giant petrel	5	1–15	36	9–95
Grey petrel	77	51–117	176	111–273
Black petrel	544	425–675	1 110	834–1 440
Westland petrel	35	16–75	83	36–177
White-chinned petrel	507	454–571	1 430	885–2 600
Flesh-footed shearwater	316	227–423	726	498–1 030
Wedge-tailed shearwater	0	0–0	0	0–0
Buller's shearwater	5	0–16	10	1–34
Sooty shearwater	418	341–521	1 340	720–2 690
Fluttering shearwater	13	2–45	25	3–93
Hutton's shearwater	12	4–28	19	5–53
Little shearwater	1	0–4	2	0–8
Snares Cape petrel	37	19–63	51	26–91
Fairy prion	23	5–70	41	9–131
Antarctic prion	1	0–2	2	0–7
Broad-billed prion	7	1–36	15	2–72
Pycroft's petrel	0	0–1	1	0–2
Cook's petrel	8	3–16	16	6–33
Chatham petrel	0	0–1	1	0–2
Mottled petrel	22	9–44	45	17–90
White-naped petrel	0	0–0	0	0–0
Kermadec petrel	0	0–0	0	0–1
Grey-faced petrel	48	21–90	100	44–187
Chatham Island taiko	0	0–0	0	0–0
White-headed petrel	6	2–13	14	5–27
Soft-plumaged petrel	0	0–1	0	0–1
Common diving petrel	14	4–39	33	9–99
South Georgian diving petrel	0	0–0	0	0–0
NZ white-faced storm petrel	26	4–94	46	8–182
White-bellied storm petrel	0	0–0	0	0–0
Black-bellied storm petrel	1	0–5	2	0–7
Kermadec storm petrel	0	0–0	0	0–0
NZ storm petrel	0	0–0	0	0–0
Yellow-eyed penguin	36	16–68	40	16–88
Northern little penguin	5	0–16	7	0–23
White-flippered little penguin	1	0–5	1	0–5
Southern little penguin	2	0–8	3	0–11
Chatham Island little penguin	1	0–9	2	0–18
Eastern rockhopper penguin	1	0–6	2	0–11
Fiordland crested penguin	6	0–32	10	0–66
Snares crested penguin	3	0–10	4	0–18
Erect-crested penguin	0	0–2	1	0–3
Australasian gannet	36	2–122	39	3–125
Masked booby	0	0–0	0	0–0
Pied shag	27	5–69	30	5–77
Little black shag	8	1–22	9	1–23
NZ king shag	0	0–1	0	0–1
Stewart Island shag	71	48–98	92	59–138
Chatham Island shag	0	0–1	0	0–2
Bounty Island shag	0	0–0	0	0–0
Auckland Island shag	0	0–1	0	0–1
Campbell Island shag	0	0–0	0	0–0
Spotted shag	339	239–464	431	289–630
Pitt Island shag	0	0–1	0	0–3
Subantarctic skua	0	0–0	0	0–0
Southern black-backed gull	45	13–95	94	27–213
Caspian tern	0	0–0	0	0–0
White tern	0	0–0	0	0–0

- risk scores are quantitative and objectively scalable between fisheries or areas, so that risk at a population level can be disaggregated and assigned to different fisheries or areas based on their proportional contribution to total impact to inform risk management prioritisation;
- the method allows explicit statistical treatment of uncertainty, and does not conflate uncertainty with risk; numerical inputs include error distributions and it is possible to track the propagation of uncertainty from inputs to estimates of risk; and
- the method readily incorporates new information; assumptions in the assessment are transparent and testable and, as new data becomes available, the consequences for the subsequent impact and risk calculations arise logically without the need to revisit other assumptions or repeat the entire risk assessment process.

The key disadvantages of the method of Richard et al (2011), many of which were addressed by subsequent iterations (Richard & Abraham 2013b, 2014), were that:

- fisheries for which no observer information on seabird interactions is available cannot be included in the analysis;
- the assumption that the vulnerabilities of particular seabirds to capture in different fisheries are independent does not allow "sharing" of scarce observer information between fisheries within the risk assessment (addressed in subsequent iterations);
- the spatial overlap method relies on appropriate spatial and temporal scales for the distributions of birds and fishing effort being used; use of inappropriate scales can lead to misleading results (partially addressed in 2013 revision);
- strong assumptions have to be made about the distribution and productivity of some taxa, the relative vulnerability of different taxa to capture by particular fisheries, cryptic mortality associated with different fishing methods, and the applicability of the allometric method of estimating Potential Biological Removals (partially addressed in 2013 revision).

Most of these limitations are a result of the scarcity of relevant data on seabird populations and fisheries impacts and can be addressed only through the collection of more information or, in some cases, sensitivity testing. Further refinement of this method would be possible if:

- Estimates of PBR could be compared with total annual human caused mortality rather than mortality from commercial fishing within the New Zealand region. Little is known about the impact of New Zealand recreational fishing on seabirds or fatalities in overseas fisheries of seabirds that forage beyond New Zealand's waters.
- Better information on cryptic mortality was available. Studies on cryptic mortality are extremely limited.
- Further observer coverage was targeted at fisheries where substantial reductions in the uncertainty about potential fatalities would result (most such fisheries are poorly observed).

It should be noted that the level two risk assessments conducted thus far (Richard et al. 2011, Richard & Abraham 2013b, 2014) includes APFs in commercial fisheries within New Zealand's EEZ but excludes non-commercial impacts, fatalities on the High Seas and in other jurisdictions, and all other anthropogenic sources of mortality. Because of this focus and the definition of PBR as a level of mortality that can support all anthropogenic sources of mortality and still lead to good population outcomes, the risk ratios estimated by Richard & Abraham (2014) will be underestimates of the total risk faced by each taxon and interpretation should be in this context. Many of the other anthropogenic sources of mortality excluded from the risk assessment are poorly understood, although MPI will shortly commission a "global" seabird risk assessment to include at least the commercial fishing components under project PRO2013-13.

6.4.5.2 FULLY QUANTITATIVE MODELLING

Fully quantitative population modelling has been conducted only for southern Buller's albatross, black petrel, white capped albatross, and Gibson's (wandering) albatross. Data of similar quality and quantity are available for Antipodean (wandering) albatross, and this modelling will be conducted in 2015 under MPI project PRO2012-10, but data for other species or populations appear unlikely to be adequate for comprehensive population modelling. The poor estimates of observable and cryptic fishing-related mortality have restricted such work to comprehensive population modelling rather than formal assessment of risk.

6.4.5.2.1 QUANTITATIVE MODELS FOR SOUTHERN BULLER'S ALBATROSS

Francis et al (2008, see also Francis & Sagar 2012) assessed the status of the Snares Islands population of southern Buller's albatross (*Thalassarche bulleri bulleri*). They estimated (see also Sagar & Stahl 2005) that the adult population had increased about 5-fold since about 1950 (Figure 6.22) at a rate of about 2% per year, and concluded from this that the risk to the viability of this population posed by fisheries had been small. This conclusion depends critically on the reliability of the first census of nesting birds conducted in 1969, but the authors give compelling reasons to trust that information. In summary, the later censuses did not find any concentrations of nests that were not present on the maps prepared during the 1969 census and the increase in counts after 1969 occurred in all census subareas and also in five colonies where counts were made in many non-census years. Francis et al (2008) noted, however, that population growth had slowed by about 2005 (and perhaps reversed) and adult survival rates were falling, but could discern neither the cause nor significance of these changes because they had included survival data only up to 2007. An additional 8 years of survival and other demographic data have since been recorded all monitored sites at the Snares Islands showed substantial declines in the number of breeding pairs from 2006 to 2010 (Sagar et al 2010) but increased since (Richard Wells, pers.comm.). The modelling will be repeated in 2015 under MPI project PRO2013-17.

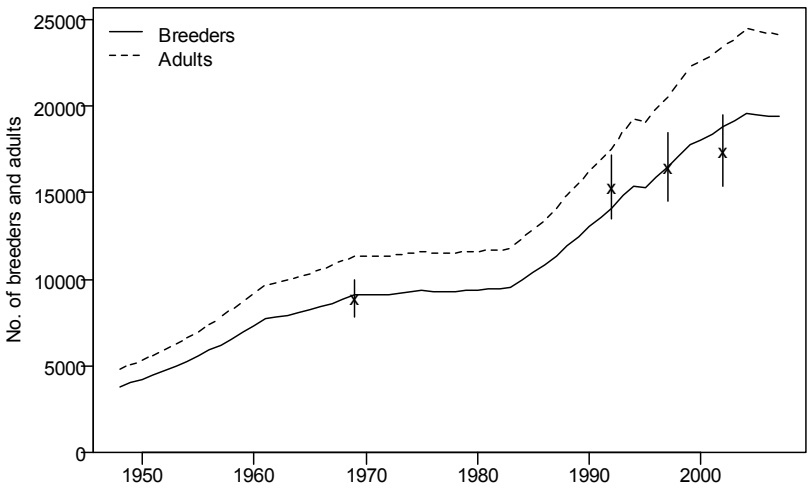


Figure 6.22: (from Francis et al 2008): Estimates from model SBA21 of numbers of breeders (solid line) and adults (broken line) in each year. Also shown are the census observations (after (Sagar & Stahl 2005) of numbers of breeders (crosses), with assumed 95% confidence intervals (vertical lines).

Fishery discards are an important component of the diet of chicks, but Francis et al (2008) were not able to assess whether the associated positive effect on population growth (e.g., from increased breeding success) is greater or less than the negative effect of fishing-related mortality.

6.4.5.2.2 QUANTITATIVE MODELS FOR BLACK PETREL

Francis & Bell (2010) analysed data from the main population of black petrel (*Procellaria parkinsoni*), which breeds on Great Barrier Island. Abundance data from transect surveys were used to infer that the population was probably increasing at a rate between 1.2% and 3.1% per year. Mark-recapture data were useful in estimating demographic parameters, like survival and breeding success, but contained little information on population growth rates. Fishery bycatch data from observers were too sparse and imprecise to be useful in assessing the contribution of fishing-related mortality. Francis & Bell (2010) suggested that, because the population was probably increasing, there was no evidence that fisheries posed a risk to the population at that time. They cautioned that this did not imply that there was clear evidence that fisheries do not pose a risk.

Subsequent analysis (Bell et al 2012) included an additional line transect survey in 2009-10 in which the breeding population was estimated to be about 22% lower than in 2004-05 (the latest available to Francis & Bell, 2010). Updating the model of Francis & Bell (2010) made little difference to estimates of demographic parameters such as adult survival, age at first breeding, and juvenile survival (which had 95% confidence limits of 0.67 and 0.91). The

uncertainty in juvenile survival gave rise to uncertainty in the estimated population trend, with a mean rate of population growth over the modelling period ranging from -2.5% per year (if juvenile survival = 0.67) to +1.6% per year (if juvenile survival = 0.91, close to the average annual survival rate for older birds) (Figure 6.23). Bell et al (2012) concluded that the mean rate of change of the population over the study period had not exceeded 2% per year, though the direction of change was uncertain. The latest counts have increased, due mainly to increases in breeding rate and (Bell et al 2013), suggesting even more uncertainty about population trend than when the quantitative modelling was last updated.

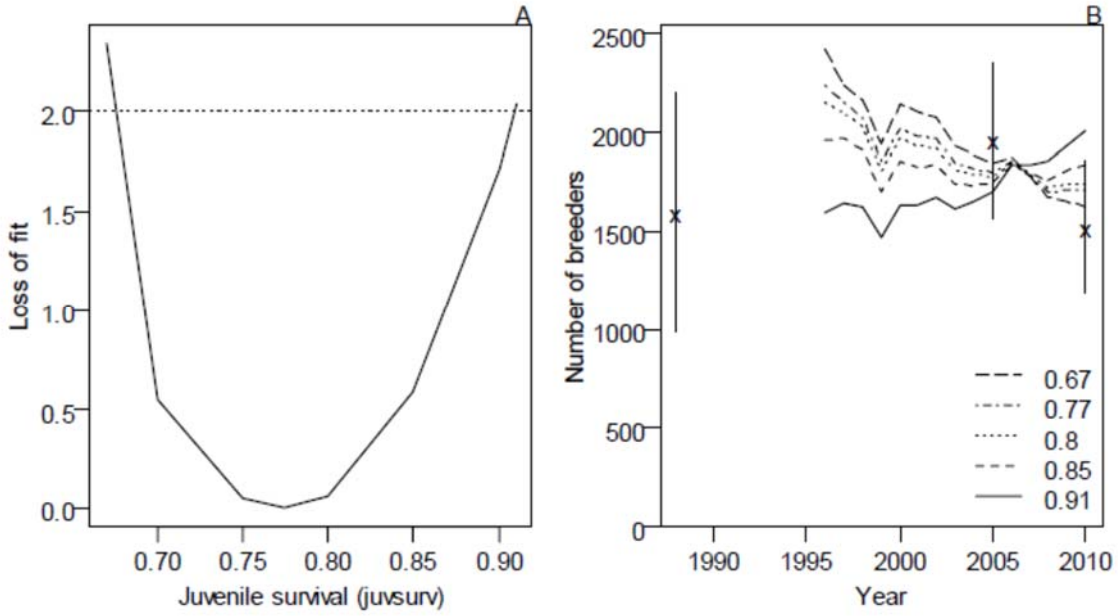


Figure 6.23: (from Bell et al 2012) Likelihood profile for annual probability of juvenile survival showing: A, the loss of fit (the horizontal dotted line shows a 95% confidence interval for this parameter); and B, population trajectories corresponding to different values of juvenile survival, together with population estimates from transect counts (crosses with vertical lines indicating 95% confidence intervals. Note that the 1988 population estimate was not used in the model.

6.4.5.2.3 QUANTITATIVE MODELS FOR WHITE-CAPPED ALBATROSS

Francis (2012) described quantitative models for white-capped albatross (*Thalassarche steadi*), New Zealand's most numerous breeding albatross, and the most frequently captured, focussing on the population breeding at the Auckland Islands. After a correction for a probable bias introduced by sampling at different times of day in one of the surveys, aerial photographic counts by Baker et al (2007b, 2008b, 2009a, and 2010a) suggest that the adult population declined at about 9.8% per year between 2006 and 2009. However, this estimate is imprecise and is not easily reconciled with the high adult survival rate (0.96) estimated from mark-recapture data. Francis (2012) also compared the trend with his estimate of the global fishing-related fatalities of white-capped albatross (slightly over 17 000 birds per year, about 30% of which is taken in New Zealand fisheries) and found that fishing-related fatalities were insufficient to account for the number of deaths implied by a decline of 9.8% per year (roughly 22 000 birds per year over the study period). The scarcity of information on cryptic mortality makes these estimates and conclusions uncertain, however. Since this modelling was conducted, further counts of white-capped albatross have been conducted (Baker et al 2014b, Figure 6.24) which show considerable annual variation. Baker et al. (2014b) consider that the substantial year to year variation in counts is real, and that trend analyses appropriate in this situation support the null hypothesis of no trend in the population.

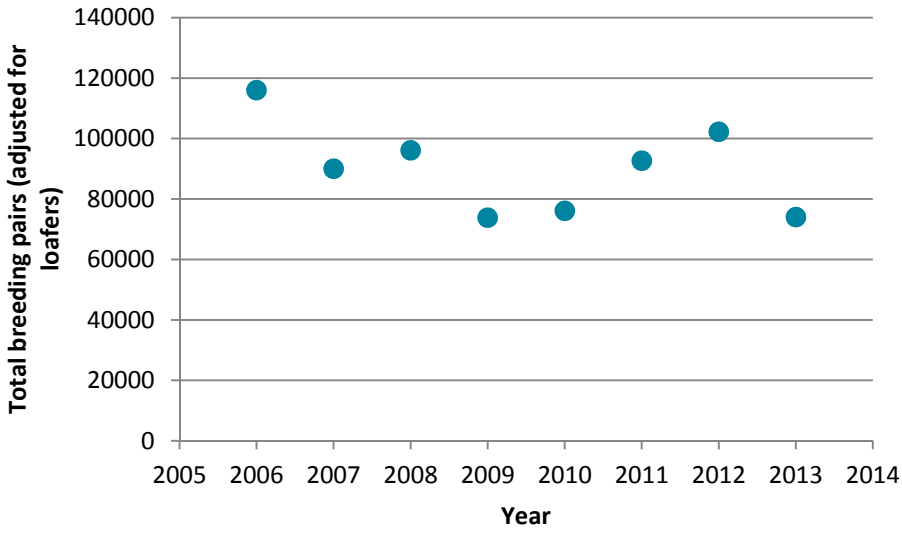


Figure 6.24: (Data from Baker et al 2014b): Total counts of white-capped albatross at the Auckland Islands (as adjusted for the presence of non-breeding birds).

6.4.5.2.4 QUANTITATIVE MODELS FOR GIBSON'S ALBATROSS

Francis et al (2013) concluded that there is cause for concern about the status of the population of Gibson's wandering albatross (*Diomedea gibsoni*) on the Auckland Islands. Since 2005, the adult population has been declining at 5.7%/yr (95% c.i. 4.5–6.9%) because of sudden and substantial reductions in adult survival, the proportion of adults breeding, and the proportion of breeding attempts that are successful (Figure 6.25). Forward projections showed that the most important of these to the future status of this population is adult survival (Figure 6.26).

The population in 2011 was 64% (58–73%) of its estimated size in 1991. The breeding population dropped sharply in 2005, to 59% of its 1991 level, but has been increasing since 2005 at 4.2% per year (2.3–6.1%). The 2011 breeding population is estimated to be only 54% of the average of 5831 pairs estimated by Walker & Elliott (1999) for 1991–97.

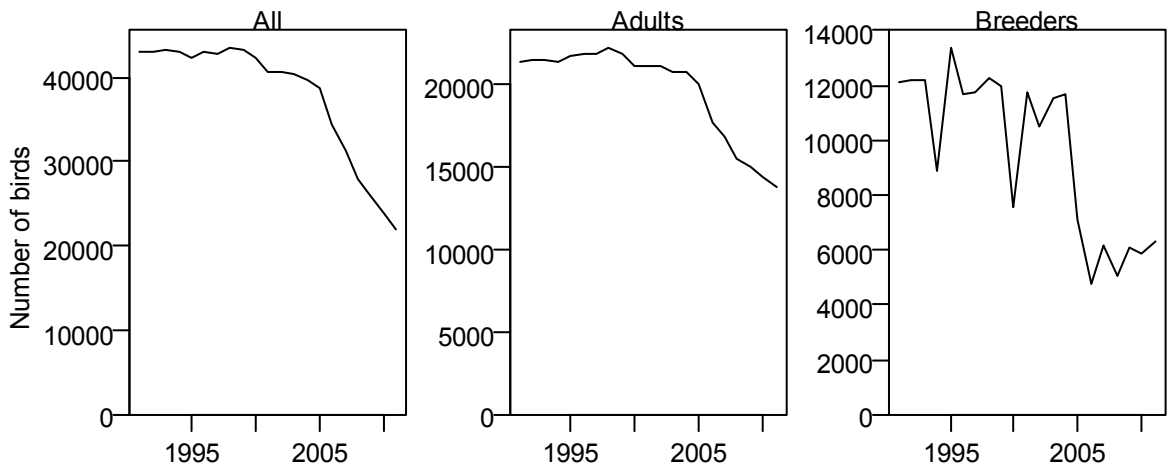


Figure 6.25: Estimated population trajectories for the whole Auckland Islands population of Gibson's wandering albatross. These were calculated by scaling up Francis et al's (2013) GIB5 trajectories to match the Walker & Elliott (1999) estimate for the whole population.

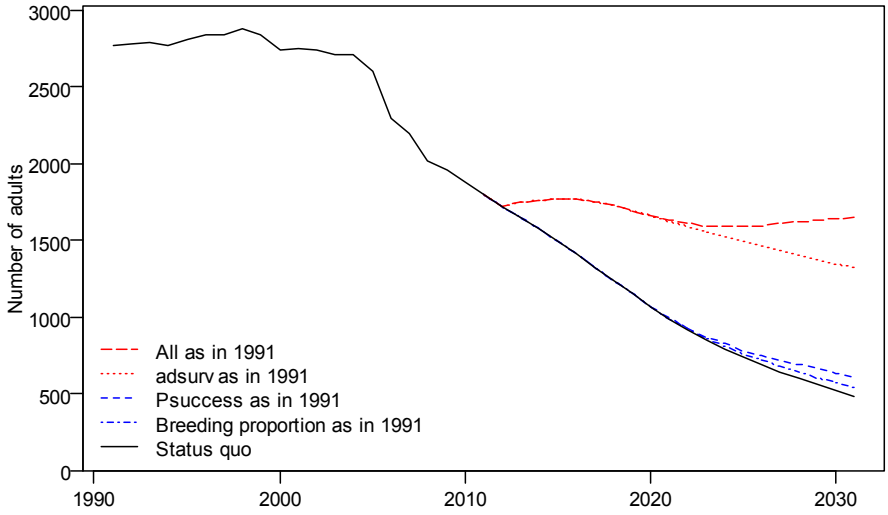


Figure 6.26: Estimated population trajectory for adults from Francis et al's (2013) model GIB5 with 20-year projections under five alternative scenarios about three demographic parameters: adult survival (adsurv); breeding success (Psuccess); and proportion of adults breeding. These scenarios differ according to whether each parameter remains at its status quo (i.e. 2011) level or recovers immediately to its 1991 level.

Francis et al (2013) found it difficult to assess the effect of fisheries mortality on the viability of this population because, although some information exists about captures in New Zealand and Australian waters, the effect of fisheries in international waters is unknown. Three conclusions are possible from the available data: most fisheries mortality of Gibson's is caused by surface longlines; mortality from fishing within the New Zealand EEZ is now probably lower than it was; and there is no indication that the sudden and substantial drops in adult survival, the proportion breeding, and breeding success were caused primarily by fishing.

6.4.5.2.5 OTHER QUANTITATIVE MODELS

This section is not intended to cover all quantitative modelling of seabird populations, rather to focus on recent studies that sought to assess the impact of fishing-related mortality.

Maunder et al (2007) sought to assess the impact of commercial fisheries on the Otago Peninsula yellow-eyed penguins using mark-recapture data within a population dynamics model. They found the data available at that time inadequate to assess fisheries impacts, but evaluated the likely utility of additional information on annual survival or an estimate of bycatch for a single year. Including auxiliary information on average survival in the absence of fishing allowed estimation of the fishery impact, but with poor precision. Including an estimate of fishery-related mortality for a single year improved the precision in the estimated fishery impact. The authors concluded that there was insufficient information to determine the impact of fisheries on yellow-eyed penguins and that quantifying fishing-related mortality over several years was required to undertake such an assessment using a population modelling approach.

Fletcher et al (2008) sought to assess the potential impact of fisheries on Antipodean and Gibson's wandering albatrosses (*Diomedea antipodensis antipodensis* and *D. a. gibsoni*); black petrel (*Procellaria parkinsoni*) and southern royal albatross (*Diomedea epomophora*). Because of problems with the available fisheries and biological data, they were unable to use their models to predict the impact of a change in fishing effort on the population growth rate of a given species. Instead, they used the models to estimate the impact that changes in demographic parameters like annual survival are likely to have on population growth rate. They found that: reducing breeder survival rate by k percentage points will lead to a reduction in the population growth rate of about 0.3k percentage points (0.4 for black petrel); and a reduction of k percentage points in the survival rate for each stage in the life cycle (juvenile, pre-breeder, non-breeder and breeder) will lead to a reduction in the population growth rate of approximately k percentage points. Fletcher et al (2008) also made estimates of PBR for 23 New Zealand seabird taxa and summarised and tabulated non-fishing-related threats for 38 taxa.

Newman et al (2009) combined survey data with demographic population models to estimate the total population of sooty shearwaters within New Zealand. They estimated the total New Zealand population between 1994 and 2005 to have been 21.3 (95% c.i. 19.0–23.6) million birds. The harvest of "muttonbirds" was estimated to be 360 000 (320 000–400 000) birds per year, equivalent to 18% of the chicks produced in the harvested areas and 13% of chicks in the New Zealand region. This directed harvest is much larger than estimates of captures in key fisheries or potential fatalities in the level 2 risk assessment (Table 6.29). Newman et al (2009) did not assess the likely impact of fishing-related mortality and did not consider the different population-level impacts of adult mortality in fisheries and chick mortality in the directed harvest, but concluded that the much larger directed harvest was not an adequate explanation for the observed declines in the past three decades.

6.4.5.2.6 GENERAL CONCLUSIONS FROM QUANTITATIVE MODELLING

Fully quantitative modelling has now been conducted for four of the five seabird populations for which apparently suitable data are available. This modelling suggests very strongly that one population had been increasing steadily (southern Buller's albatross, but note that this trend may have since reversed) and another is declining quite rapidly (Gibson's albatross). White-capped albatross and black petrel were both assessed at the time of the modelling to be more likely to be declining than not but, even for these relatively data rich populations, the conclusions were uncertain. Higher counts have been recorded for both species since the modelling was conducted. General conclusions from the modelling conducted to date, therefore, can be summarised as:

- Very few seabird populations have sufficient data for fully quantitative modelling.
- Except for the two most complete data sets (southern Buller's and Gibson's albatross) it has been difficult to draw firm conclusions about trends in population size.
- Information from surveys or census counts is much more powerful for detecting trends in population size than data from the tagging programmes and plot monitoring implemented for New Zealand seabirds to date.
- The available information on incidental captures in fisheries have not allowed rigorous tests of the role of fishing-related mortality in driving population trends.
- Although comprehensive modelling provides additional information to allow interpretation, we will have to rely on level 2 risk assessment approaches for much of our understanding of the relative risks faced by different seabird taxa and posed by different fisheries.

6.4.5.3 SEABIRD SPECIES IDENTIFIED AS BEING AT VERY HIGH RISK IN THE 2014 SEMI-QUANTITATIVE RISK ASSESSMENT

6.4.5.3.1 BLACK PETREL

The black petrel was found to be the species the most at risk from commercial fisheries in New Zealand, with a median risk ratio of 15.09 (95% c.i.: 9.65–23.26), a net decrease in the risk ratio from 22.46 in 2013 (95% c.i.: 13.23–36.44) (Figure 6.20, Figure 6.21, Table 6.26, , Richard & Abraham 2013b, with errors corrected). The mean PBR_1 was estimated at 74 (95% c.i.: 52–104), and the mean annual potential fatalities (APF) of black petrel was estimated to be 1 110 (95% c.i.: 837–1440). The estimated annual potential fatalities of black petrel were mostly in small-vessel bottom-longline fisheries.

Although the estimated risk ratio of black petrel is "Very High", the population trend of black petrel is unclear. Data from random transect surveys of the main Great Barrier Island colony, conducted in 2004–05, 2009–10, and 2012–13 suggested an apparent population decline of 22% over the 5 years to 2009–10, followed by an apparent increase of 110% between 2009–10 and 2012–13 (Bell et al. 2013). On the other hand, the trend obtained from census grid data estimated a population growth rate between -2.3% and 2.5% per year, depending on juvenile annual survival. Assuming a juvenile annual survival rate of 88%, the population growth rate was estimated to be -1.1% per year (Bell et al. 2013).

The calculation of the PBR included a correcting factor ρ to adjust the bias introduced by the approximations in the calculation of r_{max} and of the total population size from the number of annual breeding pairs (Richard & Abraham 2013a). Black petrel is the only species for which an estimate of the total population size was available,

calculated from the proportion of banded birds in the observed captures at sea, in relation to the number of birds banded that were estimated to be alive. The number of annual breeding pairs was then back-calculated from the estimate of total population size to be treated in a similar way as other species. In that case, the correction of the calculation of the total population size is unnecessary. However, because the ρ factor also corrects for the calculation of r_{max}, it was left in the PBR calculation. As a consequence, the PBR may be underestimated, and the risk ratio therefore overestimated. However, correcting for this overestimation would not change the risk category nor the ranking of this species, as removing the ρ factor from the PBR calculation altogether would still result in a median risk ratio of 5.11 (95% c.i.: 3.14–7.76).

One explanation for the apparent relative stability of the black petrel population, despite the high risk ratio, is that the population size is substantially underestimated. The population counts are made within a 35 ha study area, at the top of Mount Hobson (Hirakimata) on Great Barrier Island. In this analysis, these counts were used as a lower estimate of the population size, with an analysis of the capture of banded birds at sea providing another method for estimating the total population that are available to be caught.

There were many assumptions needed to make this estimate, and it is possible that the population on Little Barrier is larger than assumed, or that there are more breeding black petrel on Great Barrier, away from the study colony. Confirming the estimate of the entire black petrel population will help to reduce uncertainty in the risk ratio.

Further research will be conducted during the 2014-15 summer to better understand the population size of black petrel on Great Barrier Island and Little Barrier Island. This project is being conducted under DOC CSP project POP2014-02 (Contract 4623), supported by MPI project PRO2014-05.

6.4.5.3.2 SALVIN'S ALBATROSS

The risk of fisheries to Salvin's albatross was estimated to be the second highest, with a median risk ratio of 3.54 (95% c.i.: 1.81–6.47). This was a decrease from the estimate of 6.32 (95% c.i.: 3.18–12.57) in 2013 (Figure 6.20, Figure 6.21, Table 6.26, , Richard & Abraham 2013b, corrected for errors). Most of this decrease was due to changes in the demographic parameters, which included an increase in the estimated number of breeding pairs. In this assessment, the mean PBR_1 was estimated at 1010 (95% c.i.: 632–1600) and the mean annual potential fatalities at 3520 (95% c.i.: 2280–5330), mainly in trawl fisheries. Of the estimated annual potential fatalities of this species, over half were in inshore trawl fisheries, with observed captures occurring at the western, inshore end of the Chatham Rise.

Population surveys in the Bounty Islands indicated that the annual number of breeding pairs of Salvin's albatross on Proclamation Island declined by an estimated 30% between 1997 and 2011, and by 10% between 2004 and 2011 on Depot Island (Amey & Sagar 2013). There wa some indication of a decline in the number of birds attending bird-watching vessels near Kaikoura (Richard et al. 2014), with a best estimate of the rate of decline of around 5% (although not significantly different from no decline). However, Baker et al (2014a) conducted repeated their 2010 aerial survey in 2013 and found 26% more birds breeding in 2013 than in 2010. The conservation status of this species changed in 2013 from Naturally Vulnerable to Nationally Critical, according to the New Zealand Threat Classification System (Robertson et al. 2013).

6.4.5.3.3 SOUTHERN BULLER'S ALBATROSS

The third highest risk ratio was estimated to be of the southern Buller's albatross, with a median risk ratio of 2.82 (95% c.i.: 1.56–5.6). The mean annual potential fatalities was estimated to be 1240 (95% c.i.:883–1710), including 215 in surface-longline and 163 in trawl fisheries. The mean PBR_1 was estimated to be 448 (95% c.i.: 246–697). The risk ratio in 2013 was 1.74 (95% c.i.:0.91–3.75) (Figure 6.20, Figure 6.21, Table 6.26, , Richard & Abraham 2013b, corrected for errors), and the increase to 2.82 was predominantly caused by a change in the species groups (Figure 6.21). Southern and northern Buller's albatrosses were grouped together for the estimation of vulnerability in the previous assessment, whereas they were split in the 2014 assessment.

The separation of the two Buller's albatross species was somewhat arbitrary, relying on a latitudinal cut off (all captures of Buller's albatross north of 40◦S being treated as northern Buller's albatross), and a seasonal cut-off (captures outside the breeding season of southern Buller's albatross treated as northern Buller's albatross). It is possible that other observed captures, particularly those occurring close to the Chatham Islands, may have been northern Buller's albatross. It may be possible to carry out

genetic work on samples from captured specimens to clarify their taxonomic status. This would confirm assumptions made on attribution of captures to the two species.

The annual potential fatalities of southern Buller's albatross occurred in a range of fisheries, with estimated APFs of over 100 in hoki and squid trawl, and in small-vessel surface longline fisheries targeting southern bluefin tuna (Richard & Abraham 2014).

The population of southern Buller's albatross, breeding on The Snares and the Solander Islands, has sustained a long-term increase (Sagar & Stahl 2005). However, an apparent decline in the annual survival rate of breeding birds and in the recruitment of known-age birds has been found on The Snares in recent years, with the potential to lead to a decline in the overall abundance (Sagar 2014).

6.4.5.3.4 GIBSON'S ALBATROSS

Gibson's albatross were estimated in the 2013 assessment to be at "High" risk from commercial fisheries (Figure 6.20, Figure 6.21, Table 6.26, , Richard & Abraham 2013b, corrected for errors). In the 2014 assessment, their risk category increased to "Very High", and this species was here estimated to be the fourth most at-risk from commercial fisheries, with a median of 1.24 (95% c.i.: 0.69–2.43). The mean PBR_1 for this species was estimated to be 182 (95% c.i.: 98–285) and the mean APF to be 222 (95% c.i.: 161–307).

The increase in risk was due to the population size being revised downwards, and the disaggregation of royal albatrosses from Gibson's and Antipodean albatrosses for the estimation of vulnerability. Royal albatrosses do not get caught as often and separating them from the wandering albatrosses group led to an increase in vulnerability for Antipodean and Gibson's albatrosses. The disaggregation of the swordfish fishery from the small-vessel surface-longline fishery group may also have impacted the estimated APF.

Gibson's albatross have been well studied since 1991 on Adams Island, where approximately 95% of the species breeds. Monitoring of the population showed that during the period 2004–2006 there was a decrease in the number of breeding birds, in the annual survival and recruitment rate, and in nesting success. These changes may have been associated with an increase in the foraging range (Elliott & Walker 2014). In addition to captures within New Zealand waters, Gibson's albatross may also be caught in fisheries operating outside New Zealand's EEZ.

While there have been signs of recovery in recent years; improvements in recruitment, nesting success and survival (Elliott & Walker 2014), the conservation status of this species changed in 2013 from Nationally Vulnerable to Nationally Critical, according to the New Zealand Threat Classification System (Robertson et al. 2013).

6.4.5.3.5 FLESH-FOOTED SHEARWATER

The 2014 risk ratio of flesh-footed shearwater is similar to that of the 2013 assessment (Richard & Abraham 2013b), with an estimated median of 1.56 (95% c.i.: 0.63–3.42), after a number of updates, including a higher population size, a higher adult annual survival rate, and a change in the at-sea distribution. The mean PBR_1 for this species was estimated to be 521 (95% c.i.: 230–1200) and the mean APF to be 726 (95% c.i.: 495–1040), from 64 observed captures, including 30 and 27 in trawl and bottom-longline fisheries, respectively (Figure 6.20, Figure 6.21, Table 6.26, , Richard & Abraham 2013b, corrected for errors).

Flesh-footed shearwater have recently been added to the Threatened category, being classified as "Nationally Vulnerable", following a more recent survey finding a considerably lower number of breeding pairs than previously estimated, with approximately 10 000 pairs (Baker et al. 2010), from a previous estimate of between 25 000 to 50 000, noting that this estimate was based on colony visits rather than a comprehensive quantitative analysis (Taylor 2000). Moreover, long-term monitoring of the population breeding on Lord Howe Island, in eastern Australia, found that this population has been declining (Priddel et al. 2006). Waugh et al (2014) conducted further surveys at three main breeding colonies and their results indicated a probable decline for the population on Ohinau Island, and stable populations at Lady Alice Island/Mauimua and Titi Island.

Some captures observed within the New Zealand EEZ might be of birds breeding outside New Zealand, which would lead to an overestimate of the number of Annual Potential Fatalities. On the other hand, this species might is also caught in recreational fisheries (Miskelly et al. 2012), foraging in the north-eastern region of New Zealand where there is considerable recreational fishing effort (Abraham et al. 2010a). Recreational fishing is not considered in this risk assessment.

6.4.5.3.6 NEW ZEALAND WHITE-CAPPED ALBATROSS

The risk category of New Zealand white-capped albatross has not changed from the last assessment, however the median risk ratio of 1.1 (95% c.i.: 0.59–2.02) in 2014 is less than half that in the 2013 assessment, 1.89 (95% c.i.: 0.71–7.32) (Figure 6.20, Figure 6.21, Table 6.26, , Richard & Abraham 2013b, corrected for errors). All updates led to a decrease in risk ratio (Figure 6.21), however the most important change was in the demographic parameters, with the number of annual breeding pairs revised upwards, from a mean of 77 000 to a mean of 95 700 (95% c.i.: 85 400–106 000), using a bootstrapped estimate from the recent aerial surveys of the population (Baker et al. 2014). Additionally, the uncertainty in the annual survival rate was more constrained. This change in demographic parameters led the risk ratio to decrease from a median 1.77 (95% c.i.: 0.68–6.78) to 1.11 (95% c.i.: 0.6–1.99). The change in at-sea distribution and in fishing effort in recent years only led to a minor decrease in risk ratio.

The updated APFs were estimated to be 4 410 (95% c.i.: 2 800–6 540), including 471 in trawl fisheries. The mean PBR_1 was estimated to be 4 040 (95% c.i.: 2 590–6 340). Around half of the estimated annual potential fatalities of white-capped albatross are predicted to occur in poorly observed inshore trawl fisheries (1 940 estimated annual potential fatalities), with over 400 estimated annual potential fatalities in each of squid, hoki and middle-depth trawl.

The New Zealand conservation status of New Zealand white-capped albatross is "Declining". The trend in the population size is unclear, as annual aerial surveys since 2006 have shown a variable number of annual breeding pairs for this biennially breeding species (Baker et al. 2014).

White-capped albatross had very high capture rates in squid trawl fisheries. In the 1990–91 season, observers recorded captures rates of 27.9 white-capped albatross per 100 tows (Bartle 1991, Hilborn & Mangel 1997). With the elimination of the net sonde cable, the introduction of mandatory warp mitigation, and with an emphasis on practices such as better offal management, the capture rate of white-capped albatross in this fishery reduced to 4.1 (95% c.i.: 2.4 to 6.4) white-capped albatrosses per 100 tows (Abraham & Thompson 2011a). Despite this reduction in the capture rate, white-capped albatross continue to be caught in trawl nets, and there are still warp-captures, even in fisheries that use warp mitigation (Richard & Abraham 2014). Over the last three fishing years (2010-11 to 2012-13) the trawl warp or door has been recorded by observers as the source of mortality for white capped albatross in squid trawl fisheries (Table 6.30).

6.4.5.4 SOURCES OF UNCERTAINTY IN RISK ASSESSMENTS

There are several outstanding sources of uncertainty in modelling the effects of fisheries interactions on sea birds, especially for the complete assessment of risk to individual seabird populations.

Table 6.30: Method of capture for observed captures of white capped albatross in squid trawl fisheries (http://data.dragonfly.co.nz/psc/ Data version v20140131).

	Method of capture						
Fishing year	Net	Warp or door	Mitigation	Other	Tangled	Unknown	Totals
2006-07	37	4			1	1	43
2007-08	27	10	1	1			39
2008-09	51	6	1	1		2	61
2009-10	14	3		3			20
2010-11	20	9		2			31
2011-12	22	13		1			36
2012-13	45	21				7	73
Totals	216	66	2	8	1	10	791

6.4.5.4.1 SCARCITY OF INFORMATION ON CAPTURES AND BIOLOGICAL CHARACTERISTICS OF AFFECTED POPULATIONS

These sources of uncertainty can be explored within the analytical framework of the level 2 risk assessment (Richard et al 2011, Richard & Abraham 2013b, 2014), noting that the results of that exploration are constrained by the structure of that analysis. Richard & Abraham (2014) provided plots of such an exploration for 8 taxa (Figure 6.27). It can be concluded from this analysis that better estimates of average adult survival would lead to substantially more precise estimates of risk for a wide variety of taxa, including most of the species estimated to be at most risk. More precise estimates of risk would be available for black petrel, Salvin's albatross, New Zealand white-capped albatross, Chatham Island albatross, and Antipodean albatross if better estimates of potential fatalities were available, and better estimates of survival would be useful for all eight taxa. This analysis was not applied at this iteration of the risk assessment to the spatial distribution of seabirds and fisheries, although it is acknowledged that this is extremely important for the proper implementation of any spatial overlap method. Noting this limitation, this type of sensitivity analysis is a powerful way of assessing the priorities for collection of new information, including research.

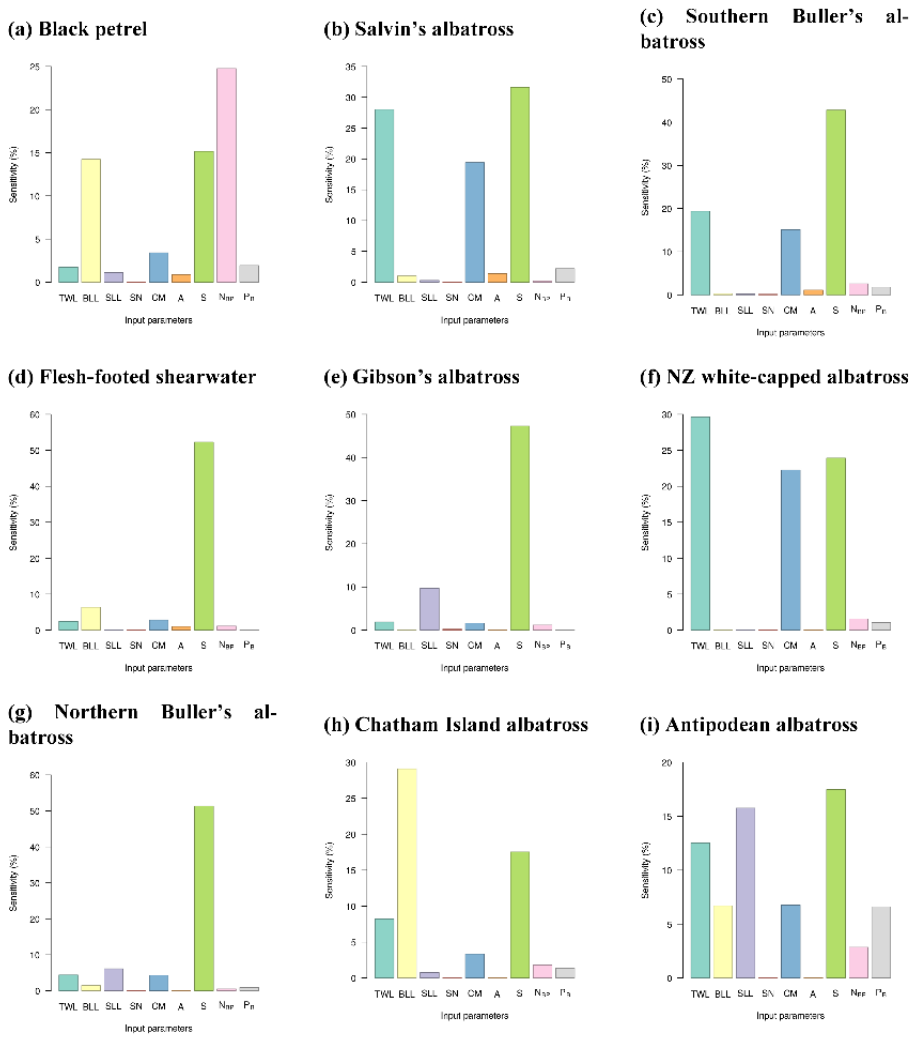


Figure 6.27: (reproduced from Richard & Abraham 2014) Sensitivity of the uncertainty in the risk ratio for the 8 seabird species with the highest risk ratio. For each seabird type, the sensitivity to the uncertainty in the following parameters is considered: annual potential fatalities in trawl, bottom-longline, surface-longline and set-net fisheries (TWL, BLL, SLL, SN, respectively); the cryptic multipliers (CM); age at first reproduction (A); adult survival (SA); the number of annual breeding pairs (N_{BP}); and the proportion of adults breeding (PB). The sensitivity is defined as the percentage of reduction in the 95% confidence interval of the risk ratio that occurs when the parameter is set to its arithmetic mean.

6.4.5.4.2 SCARCITY OF INFORMATION ON CRYPTIC MORTALITY

Cryptic mortality is particularly poorly understood but has substantial influence on the results of the risk assessment. Richard et al (2011) provided a description of the method used to incorporate cryptic mortality into their estimates of potential fatalities in the level-2 risk assessment (their appendix B authored by B. Sharp, MPI). This method builds on the published information from Brothers et al (2010) for longline fisheries and Watkins et al (2008) and Abraham (2010a) for trawl fisheries. Brothers et al (2010) observed almost 6000 seabirds attempting to take longline baits during line setting, of which 176 (3% of attempts) were seen to be caught. Of these, only 85 (48%) were retrieved during line hauling. They concluded that using only observed captures to estimate seabird fatalities grossly underestimates actual levels in pelagic longline fishing. Similarly, Watkins et al (2008) observed 2454 interactions between seabirds and trawl warps in the South African hake fishery over 189.8 hours of observation. About 11% of those interactions (263) involved birds, mostly albatrosses, being dragged under the water by the warps, and 30 of those submersions were observed to be fatal. Of the 30 birds observed killed on the warps, only two (both albatrosses) were hauled aboard and would have been counted as captures by an observer in New Zealand. Aerial collisions with the warps were about 8 times more common but appeared mostly to have little effect (although one white-chinned petrel suffered a broken wing which would almost certainly have fatal consequences).

Given the relatively small sample sizes in both of these trials, there is substantial (estimatable) uncertainty in the estimates from the trials themselves and additional (non-estimatable) uncertainty related to the extent to which these trials are representative of all fishing of a given type, particularly as both trials were undertaken overseas. The binomial 95% confidence range (calculated using the Clopper-Pearson "exact" method) for the ratio of total fatalities to observed captures in Brothers et al's (2010) longline trial is 1.8–2.5 (mean 2.1), and that for Watkins et al's trawl warp trial is 5–122 (mean 15.0 fatalities per observed capture). Abraham (2010a) estimated that there were 244 (95% c.i. 190–330) warp strikes by large birds for every one observed captured, and 6440 (3400–20 000) warp strikes by small birds for every one observed captured (although small birds tend to be caught in the net rather than by warps). There is also uncertainty in the relative frequencies and consequences of different types of encounters with trawl warps in New Zealand fisheries (Abraham 2010a, Richard et al 2011 Appendix B). Some of this uncertainty is included and propagated in the most recent risk assessment (Richard & Abraham 2013b).

A review of available information on cryptic mortality has been commissioned under CSP project INT2013-05 and supported by MPI project PRO2012-17. The final report was not available to be included at the time of this review.

6.4.5.4.3 MORTALITIES IN NON-COMMERCIAL FISHERIES.

Little is known about the nature and extent of incidental captures of seabirds in non-commercial fisheries, either in New Zealand or globally (Abraham et al 2010a). In New Zealand, participation in recreational fishing is high and 2.5% of the adult population are likely to be fishing in a given week (mostly using rod and line). Because of this high participation rate, even a low rate of interactions between individual fishers and seabirds could have population-level impacts. A boat ramp survey of 765 interviews at two locations during the summer of 2007–08 revealed that 47% of fishers recalled witnessing a bird being caught some time in the past. Twenty-one birds were reported caught on the day of the interview at a capture rate of 0.22 (95% c.i.: 0.13–0.34) birds per 100 hours of fishing. Observers on 57 charter trips recorded seabird captures at rate of 0.36 (0.09–0.66) birds per 100 fisher hours. The most frequently reported type of bird caught in rod and line fisheries were petrels and gulls. Captures of albatrosses, shags, gannets, penguins, and terns were also recalled.

The ramp surveys reported by Abraham et al (2010a) were limited and covered only two widely-separated parts of the New Zealand coastline. However, they also report two other pieces of information that suggest that non-commercial captures are likely to be very widespread. First, the Ornithological Society of New Zealand's beach patrol scheme records seabird hookings and entanglements as a common occurrence throughout New Zealand. Second, returns of banded birds caught in fisheries (separating commercial and non-commercial fisheries is very difficult) are very widely distributed around the coast (Figure 6.28).

Noting that our understanding of seabird capture rates in amateur fisheries is very sketchy, it is possible to make first-order estimates of total captures using information on fishing effort. For example, in the north-eastern region

where most of Abraham et al's (2010a) interviews were conducted, there were an estimated 4.8 (4.4–5.2) million fisher hours rod and line fishing from trailer boats in 2004–05 (Hartill et al 2007). Applying Abraham et al's (2010a) capture rate leads to an estimate of 11 500 (6600–17 200) captures per year in this area. Based on estimates of nationwide recreational fishing effort, this could increase to as many as 40 000 bird captures annually. Most birds captured by amateur fishers were reported to have been released unharmed (77% of the incidents recalled) and only three people reported incidents where the bird died. Because of likely recall biases and the qualitative nature of the survey, the fate of birds that are captured by amateur fishers remains unclear.

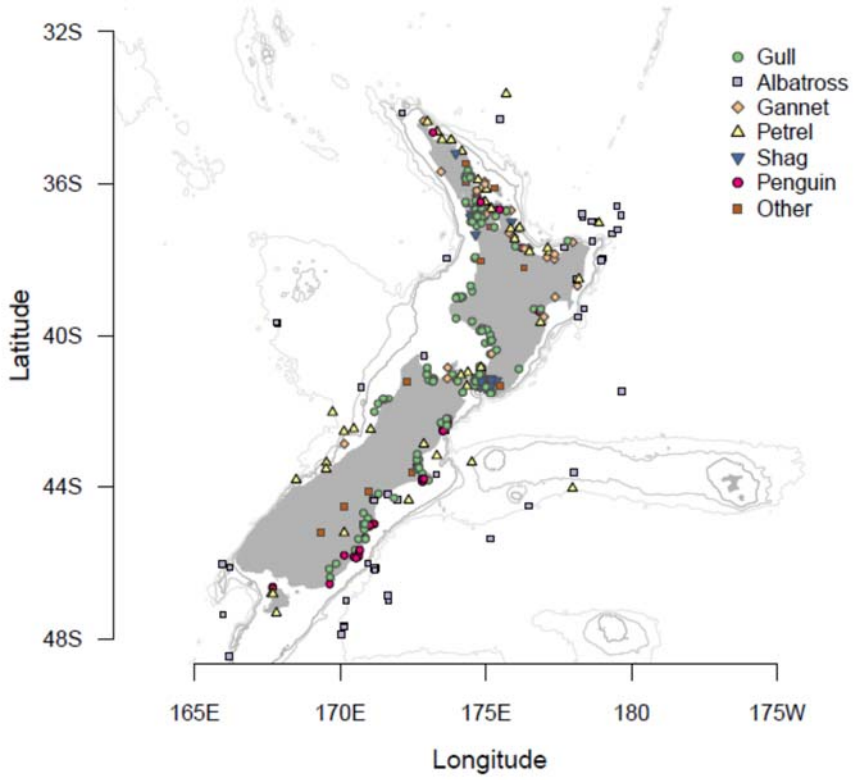


Figure 6.28: (from Abraham et al 2010a): Distribution of the reported capture locations for banded seabirds reported as being captured in fishing gear, 1952–2007. Note, band recovery locations are reported with low spatial precision and some of the inland locations may be correct.

Non-commercial fishers are allowed to use setnets in New Zealand and two studies suggest that these have an appreciable bycatch of seabirds. A study of captures in non-commercial setnets in Portobello Bay, Otago Harbour, between 1977 and 1985 (Lalas 1991) suggested that spotted shags were the most frequently caught taxa (82 recorded, compared with 14 Stewart Island shags and two little shags). Lalas (1991) suggested that up to 800 spotted shags (20% of the local population) may have been caught in the summer of 1981/82. A broader-scale study of yellow-eyed penguin mortality in setnets in southern New Zealand (Darby & Dawson 2000) suggested non-negligible captures of this species by non-commercial fishers, also reporting other seabirds like spotted shags and little blue penguin.

6.4.5.4.4 OUT OF ZONE MORTALITY.

Robertson et al (2003) mapped the distribution of the 25 breeding (mainly endemic) New Zealand seabird taxa they considered most at risk outside New Zealand waters. These ranged widely: 4 used the South Atlantic; 4 the Indian Ocean; 22 Australian waters and the Tasman Sea; 15 used the South Pacific Ocean as far afield as Chile and Peru; and 6 used the North Pacific Ocean as far north as the Bering Sea. These taxa therefore use the national waters of at least 18 countries. For example, the level-2 risk assessment described by Richard et al (2011) includes only that part of the range of each taxon contained within New Zealand waters, but many including commonly-caught seabirds like white-capped albatross and white-chinned petrel range much further and are vulnerable to fisheries in other parts

of the world. For instance, fatalities of white-capped albatross outside the New Zealand EEZ greatly exceed fatalities within the zone (Baker et al 2007, Francis 2012, (Table 6.31), and more than 10 000 white-chinned petrel are killed off South America each year (Phillips et al 2006), noting that reliable records are not available for most of the fisheries involved. Also note that white chinned petrels also breed on Prince Edward and Falkland Islands, South Georgia, Iles Crozet, and the Kerguelen group, so South American captures may be from other populations other than New Zealand's. Based on similar analyses, Moore & Zydelis (2008) concluded that a population-based, multi-gear and multi-national framework is required to identify the most significant threats to wide-ranging seabird populations and to prioritize mitigation efforts in the most problematic areas. To that end, the Agreement for the Conservation of Albatrosses and Petrels (ACAP) adopted a global prioritisation framework at the Fourth Session of the Meeting of the Parties (MoP4) in April 2012 (ACAP 2012).

Table 6.31: (from Francis 2012): Estimates of the number of white-capped albatrosses killed annually, by fishery. The first two columns are from Baker et al (2007b) (mid-point where a range was presented), including their assessment of reliability (L = low, M-H = medium-high, H = high). Updated estimates are from Watkins et al (2008, *) and Petersen et al (2009, **). Estimates not already corrected for cryptic mortality are either doubled to allow for this (***) or replaced by estimates of potential fatalities from Richard et al (2011, ***), noting that potential fatalities may considerably overestimate actual fatalities.

Fishery	From Baker et al 2007b		Updated	Incl. Cryptic mortality
South African demersal trawl	4 750	(L)	* 6650	6 650
Asian distant-water longline	1 255	(L)	–	*** 2 510
Namibian demersal trawl	910	(L)	* 1270	1 270
Namibian pelagic longline	180	(L)	** 195	*** 390
NZ hoki and squid trawl	513	(MH)	–	**** 4 920
NZ longline	60	(MH)	–	**** 199
Australian (line fisheries)	15	(MH)	–	*** 30
South African pelagic longline	570	(H)	** 570	*** 1 140
Total	8 210	–	–	17 110

6.4.5.4.5 OTHER SOURCES OF ANTHROPOGENIC MORTALITY.

Taylor (2000) listed a wide range of threats to New Zealand seabirds including introduced mammals, avian predators (weka), disease, loss of nesting habitat, competition for nest sites, coastal development, human disturbance, commercial and cultural harvesting, volcanic eruptions, pollution, plastics and marine debris, oil spills and exploration, heavy metals or chemical contaminants, global sea temperature changes, marine biotoxins, and fisheries interactions. Relatively little is known about most of these factors, but the parties to ACAP have agreed a formal prioritisation process to address and prioritise major threats (ACAP 2012). Croxall et al (2012) identified the main priorities as: protection of Important Bird Area (IBA) breeding, feeding, and aggregation sites; removal of invasive, especially predatory, alien species as part of habitat and species recovery initiatives. Lewison et al (2012) identified similar research priorities (in addition to direct fishing-related mortality), including: understanding spatial ecology; tropho-dynamics; response to global change; and management of anthropogenic impacts such as invasive species, contaminants, and protected areas. Non fishing-related threats to seabirds in New Zealand are largely the mandate of the Department of Conservation and a detailed description is beyond the scope of this document (although causes of mortality other than fishing are clearly relevant to the interpretation of risk assessment restricted to the direct effects of fishing). These threats are identified in DOC's Action Plan for Seabird Conservation in New Zealand (Taylor 2000) and various Threatened Species Recovery Plans.

6.4.5.4.6 FUTURE DEVELOPMENT OF THE RISK ASSESSMENT FRAMEWORK

The following steps were identified in the NPOA-Seabirds 2013 (MPI 2013) in order to improve the risk assessment framework that supports the implementation of the NPOA-Seabirds 2013:

- implementation of a framework and process to consolidate different risk assessment and population monitoring results into an integrated assessment, including:

- checking the algorithmic level 2 assessment results for particular high risk species-fishery interactions, in light of other available data or identifiable structural biases on a case-by-case basis;
- a mechanism to incorporate issues associated with seabird mortalities outside the EEZ and recreational fisheries risk in future assessments;
- the use of species population models or census data to constrain input parameters or interpret estimates of risk;
- routine update of the integrated fisheries risk assessment with relevant new information; and
- periodic review and update of risk management priorities in light of current risk estimates.

MPI has committed to undertake a further two iterations of the seabird level two risk assessment in 2015 and 2016, under project PRO2014-06. This project will include another review workshop such as undertaken in 2013 to assess the risk assessment structure and input parameters. Additional analyses for the 2015 iteration of the risk assessment may include, but are not limited to:

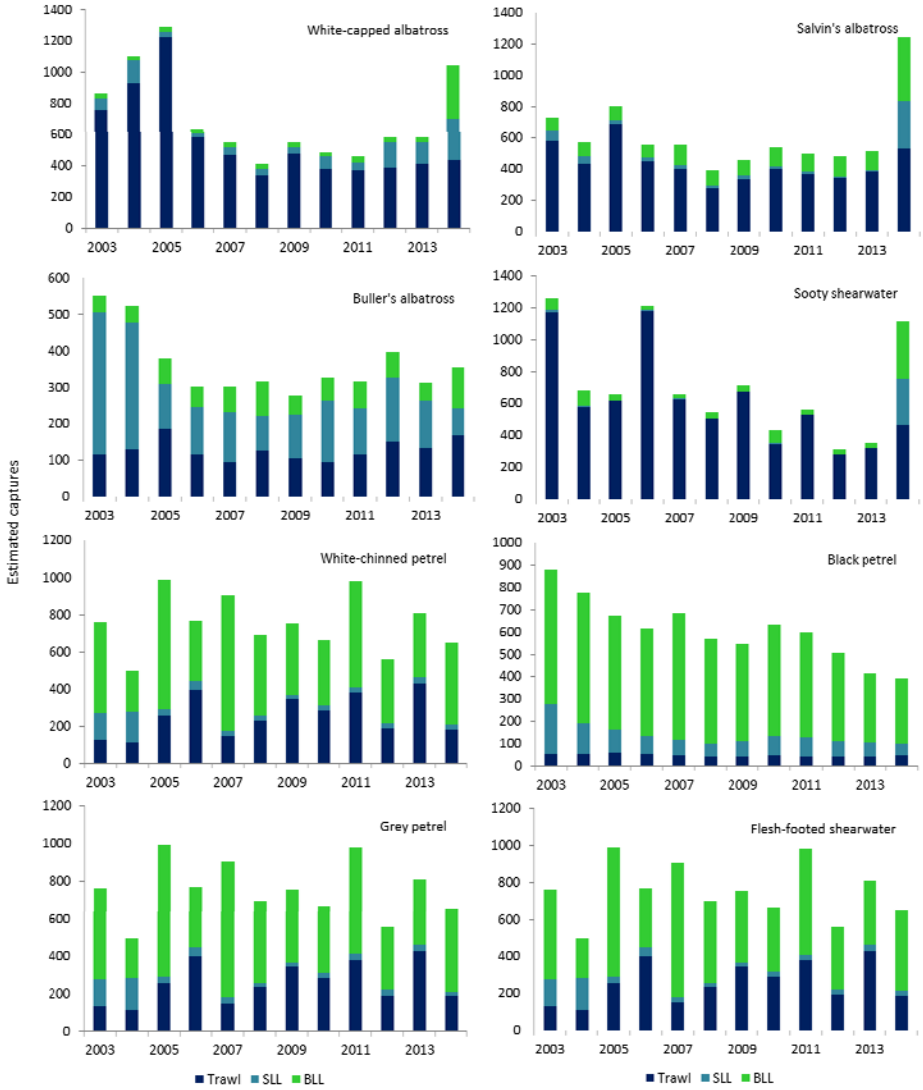
- Improving the distribution of uncertainty around N_{BPmin},
- Investigating the ability of the risk assessment to detect changes in vulnerability over time and determining the required level of coverage and observed captures to allow changes in vulnerability to be calculated,
- Simulations to test the ability of the risk assessment to detect/predict capture levels,
- Further consideration of the ρ factor, including the application of ρ where different information on abundance and overlap is used (i.e. black petrel) and determining whether and to what extent the use of N_{BPmin} leads to a bias in PBR_1.

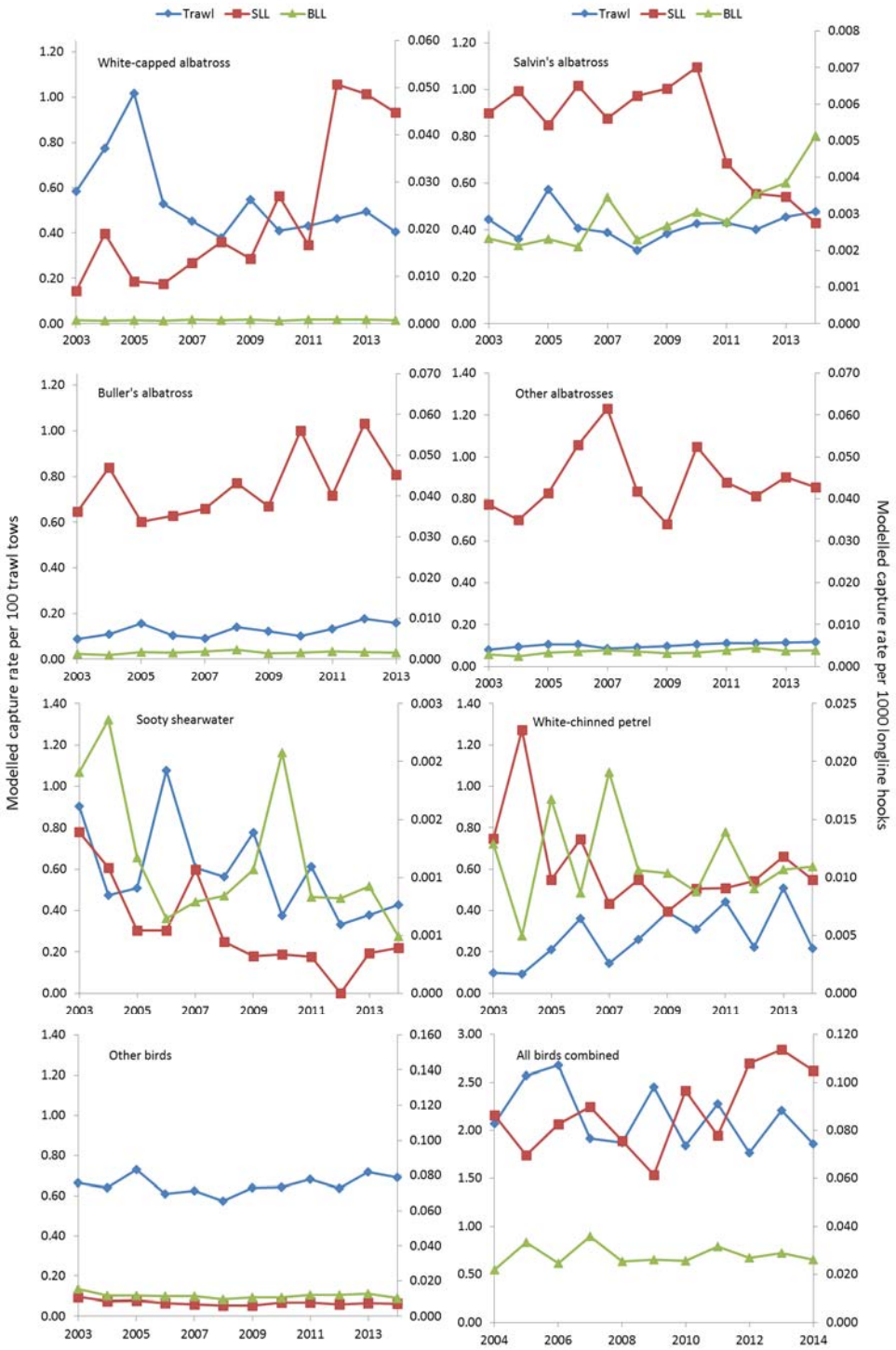
6.5 INDICATORS AND TRENDS

Population size	Multiple species and populations: see Taylor (2000)
Population trend	Multiple species and populations: see Taylor (2000)
Threat status	Multiple species and populations: see Robertson et al (2013)
Number of interactions[2]	In the 2013–14 October fishing year, there were an estimated 4378 seabird captures (excluding cryptic mortalities) across all trawl and longline fisheries (http://data.dragonfly.co.nz/psc/ Data version v2015001). About 45% of the estimated captures across these fisheries (other fisheries such as set net are excluded) were in trawl fisheries, 13% in surface longline fisheries, and 42% in bottom longline fisheries:

Bird group	Trawl	Surface longline	Bottom longline	All these methods
White-capped albatross	439	264	345	1048
Salvin's albatross	530	308	407	1245
Buller's albatross	167	75	112	354
Other albatrosses	99	109	155	363
Sooty shearwater	463	292	364	1119
White-chinned petrel	185	25	444	654
Black petrel	47	52	293	392
Grey petrel	16	24	168	208
Flesh footed shearwater	116	181	340	637
Other birds	587	18	418	1023
All birds combined	2277	660	2138	5075

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

Trends in interactions	Captures of all birds combined show a decreasing trend between 2002–03 and 2013-14 (http://data.dragonfly.co.nz/psc/ Data version v2015001) but there are substantial differences in trends between species and fisheries. Some of these estimates may have a small negative bias, see footnote 1. Captures of white-capped albatross and sooty shearwater have decreased, especially in offshore trawl fisheries: 

Trends in interactions [Continued]	Capture rate trends (excluding cryptic mortalities) are described for the four fisheries estimated to account for most captures of a species (usually accounting for 70–80% of the total). Capture rates of white-capped albatross have fallen in trawl fisheries for hoki and squid but have remained steady in inshore trawl fisheries and increased in the southern bluefin tuna longline fishery. Capture rates for other albatross species for which specific estimates were made (Salvin's and Buller's) have fluctuated without obvious trend in trawl and bottom longline fisheries but increased in surface longline fisheries. Capture rates for white-chinned petrel have increased in the squid trawl fishery but have remained steady in longline fisheries. Capture rates of sooty shearwater have declined in the ling longline fishery but have fluctuated without apparent trend in other key fisheries. Some of these estimates may have a small negative bias, see footnote 1. 

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7 COMMON DOLPHIN (*DELPHINUS DELPHIS DELPHIS*)

Scope of chapter	This chapter outlines the biology of short-beaked common dolphins (Delphinus delphis delphis), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty, where known
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	Areas with significant known fisheries interactions include waters off the west coast of the North Island, including Taranaki Bight, and to a lesser extent Cook Strait.
Key issues	Improving estimates of incidental captures in some fisheries, and assessing the potential for populations to sustain the present levels of incidental captures.
Emerging issues	Improving data and information sources for future ecological risk assessments.
MPI research (current)	PRO2013-01 Estimation of Seabird and Marine Mammal Captures; PRO2012-02 Assess the risk posed to marine mammal populations from New Zealand fisheries; PRO2014-01 Improving information on the distribution of seabirds and marine mammals.
NZ government research (current)	DOC Marine Conservation Services Programme (CSP): INT2015-01 To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities; INT2015-03 To determine which marine mammal, turtle and protected fish species are captured in fisheries and their mode of capture.
Other research	Massey University: Skull morphometrics, growth and reproductive biology, diet and nutritional ecology, fine-scale distribution and abundance, and mother-offspring dynamics of common dolphins in New Zealand. Auckland University: impacts of tourism on dolphin behaviour examining and the effectiveness of permit changes to the dolphins' responses to swimmers and boats.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
Related chapters/issues	See the JMA, chapter 34, of the Fisheries Assessment Plenary (MPI 2015)

Note: This chapter is new for the AEBAR 2015

7.1 CONTEXT

Short-beaked common dolphins (*Delphinus delphis delphis*) were first described by Linnaeus in 1758 and have a worldwide distribution. In New Zealand (NZ) waters, this species is protected under the Marine Mammal Protection Act (MMPA) of 1978 and the Fisheries Act (FA) of 1996. All marine mammals are protected under the s.2(1) of the FA. The ministers for the Department of Conservation (DOC) and the Minister for Primary Industries (MPI) can jointly approve a population management plan (PMP) for one or more species under s.14 of the Wildlife Act. This PMP can include the maximum allowable level of fishing-related mortality of the species in NZ waters and recommendation of MPI on 1) measures to mitigate fishing related mortality and 2) the standard of information to be collected on fishing related mortality. Currently, a PMP does not exist for common dolphins.

MPI manages fisheries related mortalities of common dolphins under s.15(2) of the FA "*to avoid, remedy, or mitigate the effect of fishing-related mortality of any protected species and such measures may include setting a limit on fishing related mortality.*" The 2005 Conservation General Policy administered by DOC specifies that *"protected marine species should be managed for their long-term viability and recovery throughout their natural range"*. The management of fisheries interactions with common dolphins aligns with the 2030 objective 6 to *"manage impacts of fishing and aquaculture"* and Strategic Action 6.2 to *"set and monitor environmental standards, including for threatened and protected species and seabed impacts"*.

Under the National Deepwater Plan, objective 2.5 is most relevant to the management of common dolphins in NZ waters: *"manage deepwater and middle-depth fisheries to avoid or minimise adverse effects on the long-term viability of endangered, threatened, and protected species"* (MPI 2012). The National Deepwater Plan contains information for fisheries to assess and manage marine mammal interactions with the deepwater fishing activity including a

Marine Mammal Operating Procedure (MMOP) which outlines specific mitigation practices and proper handling of incidental marine mammal captures (MPI 2012).

Management objective seven of the National Fisheries Plan for Highly Migratory Species (HMS) is to "implement an ecosystem approach to fisheries management, taking into account associated and dependent species" (MF 2010). The goals under this objective are as follows:

1. Avoid, remedy, or mitigate the adverse effects of fishing on associated and dependent species, including through maintaining food chain relationships.
2. Minimise unwanted bycatch and maximize survival of incidental catches of protected species in HMS fisheries using a risk management approach.
3. Increase the level and quality of information available on the capture of protected species.

The Draft National Fisheries Plan for Inshore Finfish states that the objectives of all groups is *"to minimise the adverse impact of fishing actives"* (MF, 2011).

7.2 BIOLOGY

7.2.1 TAXONOMY

Within the Delphindae family, common dolphin are a member of the subfamily Delphininae (Perrin 1989). Based on genetic and morphological differences, there are two currently recognised species of common dolphins, the short-beaked (*Delphinus delphis*) and the long-beaked (*D. capensis*) (Rosel 1994, Heyning 1994). There are two subspecies of the short-beaked common dolphin (*D. d. Delphis* and *D. d. ponticus* which is found only in the black sea) and two subspecies of long-beaked common dolphin (*D. c. capensis* and a nominal subspecies recognized as *D. c. tropicalis* (Jefferson 2002). Genetic and morphometric differences between common dolphin populations in the South Pacific and those from other parts of the world have cast uncertainty as to the taxonomic identity of the NZ population of common dolphins (Bell 2002, Stockin 2008, Stockin 2005). Skull morphometry values from Australia and NZ common dolphins fall between those reported for short- and long-beaked common dolphins. However, initial evidence suggests that the species in NZ waters is a larger form of the short-beaked common dolphin found elsewhere (Jordan 2015, Jordan 2012, Bell 2002). For the remainder of this chapter, 'common dolphin' will refer to the short-beaked species – *D. d. delphis*.

7.2.2 DISTRIBUTION

Common dolphins are found worldwide in tropical, sub-tropical, and temperate waters of the Pacific and Atlantic oceans (Hammond 2008, Evans, 1994) (Figure 7.1). This species also occurs in confined seas such as the Sea of Okhotsk and Sea of Japan as well as in small sub-populations in places such as the Mediterranean and Black Seas (Hammond 2008). New Zealand waters represent the southern-most limit of common dolphins. Common dolphins are found around both the North and South Island (Brager 1998, Gaskin 1968, Berkenbusch 2013, Constantine 1997) (Figures 1.2 and 1.3). However, Gaskin (1968) suggests that the distribution of common dolphins in NZ waters is constrained to warmer waters (greater than ca. 14°C) and is limited by the subtropical East Cape Current in the north and the subtropical convergence in the south.

Common dolphins are frequently observed along the northern and eastern coast of the North Island in the Bay of Islands, Hauraki Gulf, Mercury Bay, and in small groups, outside Wellington Harbour (Gaskin 1968, Constantine 1997, Neumann 2005, O'Callaghan 2002). Similar to other populations, common dolphins in NZ waters exhibit inshore and offshore daily and seasonal movements (Meynier 2008, Neumann 2001, Stockin 2008). The seasonal distribution of common dolphins is largely determined by the behaviour of their prey. Common dolphins are known to forage on small schooling fish that are strongly linked to sea surface temperature (SST). As a result, both common dolphins and their prey are found close to shore in the spring and summer when SST is high and further offshore in the autumn when SST drops (Neumann 2001, Stockin 2008, Neumann 2001). This species is also known to adjust their seasonal movements to take advantage of warmer water during a La Nina event (Neumann 2001).

Common dolphins are encountered in single and large multi-species groups with both seabirds and other marine mammals (hundreds to thousands) and found in waters both nearshore and thousands of kilometres offshore, in pelagic waters (Evans 1994). In NZ waters, they are known to form large aggregations with approximately 10 seabird and seven cetacean species. Of the seabird species, common dolphins are most often associated with the

Australasian gannet (*Morus serrator*). Associations with other cetaceans include: bottlenose dolphins (*Tursiops truncatus*), striped dolphins (*Stenella coeruleoaba*), Hector's dolphin (*Cephalorhynchus hectori hectori*), Dusky dolphin (*Lagenorhynchus obscurus*), Minke whale (*Balaenoptera acutorostrata*), Sei whale (*Balaenoptera borealis*), and Bryde's whales (*Balaenoptera brydei*) (Stockin 2009).

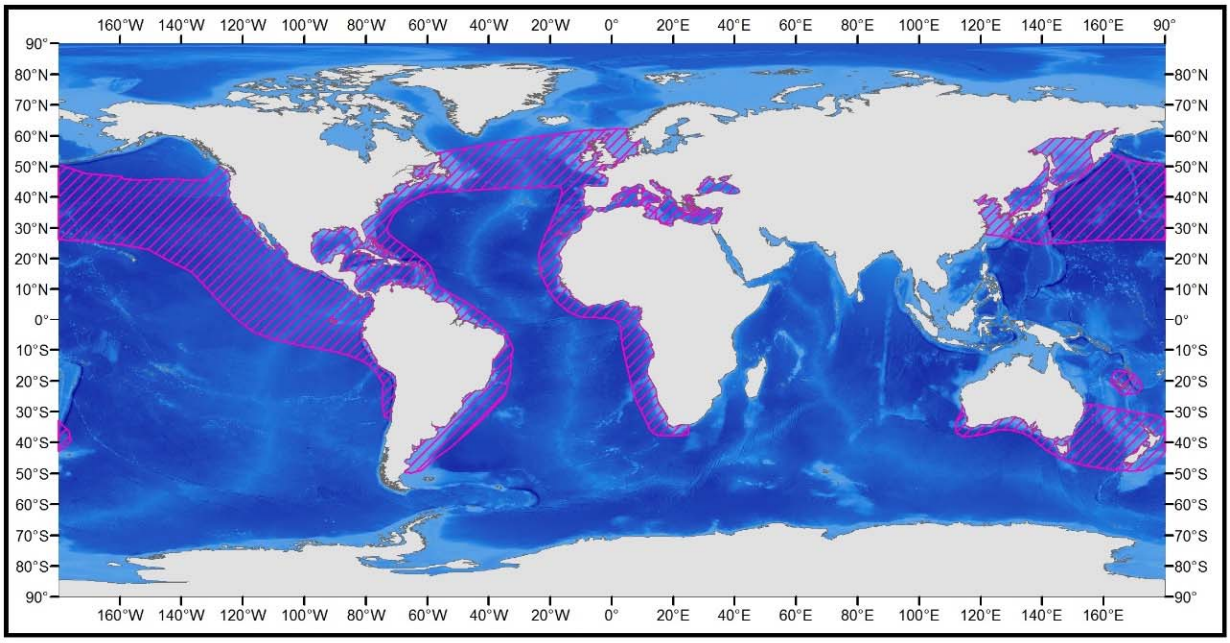


Figure 7.1: Worldwide distribution of short-beaked common dolphins (*Delphinus delphis delphis*) provided by the International Union for the Conservation of Nature (IUCN) (Hammond 2008). Magenta hatched areas indicate range.

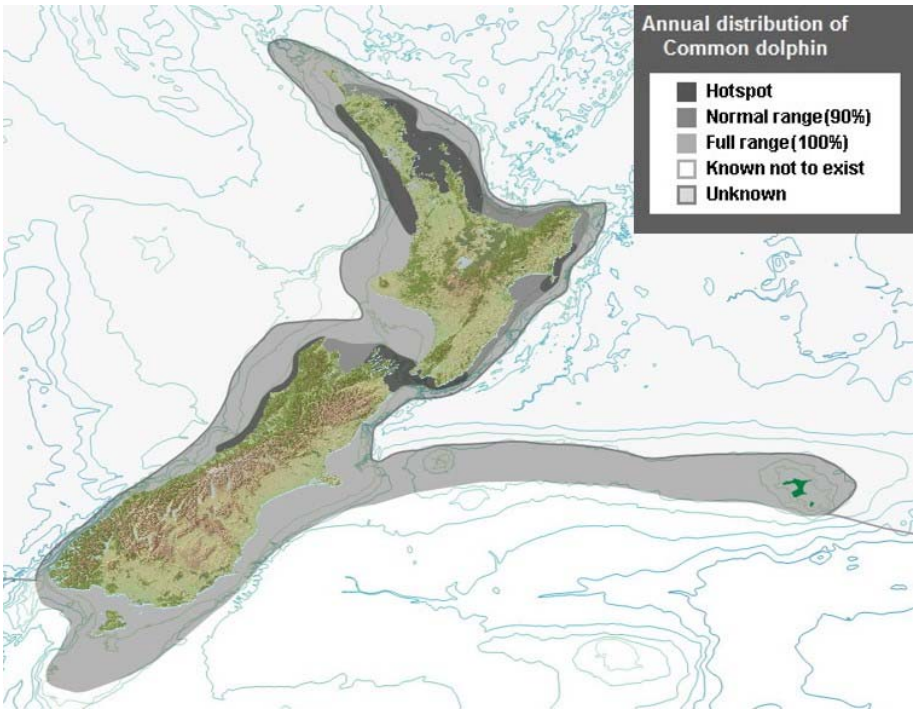


Figure 7.2: Distribution of short-beaked common dolphins (*Delphinus delphis delphis*) in New Zealand waters (from www.nabis.govt.nz).

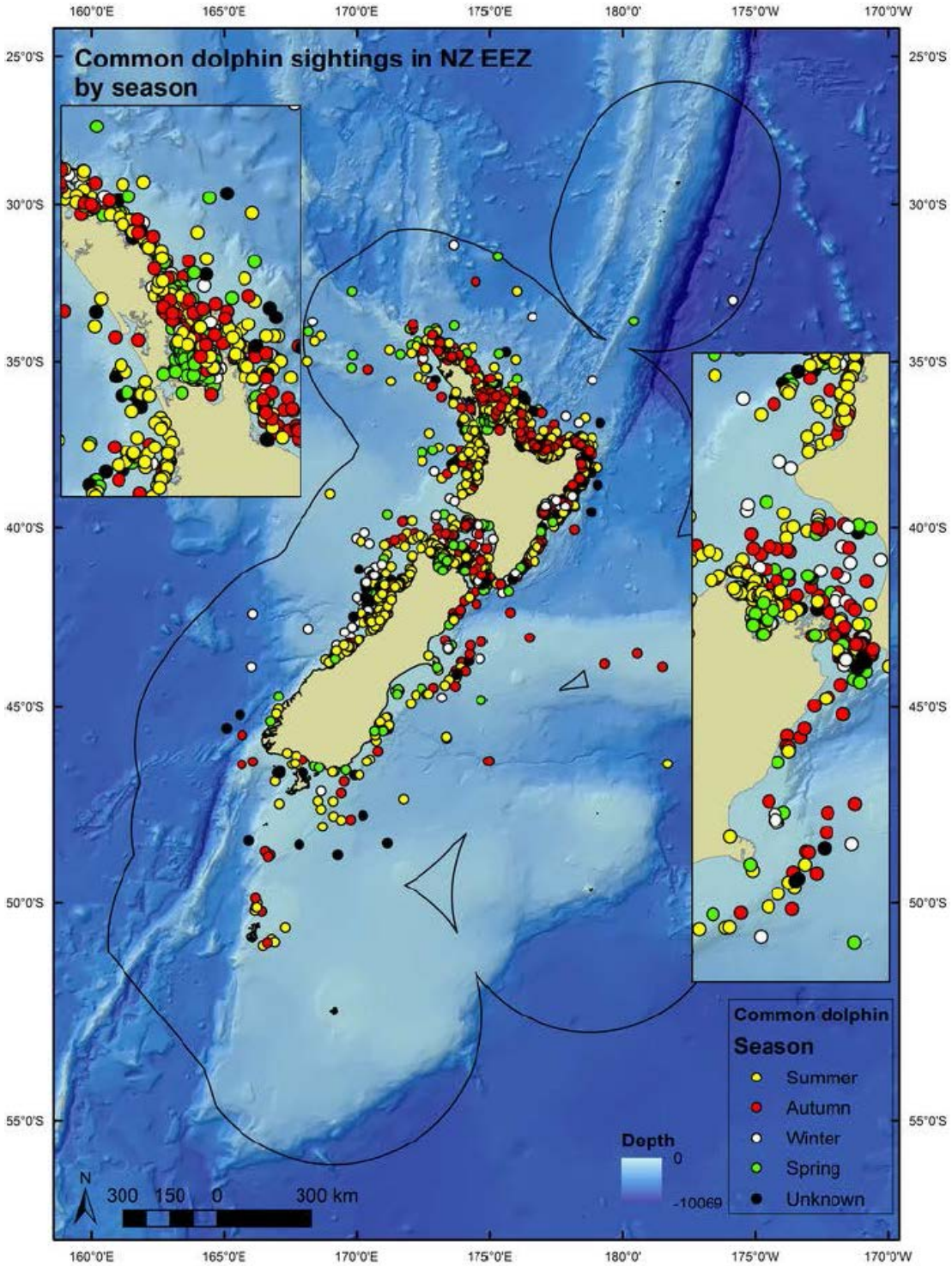


Figure 7.3: Systematic and opportunistic sightings of short-beaked common dolphins (*Delphinus delphis delphis*) in New Zealand waters between 1970 and 2013. Data sources include Department of Conservation (DOC), Cawthorn (2009), opportunistic at-sea sightings (NIWA), and the Centralised Observer Database (COD). (Sightings are indicative of the distribution only). Figure from Berkenbusch et al. (2013).

7.2.3 FORAGING ECOLOGY

The diet of common dolphins has primarily been assessed from the stomach contents of stranded and incidentally captured animals. Studies on common dolphins worldwide have documented the primary prey items as small schooling epipelagic and mesopelagic fish such as mackerel, sardines, and anchovies, as well as squid (Hammond 2008, Young 1994, Silva 1999, Bearzi 2003, Pusineri 2007, Overholtz 1991, Morizur 1999). While there is abundant information on the diet of common dolphins for many populations, there is relatively little information for common dolphins in NZ waters in comparison.

Although research has specifically identified the Hauraki Gulf as an area extensively used for feeding, common dolphins forage in waters all around NZ (Stockin 2009). In one study, common dolphins off the east coast of the North Island were observed foraging on schools of jack mackerel (*Trachurus novaezelandiae*) , schools of juvenile kahawai (*Arripis trutta),* yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), and, on one occasion, a school of parore (*Girella tricuspidata*), and garfish (*Hyporamphus ihi*) (Neumann 2003). The prevalent prey species from the stomach contents of animals stranded around the NZ coastline (n=27) and animals incidentally captured in the jack mackerel fishery off the west coast of the North Island (n=10) included arrow squid (*Nototodarus* sp.), anchovy (*Engraulis australis*), jack mackerel (*Trachurus* spp.) (Meynier 2008). In another study, pilchard (*Sardinops neopilchardus*), and garfish (*Hyporhamphus ihi*) were the predominant prey items found in the stomachs of nine New Zealand common dolphin carcasses (n=9) classified as 'entanglement' (Stockin 2009).

The similarity in prey items found in the stomachs of coastal and offshore animals provides further support that common dolphins in NZ make daily excursions between nearshore and offshore environments (Meynier 2008). In addition, many of the prey species (e.g. squid) found in the stomachs of common dolphins are found in the deep scattering layer which migrates towards the surface at night (Hammond 2008, Neumann 2003). Neumann (2003) cite personal communication with S. Morrison in which common dolphin were sighted by crew members of squid boats during nocturnal fishing in Mercury Bay suggesting that time of day may provide important foraging opportunities for this species. The ability of common dolphins to feed on small schooling fish in shallow coastal waters during the day and on prey in the deep scattering layer in pelagic waters at night may indicate foraging plasticity (Neumann 2001). Acoustic research in New Zealand waters showed that during the day the mesopelagic layer occupied waters deeper than 200 m, then rapidly ascended to close to the surface after sunset; throughout the night, this layer dispersed downwards but remained in depths of less than 200 m until dawn when the it descended to day depths (McClatchie 2003, O'Driscoll, 2009). O'Driscoll et al. (2013) found that schools of Jack mackerel ascended and dispersed at night and were seen in depths of 10–30 m before dawn

To exploit a large range of prey species, common dolphins exhibit a variety of foraging strategies. In NZ waters, both individual and co-ordinated feeding strategies have been documented (Neumann 2003). Individual foraging strategies include four types of behaviour: high-speed pursuit (traveling at high velocity in a zig-zag erratic fashion), fish-whacking (fish whacked with tail-fluke) and kerplunking (rapid tail-fluke movement in shallow water) (Neumann 2003, Constantine 1997). Furthermore, co-ordinated foraging strategies include: wall formation (driving fish into shallower water), carouseling (herding fish against the water surface), and bubble-blowing (startling herded fish).

Common dolphins are often observed foraging in association with other species (Neumann 2003). Rather than initiating feeding as a multi-species group, research indicates that birds and cetaceans may alert one another to prey by their presence and behaviour (Neumann 2003).

7.2.4 REPRODUCTIVE BIOLOGY

Despite their global distribution, relatively little information exists on the reproductive biology of common dolphins. Most of the existing information comes from studies on common dolphin populations in the North Pacific, Eastern Tropical

Pacific, or North Atlantic and may or may not be applicable to the population of animals in NZ waters. Male and female age of sexual maturity for common dolphins in the North Pacific is 10.5 years for males and 8.0 years for females with lengths ranging 179-182 cm and 170.7-172.8 cm, respectively (Ferrero 1995). In the North Atlantic population, males reach sexual maturity at 9.5 years and 213 cm and females at 8.3 years and 200 cm (Westgate 2007). A later age of sexual maturity for males may be the result of delayed breeding until the testes are large enough to compete with other males (Westgate 2007).

Testes weight of sexually mature males ranges from 273.2 to 1,190 g (Ferrero 1995). Male common dolphins in the North Atlantic exhibit seasonal changes in testes size with largest testes occurring in mid-July and smallest in October (Westgate 2007). The peak in testes size corresponds with the timing of ovulation, conception and parturition and changes five-fold between maximum expansion and retraction. In mature males, testes comprised 2.2-3% of their total body mass (Westgate 2007). Results from Westgate and Read (2007) suggest common dolphins in the North Atlantic engage in sperm competition as evidences by the seasonal change in testes size. The slight sexual dimorphism between sexes, in addition to seasonal changes in testes size, indicate that males compete for access to oestrous females and that females likely mate with many males (Westgate 2007). Given that many common dolphins in temperate environments exhibit reproductive seasonality, it is likely that the NZ population of animals also exhibits a peak in reproduction that may correspond to seasonally abundant prey or optimal water temperatures.

Although gestation time for common dolphins in NZ waters is unknown, the length of gestation for this species is about 11 months for the North Pacific population, 11-12 months for the North Atlantic population, and 11 months for the Black Sea population (Westgate 2007, Ferrero 1995, Gaskin 1972). Like all odontecetes, common dolphins give birth to a single calf, though one occurrence of a twin birth was reported off the coast of Spain (Gonzalez 1999). At parturition, Westgate and Read (2007) estimated the length of neonate common dolphins in the North Atlantic at 93.2 cm. Neonates nurse for approximately six months and begin foraging at three to six months of age (Brophy 2009). Common dolphins in the North Atlantic were found to have a minimum inter-birth interval of two years (Westgate 2007).

In NZ waters, calves are seen year-round in the Hauraki Gulf, however, peak numbers are recorded in late spring and early summer months of December and January (Stockin 2008). Common dolphins are considered a social species, showing non-random associations with other individuals. Sexual segregation in which animals divide into 'bachelor' (adult males), and 'nursery' (adult females and calves) groups has been observed in common dolphins in NZ waters (Neumann 2001, Neumann 2002, Viricel 2008). Mixed-sex groups also occur though they are usually associated with mating activities. The lack of stability in group composition is known as a 'fission-fusion' society in which group composition changes almost daily (Connor 2000, Neumann 2001).

7.2.5 POPULATION BIOLOGY

The abundance of common dolphins is estimated at 4,000,000 worldwide with population estimates existing for many regions: 370,000 in the western U.S.; 3,000,000 in the Eastern Tropical Pacific; 30,000 off the eastern U.S.; 96,000 in the Black Sea; 60,000 on the eastern Atlantic continental shelf; 14,700 in the Alboran Sea; 75,000 in the Celtic Sea Shelf; and 19,400 in the western Mediterranean Sea (Jefferson 2011, Hammond 2008).

Although there is currently no abundance estimate for common dolphins in NZ waters, they are considered the most abundant and widespread cetacean recorded in the Hauraki Gulf, an important foraging and nursery area, in the summer (O'Callaghan 2002). Unlike common dolphins in other areas of NZ waters, in the Hauraki Gulf, this species exhibits high site fidelity (Stockin 2014, Stockin 2008).

The maximum age of short-beaked common dolphins in western North Atlantic teeth was estimated at > 30 years using teeth samples from 204 by-caught and stranded animals (Westgate 2007). Similarly, growth layers of teeth collected from 206 common dolphins in NZ waters that were

stranded or by-caught in the midwater trawl fishery for jack-mackerel (*T. novaezelandiae*) estimated maximum age at >20 years and 29 years for males and females, respectively (Stockin 2011, Murphy 2014). Seven common dolphins incidentally caught by New Zealand fisheries and returned for autopsy were aged between 4 and 11 years (based on dentinel growth layers) (Duignan 2003, 2004, Duignan 2005).

Microsatellite analyses of nearshore and offshore NZ common dolphins suggest that these animals have recently diverged (Stockin 2014). In addition, the presence of high genetic variation at the southern limit of their distribution suggests that the overall population in NZ waters may be expanding and that there are fine-scale population level differences (Stockin 2014).

Common dolphin populations are subject to many natural and anthropogenic threats that include but are not limited to: stranding, disease, predation, toxins, habitat loss, vessel-strike, recreational and commercial fishing, and tourism-based activities. The cumulative impact of these threats on common dolphin populations has not been assessed. Drivers of common dolphin mortality include seasonal environmental variation, commercial fisheries interactions, habitat degradation, high-intensity acoustic disturbance, and disease (Murphy 2013).

The Mediterranean Sea population of common dolphins was greatly reduced due to four main factors: 1) habitat loss, 2) prey depletion, 3) incidental captures by fisheries, and 4) immuno-suppression caused by chemical contamination, and 4) environmental fluctuations (Bearzi 2003). In addition, at least 840,000 animals were removed from the Black Sea by hunters between 1946 and 1983, after which the population further declined due to disease and overfishing of prey species (Hammond 2008).

In the absence of a population estimate for common dolphins in NZ waters, the impact of natural and human-induced effects cannot be accurately determined. Two of the main known threats to common dolphins in NZ waters are incidental capture by fisheries and tourism-related impacts (Thompson 2013, Neumann 2005, Meissner 2015, Constantine 1997, Stockin 2009). Fisheries related threats are discussed in detail in the sections 1.3 and 1.4.

7.2.6 CONSERVATION BIOLOGY AND THREAT CLASSIFICATION

Common dolphins are currently listed as a species of least concern under the International Union for the Conservation of Nature (IUCN) Red List of Threatened species with the exception of the Mediterranean sub-population which is listed as 'endangered' (Hammond 2008).

In 2010, the conservation status of New Zealand marine mammals was reassessed using the 2008 version of the New Zealand Threat Classification system (Baker 2010). Based on several levels of criteria, common dolphins were classified as 'not threatened' with the qualifiers that the information was considered 'data poor', that the species was 'secure overseas', and that some sub-populations were 'threatened overseas'.

7.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

Interactions between cetaceans and fisheries occur worldwide. Cetaceans have been incidentally captured by numerous types of fishing gear including trawl nets, purse seine nets, and static nets such as driftnets or gillnets (Reeves 2005). Hall et al. (2000) state that cetaceans are at greater risk of capture by mid-water trawls which are towed faster than bottom trawls and usually target fish and squid. As a result, cetaceans may be captured when foraging in areas where fisheries using such gear also operate.

Due to their high global abundance, interactions between common dolphins and fisheries are not unusual. The highest rates of interactions are associated with fisheries that use trawl, purse seine, and drift nets. Outside New Zealand, perhaps the most well-known interaction occurs in the Eastern Tropical Pacific where common dolphins are found in association with yellowfin tuna (*Thunnus albacares*). In the 1960s, about 350,000 common dolphins were estimated to have been taken by this purse seine fishery (Joseph 1994). However,

due to mitigation measures introduced in the 1970s, the rate of dolphin captures has been greatly reduced and is no longer a conservation concern (Reeves 2003).

In addition to the Eastern Tropical Pacific, interactions between common dolphins and fisheries are known to occur in the north and south Atlantic and Pacific oceans. Common dolphins were the most commonly caught cetacean in the U.S. shark and swordfish gillnet fishery with an estimated mortality of 861 dolphins between 1996 and 2002 (Carretta 2005). In the U.K and the French pelagic trawl fishery for bass, ca. 800 common dolphins were taken annually (Hammond 2008). In addition, the pelagic pair-trawl fishery off southwest England captured approximately 200 common dolphins per annum, with most animals being captured at night (de Boer 2012). Male dolphins were at a greater risk of capture in pair-trawls offshore whereas females and calves were more vulnerable to gillnets close to shore (de Boer 2012). Other areas where interactions between common dolphins and fisheries are known to occur include:

- The North Sea, predominantly in gill nets (Reijnders 1990)
- Off the coast of Africa, predominantly in gill net and purse seine fisheries (Maigret 1994, Jefferson 1997)
- Off the south coast of Australia, mostly in gill nets or anti-shark netting (Kemper 2005)
- Off the coast of Portugal, where 59% of 124 by-caught common dolphins were by caught in primarily gill and seine nets between 1975 and 1998 and where fisheries interactions were responsible for up to 44% of stranding (Silva 2003)
- The Mediterranean Sea, where dolphins have a moderate (6-30% of sightings) or strong (35-50% of sightings) association with foreign purse seine tuna fishing, dolphin fish fishing activities, and illegal drift nets for swordfish offshore) (Vella 2005, Tudela 2005, Bearzi 2008)
- The Black Sea, in pelagic trawl nets {(Hammond 2008, Reeves 2006)

The Mediterranean Sea sub-population of common dolphins has been declining since the 1960s and has been subjected to the effects of illegal drift-netting and other anthropogenic impacts (Reeves 2003, Forcada 1998, Piroddi 2011). It is believed that overfishing in the Mediterranean Sea has outcompeted common dolphins for prey (Bearzi 2003). Bearzi et al. (2008) found that 10 active purse seine vessels were responsible for removing 33% of the biomass and suggested that they had the largest impact on dolphin prey species.

To reduce mortality from incidental captures, many countries have put implemented monitoring programmes to mitigate direct fisheries impacts to common dolphins. For example, after the creation of the U.S. Marine Mammal Protection Act in 1972, observer coverage in the purse seine fishery was increased to 100% to ensure compliance. The European Union has also introduced legislation to establish observer programmes for most fisheries {(Hammond 2008). Other measures to reduce unwanted bycatch include: modification of fishing gear and methods (acoustic deterrents), input and output controls (limiting fishing effort or capacity), compensatory mitigation (investing in conservation projects), establishment of Marine Protected Areas (MPAs), fleet communication (reporting real-time observation of unpredictable bycatch hotspots), industry self-policing (peer pressure from within the industry), handling and release practices (backing down and hand rescue procedures to release dolphins), and changing gear (using alternative fishing methods that results in lower bycatch) (Gilman 2009).

7.4 STATE OF KNOWLEDGE IN NEW ZEALAND

Common dolphins and fisheries in NZ waters often target the same fish species in the same areas. Early reports to the International Whaling Commission suggested that during June 1979 and April 1992, common dolphins were captured in trawl nets, crayfish pots, and purse seine nets (see Berkenbusch et al. 2013). Scientific observer data show that the primary fishery in New Zealand waters

that is responsible for common dolphin mortality has been the mid-water trawl fishery for jack mackerel species. Evidence from the early 1990s, after the establishment of the government observer programme, indicated that single and multiple captures of common dolphins occurred in the trawl nets of foreign-chartered trawlers targeting jack mackerel species off the west coast of New Zealand, in Quota Management Areas 7, 8, and 9 (61 animals between 1989-90 and 1992-93, see Baird 1994). This fishery operated offshore in the north and south Taranaki Bight waters, mainly in the summer months of November to April. During these years, observers reported a change in this fleet from the use of bottom trawls with headline heights of 5.2–9.8 m to midwater trawls with headline heights of 20–45 m (MPI unpublished observer data). The midwater trawls could be towed near the bottom during the day and in the water column at night and thus follow the movement of the jack mackerel schools. Alternatively, both gear types were used, alternating according to time of day.

Midwater nets were towed for 4-6 h and nets hauled between 2330 and 0615 h were responsible for almost all the dolphin captures, particularly in south Taranaki Bight in 70-130 m depths (Baird 1994). These mortalities resulted in the development of voluntary Codes of Practice (COPs) by the company operating the vessels which aims to outline best practices to remedy, mitigate, or avoid incidental captures (Rowe 2007) (see Baird 1994, appendix 9). The COPs addressed several aspects of the fishing operation thought to increase the likelihood of capture, mainly: the practice of undertaking a U-turn with the trawls doors up but the net in the water near the surface; the timing of setting; and the vessel lighting during night fishing activities. In addition, the codes may include recommendation for gear modifications and voluntary area closures (Rowe 2007). The government response led to increased observer coverage and provision for the necropsy of captured animals. MPI observer data shows that 10 common dolphins have been autopsied since 1994 (see also Duignan et al. 2003, Duignan et al. 2004, Duignan & Jones 2005). However, capture incidents continued to occur until this fleet of vessels ceased fishing in NZ waters in the mid-late 1990s (Baird 1996).

Subsequently, midwater trawling for jack mackerels has remained the main method and target fishery responsible for common dolphin captures (based on observer data) (see Abraham & Thompson 2011). However, since the late 1990s, the observed common dolphin captures have been almost entirely from a different fleet of large foreign-charted trawlers operating mainly off the west coast of the North Island during summer months (Thompson et al. 2013a).

These vessels use mid-water nets with headline heights of 30-60 m in depths of less than 200 m. The largest capture event in this fishery caught 9 dolphins in one tow (Thompson et al. 2013a). Observer coverage between 1995-96 and 2010-11 was at least 20% for most fishing years but fluctuated considerably between 7 and 70% (Thompson et al. 2013a). The vessels are required to follow Operational Procedures for mitigating incidental captures of marine mammals as agreed by quota owners (see section 1.4.2 for a fuller explanation).

Headline depth of trawl nets (distance from the headline to the surface) was found to be an important factor in explaining common dolphin captures in this fishery (Thompson 2013). The majority of dolphin captures occurred when headline depth was between 10 and 40 m; however, 50% of observed capture events and 54% of common dolphins captured in large vessel mackerel fishery occurred on the 10% of the observed trawls that had a headline depth < 30 m (Figure 7.4) (Thompson 2010). Thompson et al., 2013, 2010) estimated that an increase of 21 m in headline depth may reduce the number of common dolphin captures by half. Longer tows caught more dolphins, as did tows in darkness, and tows conducted in the waters off the north Taranaki Bight. Of all shallow trawl tows (headline depths <40 m), 69% occurred at night when the fish migrate to the surface (Thompson 2013). Common dolphins are known to follow diel migrating prey, which likely explains higher captures rates in shallow waters at night. Table 7.1 shows common dolphin captures in the jack mackerel fishery from 1989–90 to 1994–95. Most common dolphin captures occurred when conducting mid-water trawls at night. The number of captures between 1995–96 and 2001–02 fishing

years ranged between zero and 31 animals (Thompson 2013).

Captures have also been reported occasionally from observed trawl fisheries that targeted other middle depth species such as barracouta, hoki, and arrow squid, as well as trawl nets targeting inshore species such as trevally and tarakihi (MPI unpublished data). One common dolphin was released alive after being caught on an observed tuna surface longline in the Bay of Plenty (MPI unpublished data). The distributions of the fishing effort and observed captures for 2002-03 to 2012-13 are shown for all trawl fisheries (Figure 7.5) and for jack mackerel fisheries (Figure 7.6). During this time period there were 150 observed captures of common dolphins in trawl fisheries, 134 of which occurred in the jack mackerel fishery (see section 1.4.1, Tables 1.3 & 1.4).

There were no observed common dolphin captures by the following NZ fisheries between 2002-03 and 2012-13: surface longline (southern bluefin, albacore and bigeye tuna, and swordfish); bottom longline (ling, snapper, mullet); and purse seine (mackerel and skipjack tuna). It should be noted that the proportion of the commercial effort covered by observers is highest in deepwater trawl fisheries, with relatively small amounts of effort observed for inshore trawl fisheries and fisheries using other types of fishing gear (see Abraham & Thompson 2011). Between 1995-96 and 2011-12 fishing years, observer effort in the middle-depth, inshore, and flatfish trawl fisheries was 3.4%, 0.5% and 0.3%, respectively (Berkenbusch 2013).

7.4.1 QUANTIFYING FISHERIES INTERACTIONS

Bayesian models were applied to fishing effort and observer data collected from trawl fisheries to estimate the number of common dolphin captures within NZ's EEZ (Abraham 2011) (Figure 7.7). Note that while there were a small number of live captures, most capture events resulted in dolphin mortality. A separate two-step Bayesian hurdle model was developed by Thompson et al. (2010) to estimate the number of captures by the jack mackerel trawl fishery off the west coast of the North Island (Figure 7.8). The first part of the model estimated the presence of a capture event and the second part estimated how many capture events occurred if a capture event was estimated to have been present. Because no captures were recorded from smaller vessels, this analysis only included data from vessels > 90 m in length (Thompson 2010). However, observer coverage of these vessels was limited to 0–0.5% for the years analysed (Thompson et al. 2010). Model based capture estimates have been created for fishing years since 1995–96 (Thompson 2013) and are presented in Table 7.2.[1]

During the 2002–03 and 2013–14 fishing seasons, less than three percent of the total trawl effort (number of tows) occurred in the jack mackerel fishery, yet 89% of the 150 common dolphin captures occurred in this fishery (Tables 7.2 and 7.3).

[1] As part of its data reconciliation processes, MPI has identified that less than 2% of observed protected species captures between 2002 and 2015 were not recorded in Centralised Observer Database (COD). Steps are being taken to update the database and estimates of protected species captures and associated risks. Accordingly, some estimates of protected species captures or risk in this common dolphin chapter may have a small negative bias. Updated estimates will be reviewed by the Aquatic Environment Working Group in the second quarter of 2016.

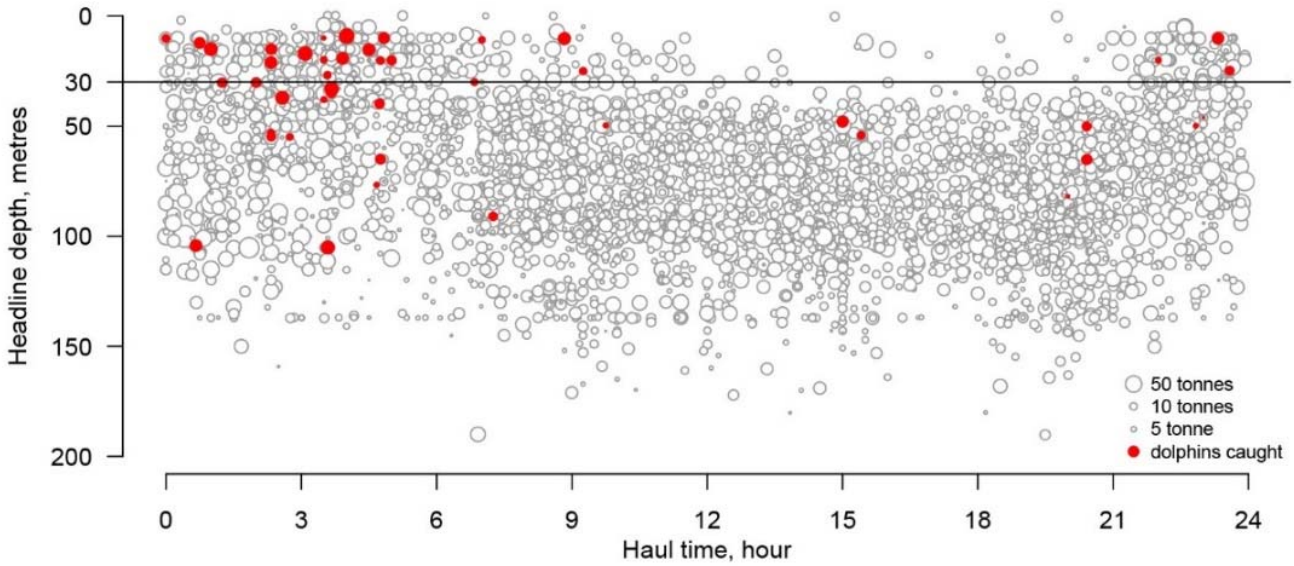


Figure 7.4: Headline depth versus the haul time for observed trawls in the large-vessel jack mackerel fishery. The catch weight is indicated by the size of the circles. Tows where an observed common dolphin capture event occurred are filled. Table from Thompson et al. 2010, figure 8.

Table 7.1: Total and observed numbers of tows, observed number of dolphin mortalities and the number of events (tows) which incidentally caught dolphins in the jack mackerel fishery around the North (NT) and South (ST) Taranaki Bights by gear type (MW: mid-water and BT: Bottom Tow), and time of day (D-Day and N-Night) for fishing years 1989-90 to 1994-95. Red bold numbers indicate that the species was confirmed as common dolphin (*Delphinus delphis delphis*). Table reproduced from Baird (1994, 1996).

Fishing year	Region	Gear	Time of Day	Effort		Observed captures	
				Fishing tows	% Observed	Mortality	Events
1989-1990	NT	BT	D	1191	48	0	0
	NT	MW	D	41	0	0	0
	NT	BT	N	173	6	0	0
	NT	MW	N	28	1	0	0
	ST	BT	D	1418	139	0	0
	ST	MW	D	15	6	0	0
	ST	BT	N	186	6	0	0
	ST	MW	N	105	90	**23**	10
1990-1991	NT	BT	D	603	2	0	0
	NT	MW	D	53	0	0	0
	NT	MT	N	72	0	0	0
	NT	MW	N	63	0	0	0
	ST	BT	D	676	47	0	0
	ST	MW	D	147	110	0	0
	ST	BT	N	84	12	0	0
	ST	MW	N	146	73	0	0
1991-1992	NT	BT	D	1523	101	0	0
	NT	MW	D	361	4	0	0
	NT	BT	N	279	36	**2**	2
	NT	MW	N	500	3	**5**	3
	ST	BT	D	618	74	**1**	1
	ST	MW	D	151	3	0	0
	ST	BT	N	95	7	**5**	1
	ST	MW	N	146	15	16	5
1992-1993	NT	BT	D	1759	135	0	0
	NT	MW	D	21	3	0	0
	NT	BT	N	438	22	0	0
	NT	MW	N	156	16	0	0
	ST	BT	D	588	112	0	0
	ST	MW	D	51	0	0	0
	ST	BT	N	48	6	0	0
	ST	MW	N	305	28	**9**	3
1993-1994	NT	BT	D	1494	78	0	0
	NT	BT	D	219	19	0	0
	NT	MT	N	309	13	0	0
	NT	MW	N	300	28	0	0
	ST	BT	D	645	155	0	0
	ST	MW	D	120	20	0	0
	ST	BT	N	35	14	0	0
	ST	MW	N	279	71	8	5
1994-1995	NT	BT	D	391	17	0	0
	NT	MW	D	399	80	0	0
	NT	BT	N	93	9	0	0
	NT	MW	N	258	74	0	0
	ST	BT	D	198	41	0	0
	ST	MW	D	228	73	6	3
	ST	BT	N	27	13	0	0
	ST	MW	N	147	74	15	3

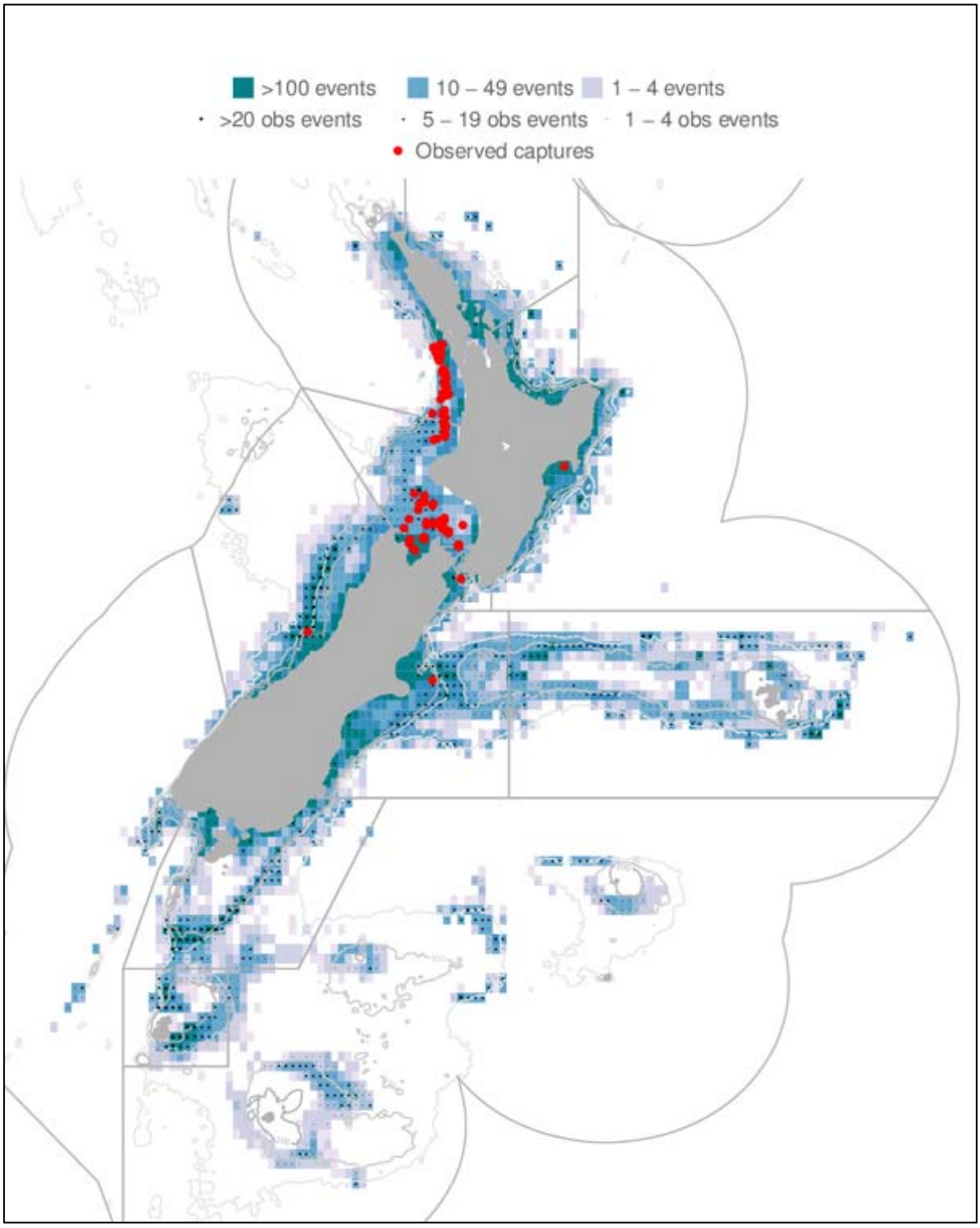


Figure 7.5: Distribution of all trawl fishing effort and observed common dolphin (*Delphinus delphis delphis*) captures, 2002-03 to 2012-13 (for more information see MPI data analysis at https://data.dragonfly.co.nz/psc/ data version v20140201). Fishing effort is mapped into 0.2-degree cells, coloured to represent the number of tows. Observed fishing events are indicated by black dots, and observed capture events are indicated by red dots. Fishing effort is shown for all tows with latitude and longitude data, where three or more vessels fished within a cell.

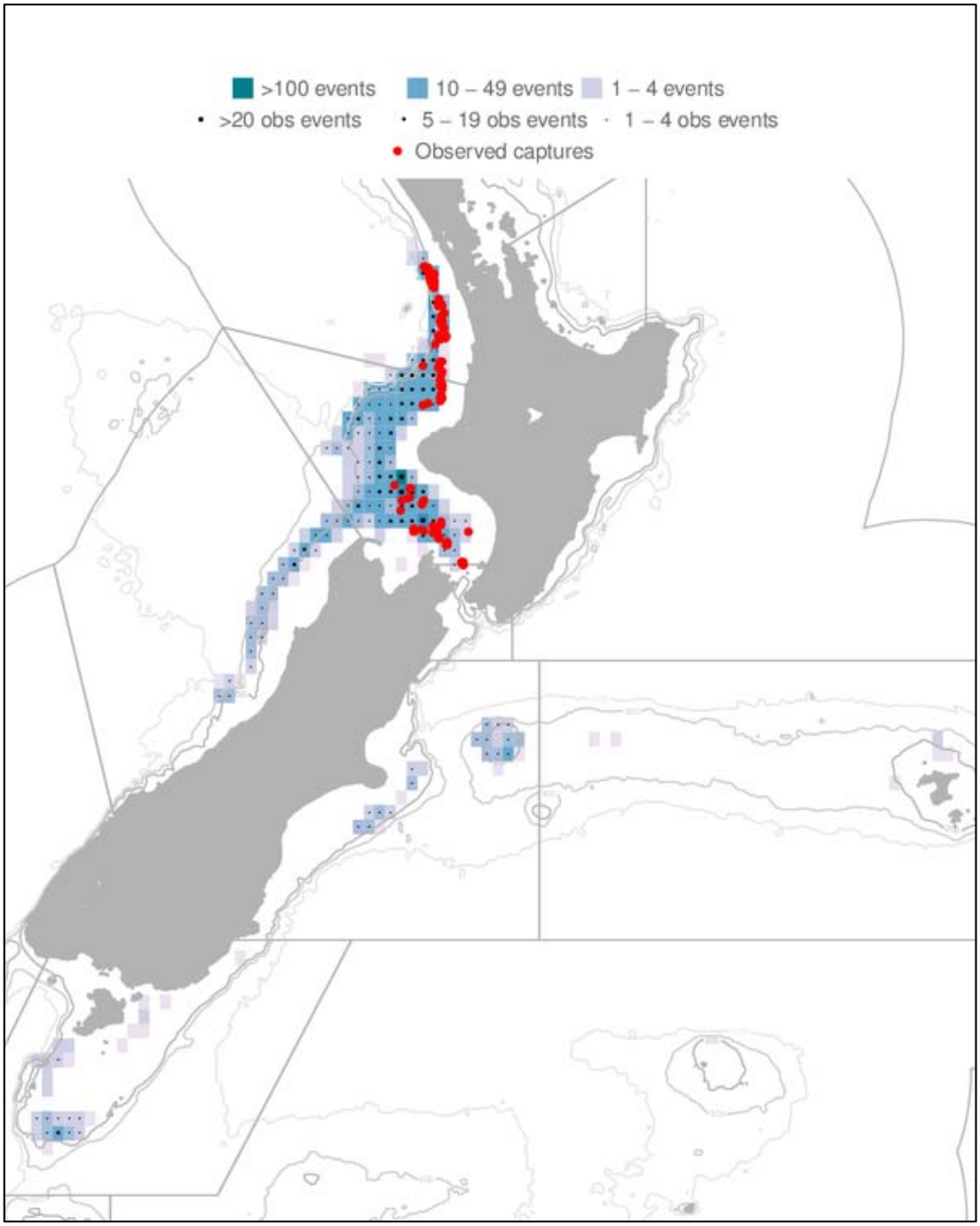


Figure 7.6: Distribution of trawl fishing effort for jack mackerel and observed common dolphin (*Delphinus delphis delphis*) captures, 2002-03 to 2012-13 (for more information see MPI data analysis at https://data.dragonfly.co.nz/psc/ data version v20140201). Fishing effort is mapped into 0.2-degree cells, coloured to represent the number of tows. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing effort is shown for all tows with latitude and longitude data, where three or more vessels fished within a cell

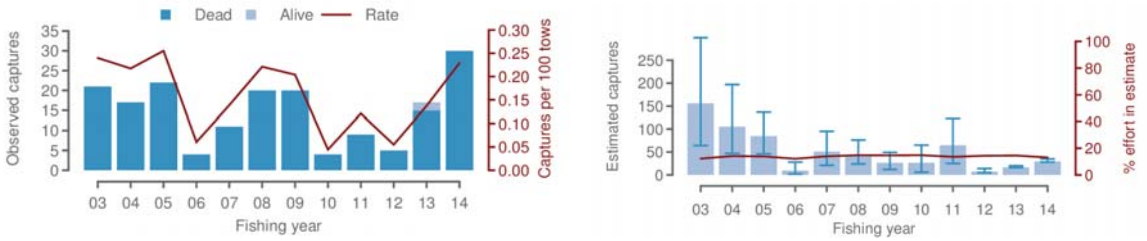
Table 7.2. Fishing and observed effort (number of tows), the number and rate of observed captures, and estimated mean from statistical models of common dolphin (*Delphinus delphis delphis*) captures by modelled trawl fisheries by fishing year in the New Zealand EEZ (see MPI data analysis at https://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the total number of fishing tows, the percentage of tows that were observed; the number of observed captures (both dead and alive); the capture rate (captures per hundred tows); and the mean number of estimated total captures (with 95% confidence interval). For more information on the methods used to prepare the data, see Thompson et al. 2010 and 2013.

Fishing year	Effort		Observed captures		Estimated captures	
	Fishing tows	% Observed	Number	Rate	Mean	95% c.i.
2002-2003	130 174	5.3	21	0.31	142	58-270
2003-2004	120 868	5.4	17	0.26	100	46-180
2004-2005	120 438	6.4	22	0.29	79	42-127
2005-2006	109 923	6.0	4	0.06	10	2-27
2006-2007	103 306	7.7	11	0.14	50	21-92
2007-2008	89 524	10.1	20	0.22	42	23-69
2008-2009	87 548	11.2	20	0.20	25	12-47
2009-2010	92 888	9.7	4	0.04	25	6-57
2010-2011	86 090	8.6	9	0.12	60	25-110
2011-2012	84 429	10.8	5	0.06	7	5-14
2012-2013	83 722	14.8	17	0.14	16	16-20
2013-2014	85 091	15.4	30	0.23	29	28-35

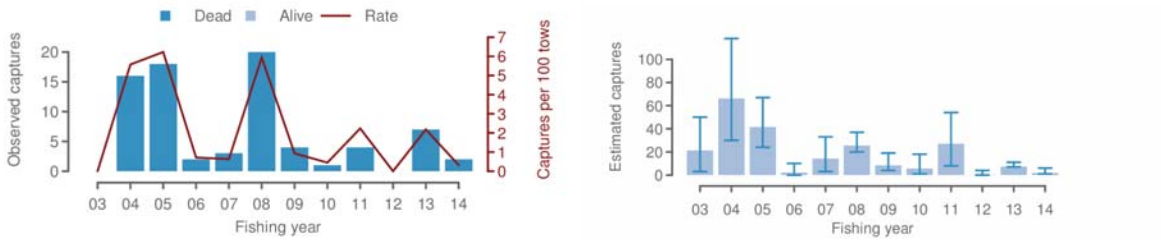
Table 7.3: Fishing and observed effort (number of tows) and the number, rate, and estimated mean for common dolphin (*Delphinus delphis delphis*) captures by jack mackerel fisheries by fishing year in the New Zealand EEZ (see MPI data analysis at https://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the total number of trawl tows, the number of tows observed and the percentage of tows that were observed; the number of observed captures (both dead and alive); the capture rate (captures per hundred tows); and the mean number of estimated total captures (with 95% confidence interval). For more information on the methods used to prepare the data, see Thompson et al. 2010 and 2013.

Fishing year	Effort		Observed captures		Estimated captures	
	Fishing tows	% Observed	Number	Rate	Mean	95% c.i.
2002-2003	3 076	11.3	21	6.07	142	58-270
2003-2004	2 383	6.4	17	11.18	99	46-180
2004-2005	2 509	22.2	21	3.76	78	42-126
2005-2006	2 808	25.3	2	0.28	10	2-27
2006-2007	2 711	29.5	11	1.38	50	21-92
2007-2008	2 649	30.8	20	2.45	41	23-69
2008-2009	2 170	37.47	11	1.35	25	12-46
2009-2010	2 406	32.67	4	0.51	25	6-57
2010-2011	1 880	31.54	7	1.18	60	25-110
2011-2012	2 032	76.28	5	0.32	7	5-14
2012-2013	2 208	87.64	15	0.78	15	15-19
2013-2014	2 447	89.4	28	1.28	29	28-34

a) EEZ



b) West Coast North Island



c) Taranaki

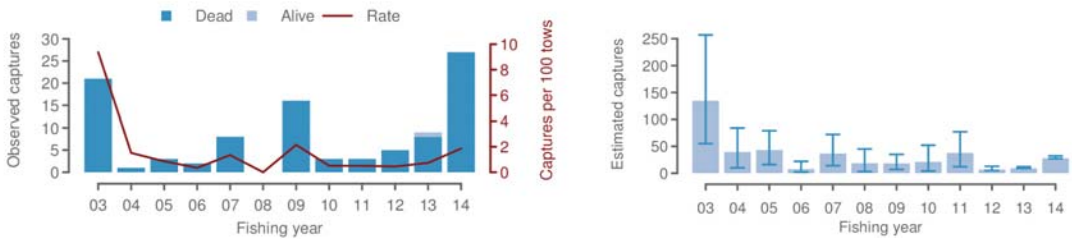
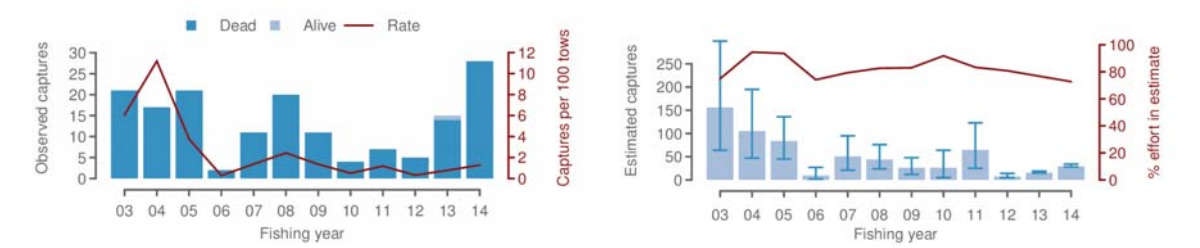
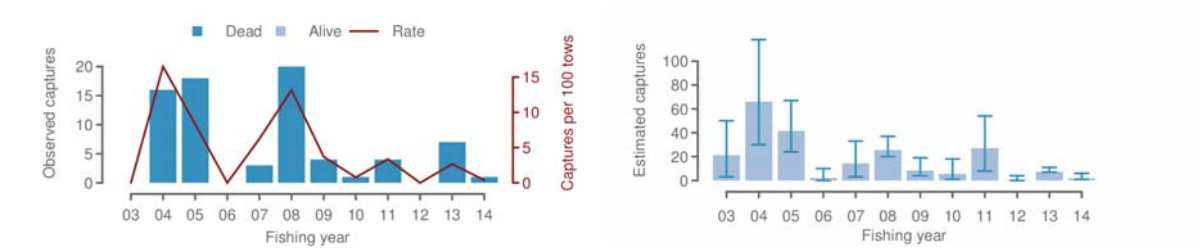


Figure 7.7: Observed captures of common dolphins(*Delphinus delphis delphis*) (dead and alive) in modelled trawl fisheries, the capture rate (captures per hundred tows) and the mean number of estimated total captures (with 95% confidence interval) by fishing years from 2002/2003 to 2013/2014, inclusive of three regions: (a) New Zealand's EEZ; (b) West coast of North Island; and (c) the Taranaki region (MPI data analysis at https://data.dragonfly.co.nz/psc/ data version v20140131). Percentage effort included in the estimation is shown when it was less than 100%. For more information on the methods used to prepare the data, see Thompson el al. 2010 and 2013.

a) EEZ



b) West Coast North Island



c) Taranaki

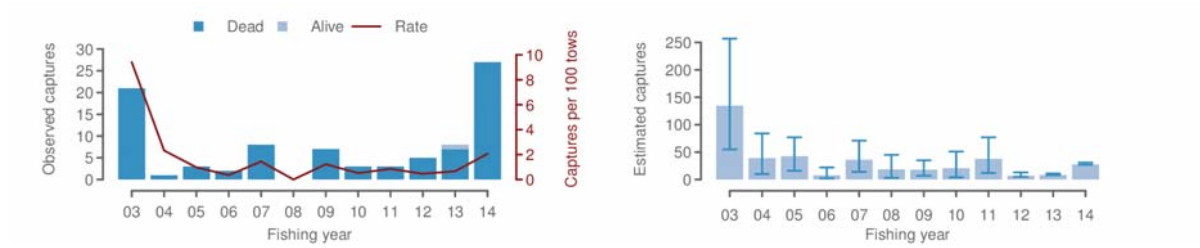


Figure 7.8: Observed captures of common dolphins (*Delphinus delphis delphis*) (dead and alive) in the jack mackerel trawl fisheries, the capture rate (captures per hundred tows) and the mean number of estimated total captures (with 95% confidence interval) by fishing years from 2002/2003 to 2013/2014 for three regions: (a) New Zealand's EEZ; (b) West coast of North Island; and (c) the Taranaki region (MPI data analysis at https://data.dragonfly.co.nz/psc/ data version v20140131). Percentage effort included in the estimation is shown when it was less than 100%. For more information on the methods used to prepare the data, see Thompson el al. 2010 and 2013.

7.4.2 MANAGING FISHERIES INTERACTIONS

Because little is known about the population of common dolphins in NZ, the impact of fisheries on the population cannot be assessed. Given the large numbers of common dolphins worldwide, it is unlikely that the interaction between common dolphins and fisheries will have an adverse effect in the global setting. However, there is still debate regarding the taxonomy of common dolphins found in NZ waters and whether a unique sub-population inhabits NZ's EEZ. Without species confirmation and population estimates for common dolphins around NZ, the impact of fisheries cannot reliably be determined.

Management by MPI has focused on monitoring marine mammal catches via the observer programme. In addition, MPI and the deepwater quota owners and trawl operators have developed a Marine Mammal Operating Procedure (MMOP) that specifies how skippers of trawlers greater than 28 m in length should manage the risk of and provide reports on marine mammal interactions. Observer reviews provide information that contributes to managing interaction of the deepwater fleet. Specific risk management actions are applicable across the JMA trawl fisheries with specific extra requirements north of latitude 40° 30' S where interactions are known to be most likely.

The requirements include not shooting gear when dolphins are present, assigning an officer on watch and deck to report sightings, closing gear during turns by keeping doors at or above surface, use of acoustic dissuasive devices attached to net on night-time tows for jack mackerel spp., and in the northern area not shooting or hauling between 03230 and 0430 hrs. Additionally all vessel officers are briefed annually on the risk factors regarding common dolphin captures especially area, depth and temporal factors. The full requirements can be seen at http://deepwatergroup.org/wp-content/uploads/2014/07/Marine-Mammals-Operational-Procedures-2014-15.pdf.

Vessels are required to report any captures to all vessels in the vicinity (by VHF radio) and must also notify the DeepWater Group (DWG) and record captures in the ship's log any time a common dolphin is caught within a 24 hour period (see Annual Review Report for Deepwater Fisheries, http://www.mpi.govt.nz/ document-vault/ 4090) for more information).

7.4.3 MODELLING POPULATION-LEVEL IMPACTS OF FISHERIES INTERACTIONS

Because common dolphins are abundant globally, fisheries interactions are not considered a threat to the population. However, small sub-populations of common dolphins such as the Mediterranean Sea population have been significantly impacted by fishing.

Although modelling exercises have been able to estimate the annual number of common dolphin captures by fisheries in NZ waters, the population size needs to be determined before the impact of fisheries on this species can be fully assessed. The interactions between commercial fisheries and marine mammals in NZ waters was assessed in the marine mammal risk assessment project PRO202-02 (Berkenbusch 2013). However, with no data on the population size of common dolphins in NZ, population level impacts by fisheries could not be qualified for this species. A modelling exercise (PRO2014-01) to predict habitat suitability of common dolphins and other cetaceans in NZ's EEZ is currently underway use existing sightings data.

Overall, a considerable proportion of observed common dolphin bycatch in NZ waters has been by trawl fisheries targeting jack mackerel (*Trachurus declivis, T. murphyi,* and *T. novaezelandiae*) on the west coast of the North Island. Sufficient observer coverage between 1995-96 and 2011-12 fishing years allowed the estimation of total common dolphin captures. Estimated captures per year varied from 0.15 (95% c.i. 0.00-1.74) and 6.27 (c.i. 2.49-12.27) per 100 tows over this 16 year period (Thompson 2013, Berkenbusch 2013).

7.4.4 SOURCES OF UNCERTAINTY

While there is an abundance of knowledge on common dolphins worldwide, relatively little is known about this species in NZ waters. The latest research suggests that common dolphins in NZ waters are a larger form of the short-beaked common dolphin found elsewhere, however further work is needed to verify this finding which is currently based on a small sample size (Jordan 2012). Perhaps the most fundamental data lacking for common dolphins around NZ is population size. Currently, the population size of common dolphins in NZ waters cannot be estimated due to the lack of empirical data on basic life history parameters. Only when this information is known can a Population Viability Analysis (PVA) be conducted to

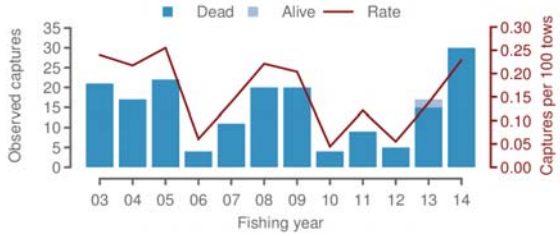
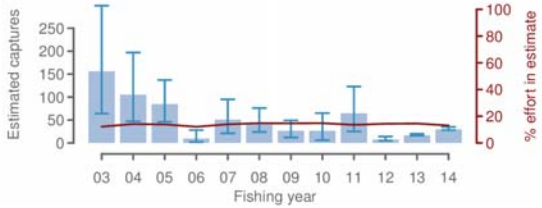
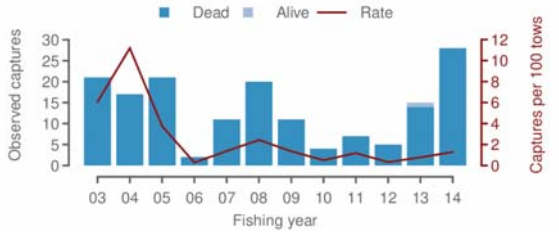
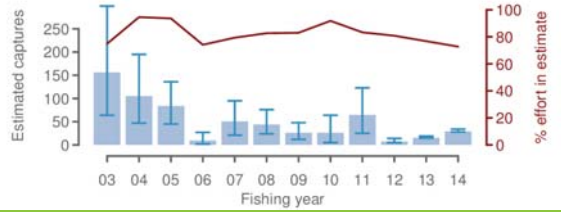
estimate the impacts of fishing interactions and other anthropogenic and natural events on the population.

Having a better understanding of common dolphin behaviour will also aid our understanding of how to mitigate fisheries interactions. For example, not much is known about the behaviour of female/calf 'nursery' and male 'bachelor' groups and whether one or the other might be more at risk from fishing activities. In addition, knowledge of dive behaviour is severely lacking for common dolphins, in general, and for the New Zealand population in particular. Knowing the dive depth, as well as dive and surface durations of common dolphins will enhance our understanding of interactions with specific fisheries.

Finally, there are few data available on the incidental capture of common dolphins from the large fleet of small vessels which operate in shallow inshore waters and have low or no observer coverage. Recreational fishers are not monitored and do not have COPs or use acoustic deterrents (Rowe 2007). As a result, the impact to common dolphins by these vessels is not known. In addition, a better understanding how the parts of the fishing operation (setting, towing, or hauling) contribute to common dolphin captures may be useful in further developing mitigation measures to reduce interaction and captures of common dolphins. This may include the fishing strategy used by fishers such as the path of the net through the water column and the use of U-turns with the net raised to near the surface.

While mitigation measures include the use of acoustic deterrents, or pingers, on nets, these measures only apply to a subset of the fishing fleet and the effectiveness of these devices is not known. Previous research in NZ showed that stationary pingers in Akaroa Harbour effectively displaced Hector's dolphins from the area (Stone 1997). However, there have been no at-sea trials undertaken to determine the effectiveness of pingers in deterring dolphins in off-shore waters due to the risk of animals dying in control nets (Rowe 2007). Without further research, the effectiveness of these devices cannot be adequately assessed.

7.5 INDICATORS AND TRENDS

Population size	Unknown in New Zealand EEZ, but approximately 4,000,000 worldwide2.
Population trend	Unknown
Threat status	NZ: Not Threatened, Data Poor, Secure Overseas, and Threatened Overseas (for some populations) in 20103. IUCN: Least Concern, in 20084.
Number of interactions5	29 estimated captures (95% CI 28–34) in modelled trawl fisheries in 2013–14 30 observed captures in trawl fisheries in 2013–14 29 estimated captures (95% CI 28–34) in the jack mackerel trawl fisheries in 2013–14 28 observed captures in the jack mackerel trawl fisheries in 2013–14
Trends in interactions	Trawl fisheries:   Jack mackerel trawl fishery:  

[2] Hammond et al. (2008).

[3] Baker et al (2010b).

[4] Hammond et al. (2008).

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

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THEME 2: NON-PROTECTED BYCATCH

8 FISH AND INVERTEBRATE BYCATCH

Scope of chapter

This chapter outlines the main non-protected species (fish and invertebrates) caught as bycatch in New Zealand's major offshore fisheries, with summaries of the amounts caught and discarded. Small amounts of some protected species (e.g. deep-sea corals) may also be included. Previous research in this field has been conducted fishery by fishery with no spatial breakdown of annual catch totals, but this year all historical analyses for deepwater fisheries were re-assessed with stratification aligned to standardised areas. This has provided estimates of bycatch and discarding across all offshore fisheries within separate regions of New Zealand fisheries. Research begun in 2013 to analyse individual species bycatch over time for each of the Tier 1 Deepwater fisheries has continued, with updated estimates for some fisheries and for the 2012–13 fishing year. This chapter present the latest available information, however the last date of detailed analysis differs between fisheries, e.g. the Hoki/Hake/Ling fishery was analysed in 2015, the Jack Mackerel fishery in 2007 (see Table X.1 for more details)..

The fisheries summarised are as follows:

Trawl fisheries:	Longline fisheries:	Other fisheries
Arrow squid	Ling (bottom)	Albacore tuna troll
Hoki/hake/ling	Tuna (surface)	Skipjack tuna purse seine
Jack mackerel		
Southern blue whiting		
Orange roughy		
Oreo		
Scampi		

Area

Total annual bycatch and discard levels are summarized for 10 of the 11 fishery areas shown in Figure 8.1. Bycatch from the small amount of fishing in the Kermadec area is not addressed, but a Marine Sanctuary for that area is due to come into effect from 1 October 2016 which will prohibit all forms of fishing within KERM10.

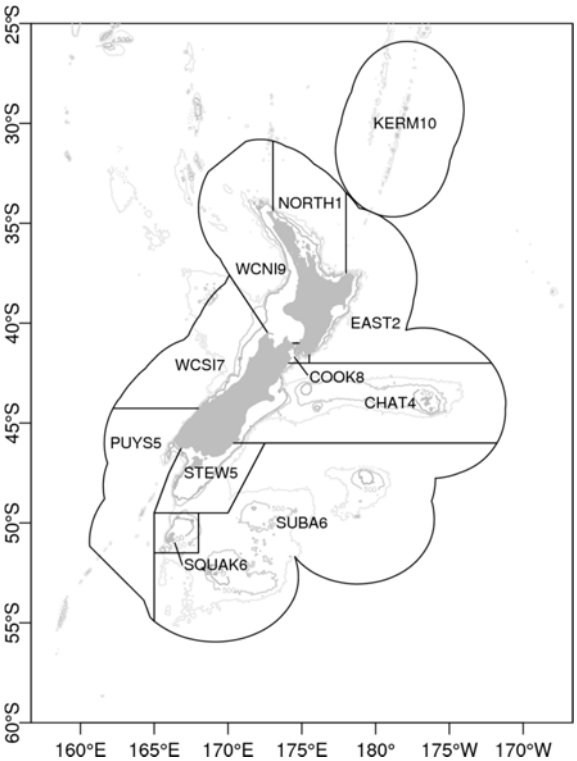

Figure 8.1: Standardised assessment areas for estimation of total non-protected fish and invertebrate bycatch in offshore fisheries.

Focal localities	**Trawl fisheries** *Arrow squid*: Auckland Islands and Stewart/Snares Shelf (80–300 m). *Hoki/hake/ling*: Chatham Rise, West Coast South Island, Campbell Plateau, Puysegur Bank, and Cook Strait (200–800 m). *Jack mackerel*: West coast of the North and South Islands, Chatham Rise, and Stewart-Snares Shelf (0–300 m). *Southern blue whiting*: Campbell Plateau and Bounty Plateau (250–600 m). *Orange roughy*: The entire New Zealand region (700–1200 m). *Oreos*: South Chatham Rise, Pukaki Rise, Bounty Plateau, and Southland (700–1200 m). *Scampi*: East coasts of the North and South Islands, Chatham Rise, and Auckland Islands (300–450 m). **Longline fisheries** *Ling (bottom)*: Chatham Rise, Bounty Plateau, and Campbell Plateau (150–600 m). *Tuna (surface)*: East coast of the North Island and west coast of the South Island. **Other fisheries** *Albacore tuna troll*: West coasts of the North and South Islands. *Skipjack tuna purse seine*: Northern North Island
Key issues	• Under-utilisation of high volume, low value bycatch species, especially rattails, spiny dogfish, deepsea sharks, blue sharks, porbeagle sharks, and swimming crabs. Since 1 October 2014, it has been illegal for a commercial fisher to remove the fins from any shark and discard the body of the shark at sea in New Zealand. • Potential for further reduction of discards by discretionary fishing practices such as the use of mid-water nets, and as has already been occurring with the increasing prevalence of fishmeal plants in recent years. • Unseen mortality in longline fisheries due to predation by large fish and sharks, marine mammals, seabirds, and sea lice. • Lack of bycatch and discards information for most inshore (0–200 m) fisheries because of low observer coverage, and simpler reporting requirements prior to 1 October 2007 which saw most catch and effort data aggregated per day and by statistical area (Catch Effort and Landing Return). Collection of more detailed fishing event catch and effort data for smaller trawl (6–28 m), longline, and setnet vessels began on 1 October 2007. Work is underway to implement electronic monitoring tools on inshore vessels for data collection which may help address this issue.
Emerging issues	• Trends of increased rates and levels of bycatch and discarding in several categories of catch, especially non-QMS fish species and invertebrates. • The effect on bycatch rates in the ling longline fishery of a change to heavier fishing gear (including integrated weights) as used in the Antarctic toothfish fishery. • Increased trawl distance/time in the squid, scampi, and orange roughy fisheries due to changes in fleet composition, fishing gear or reduction of target species catch rates—leading to greater bycatch levels in some categories.
MPI Research (current)	DAE201002 (bycatch and discards in deepwater fisheries) HMS201301 (bycatch in tuna longline fisheries) ENV201504 (estimation of incidental captures, fish bycatch and discards using electronic monitoring)
NZ Government Research (current)	None
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture.
Related chapters/issues	Chondrichthyans (sharks, rays, and chimaeras)

Note: This chapter has been fully updated for the AEBAR 2015

8.1 CONTEXT

Management of non-protected species bycatch aligns with Fisheries 2030 Objective 6: *Manage impacts of fishing and aquaculture*.

For this study *non-target fish species catch* is equivalent to *bycatch*, defined as "all fish caught that were not the stated target species for that tow whether or not they were discarded" (McCaughran 1992). *Discarded catch* (or *discards*) is defined as "all the fish, both target and non-target species, which are returned to the sea whole as a result of economic, legal, or personal considerations" (McCaughran 1992). *Discarded catch* in this report includes estimates of any fish lost from the net at the surface. Estimates of *non-target catch*, if required, can be obtained from this report by adding target species *discards* to total *bycatch*.

DEEPWATER TRAWL AND BOTTOM LONGLINE FISHERIES

The management of non-protected species bycatch in the deepwater and middle-depth fisheries is described in the National Fisheries Plan for Deepwater and Middle-depth Fisheries (the National Deepwater Plan). Under the National Deepwater Plan, the objective most relevant for management of non-protected species bycatch is Management Objective 2.4: *Identify and avoid or minimise adverse effects of deepwater and middle-depth fisheries on incidental bycatch species*. Specific objectives for the management of non-protected species bycatch are outlined in the fishery-specific chapters of the National Deepwater Plan. Estimation of non-protected species bycatch was carried out for each of the Tier-1 Deepwater fisheries on an annual rotational basis, with each of the following fisheries updated about every 4–5 years:

- arrow squid
- ling bottom longline
- hoki/hake/ling trawl
- jack mackerel trawl
- southern blue whiting trawl
- orange roughy/oreo trawl
- scampi trawl

SURFACE LONGLINE, TROLL, AND PURSE-SEINE FISHERIES

Non-protected fish species bycatch in the fisheries for Highly Migratory Species (HMS) is addressed in the HMS fish plan. Tuna fisheries incidental bycatch was examined, with updates every 2–3 years planned. Some data on bycatch in the Albacore tuna troll fishery and the skipjack tuna purse seine fishery were also available.

INSHORE FISHERIES

The three National Fisheries Plans for Inshore species (finfish, shellfish and freshwater fisheries) also included objectives which address non-protected species bycatch, but research on these objectives has yet to be conducted. However, summaries of the main bycatch species have occasionally been included in reports from fisheries characterisation projects, for example school shark, red gurnard, and elephantfish (Starr et al 2010a, b, c, Starr & Kendrick 2012, Starr & Kendrick 2013).

8.2 GLOBAL UNDERSTANDING

Bycatch of unwanted zero or low value species and discarding of these and of target species that are damaged or too small to process are significant issues in many fisheries worldwide. Few, if any, fisheries are completely without bycatch and this issue has been the subject of many studies and international meetings. Saila (1983) made the first comprehensive global assessment and estimated, albeit with very poor information, that at least 6.7 million tonnes was discarded each year. Alverson et al (1994) extended that work and estimated the global bycatch at 27.0 (range 17.9–39.5) million tonnes each year. An update by Kelleher (2005) suggested global bycatch of about 8% of the global catch, or 7.3 million tonnes, in 1999–2001.

Tropical shrimp trawl fisheries typically have the highest levels of unwanted bycatch, with an average discard rate of 62% (Kelleher 2005), accounting for about one-quarter to one-third of global bycatch. Discard rates in demersal trawl fisheries targeting finfish are much lower but, because they are so widespread, make a considerable contribution to total global discards. Tuna longline fisheries have the next largest contribution and tend to have greater unwanted bycatch than other line fisheries (Kelleher 2005).

The estimated global level of discards reduced considerably since the Alverson et al (1994) estimate, but differences in the methodology and definition of bycatch used (see Kelleher 2005, Davies et al 2009) make it difficult to quantify the decline. The main reasons for the decline in bycatch may be due to a combination of higher retention

rates, better fisheries management, and improved fishing methods.

Bycatch and discard estimation is frequently very coarse, and estimates of rates based on occasional surveys are often scaled up to represent entire fisheries and applied across years, or even to other fisheries (e.g., Bellido et al 2011). Data from dedicated fisheries observers are also frequently used for individual fisheries, and these are considered to provide the most accurate results, providing that discarding is not illegal (leading to bias due to "observer effects", Fernandes et al 2011). Ratio estimators similar to those applied in New Zealand fisheries are frequently used to raise observed bycatch and discard rates to the wider fishery, and the methods used in New Zealand fisheries are broadly similar to those used elsewhere (e.g., Fernandes et al 2011, Borges et al 2005). A new methodology has recently been developed for New Zealand fisheries which may replace the ratio method. This method uses multiple predictor variables in a model-based estimation process fitted using Bayesian methods and has shown in simulation studies to provide estimates with less bias and improved precision (Edwards et al. 2015).

Discard data are increasingly incorporated into fisheries stock assessments and management decision-making, especially with the move towards an Ecosystem Approach to Fisheries (EAF) (Bellido et al 2011), and as third party fishery certification schemes more closely examine the effects of fishing on the ecosystem. These data were also used to assess impacts on non-target species (e.g., Pope et al 2000, Casini et al 2003).

8.3 STATE OF KNOWLEDGE IN NEW ZEALAND

8.3.1 OVERVIEW

Estimation of annual bycatch and discard levels of non-protected species in selected New Zealand fisheries have been undertaken at regular intervals since 1998 (Table 8.1).

Table 8.1: Summary of research into bycatch and discards in New Zealand fisheries.

Trawl fisheries	Report
Arrow squid trawl (SQU)	Anderson et al (2000) Anderson (2004b) Ballara & Anderson (2009) Anderson (2013a) Anderson (2013b) Anderson (2014b) Ballara (2015) Edwards et al. (2015)
Hoki trawl (HOK)	Clark et al (2000) Anderson et al (2001) Anderson & Smith (2005) Ballara et al (2010) Anderson (2013b) Anderson (2014b) Ballara (2015) Ballara & O'Driscoll (in prep)
Hake trawl (HAK)	Ballara et al (2010) Anderson (2013b) Anderson (2014b) Ballara (2015) Ballara & O'Driscoll (in prep)
Ling trawl (LIN)	Ballara et al (2010) Anderson (2013b) Anderson (2014b) Ballara (2015) Ballara & O'Driscoll (in prep)
Ling longline (LLL)	Anderson et al. (2000) Anderson (2008) Anderson (2013a) Anderson (2013b) Anderson (2014a) Anderson (2014b) Ballara (2015) Edwards et al. (2015)
Jack mackerel trawl (JMA)	Anderson et al (2000) Anderson (2004b) Anderson (2007) Anderson (2013b) Anderson (2014b) Ballara (2015) Roux (in prep)
Southern blue whiting trawl (SBW)	Clark et al (2000) Anderson (2004a) Anderson (2009b) Anderson (2013b) Anderson (2014b) Ballara (2015)
Orange roughy trawl (ORH)	Clark et al (2000) Anderson et al (2001) Anderson & Clark (2003) Anderson (2009a) Anderson (2011) Anderson (2013b) Anderson (2014b) Ballara (2015)
Oreo trawl (OEO)	Clark et al (2000) Anderson (2004a) Anderson (2011) Anderson (2013b) Anderson (2014b) Ballara (2015)
Scampi trawl (SCI)	Clark et al (2000) Anderson (2004a) Ballara & Anderson (2009) Anderson (2012) Anderson (2013b) Anderson (2014b) Edwards et al. (2015)

Table 8.1 [Continued]: Summary of research into bycatch and discards in New Zealand fisheries.

Other fisheries	Report
Albacore tuna troll	Griggs et al (2014)
Skipjack tuna purse seine	Anon (2013)

TRAWL AND BOTTOM LONGLINE FISHERIES

The estimation process for the trawl and bottom longline fisheries used rates of bycatch and discards in various categories, i.e., in recent analyses "all QMS species combined (QMS)", "all non-QMS species combined (non-QMS)", and "all invertebrate species combined (INV)". It also used fishery strata in the observed fraction of the fishery, and effort statistics from the wider fishery, to calculate annual bycatch and discard levels. This ratio-based approach estimates precision by incorporating a multi-step bootstrap algorithm which takes into account the effect of correlation between trawls in the same observed trip and stratum. For this report, additional estimates of annual bycatch and discards were re-calculated from archived data where possible for each of the QMS, non-QMS, and INV species categories using standardized areas (Figure 8.1), but without estimates of precision. The original analyses were based on a stratification using different sets of areas and in some cases additional strata such as depth or gear-type. For this re-calculation, the estimated values for each area were scaled so as to have the same annual total as the published values. To enable totals to be calculated across all fisheries within each area, bycatch and discard estimates for years/fisheries where data has yet to become available were assumed to be equal to that of the last year for which an estimate has been published.

Estimates of the annual bycatch of a wide range of individual species were also made in the most recent analysis of the arrow squid trawl fishery and ling longline fishery (Anderson 2013a, Anderson 2014a), and also in a more simplified manner for all other Deepwater Tier 1 fisheries (Anderson 2014b).

In some cases the apparent increase or decrease in bycatch of a species is likely to be the result of external factors including the introduction of new species to the QMS, new species-specific 3-letter codes to replace generic codes, and improvements in species identification over time, e.g., the increase in recorded bycatch of floppy tubular sponge in the hoki/hake/ling trawl fishery reflects the improved identification of sponges in more recent years, and use of the species specific code for giant spider crab (GSC) instead of unspecified crabs (CRB) in the hoki/hake/ling trawl fishery. Some codes may also have been misused, e.g., in the arrow squid fishery, the increase in recorded bycatch of smooth red swimming crab (*Nectocarcinus bennetti*) appears to be at the expense of bycatch of the similar-looking paddle crab (*Ovalipes catharus*) with the seemingly generic species code (PAD).

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

SURFACE LONGLINE FISHERIES

The estimation process used for surface longline fisheries was similar to that used for trawl and bottom longline fisheries, with each species assessed separately. In this case CPUE was calculated as the number of fish observed caught per 1000 hooks set stratified by fishing year, fleet (Foreign Licenced, Foreign Chartered, and Domestic), and area. CPUE was expressed using a ratio of means estimator (see Bradford 2002, Ayers et al 2004). The total number of each species caught in each stratum was estimated by scaling up the CPUE to the total number of hooks set. These numbers were then summed across strata to give total annual catch estimates. An analytical estimator was used to calculate variance, using an adjustment to account for correlation between variance and the mean of the effort variable (after Thompson 1992). Additional estimates of annual bycatch within the standardized areas used for the deepwater trawl and bottom longline fisheries are currently not available.

TROLL AND PURSE SEINE FISHERIES

Fish bycatch research in these fisheries is limited to annual summaries of observer recorded species catches, without any attempts to raise observed catch rates to the total commercial fishery.

INSHORE FISHERIES

Some bycatch information is available from some fishery characterisation studies (see Section 8.1) but there were no detailed analyses of bycatch and discards from inshore fishing principally because of the lack of observer data. Most of the analyses of bycatch and discards for offshore fisheries were reliant on observer data, e.g., Anderson 2012, 2013a, and similar analyses for inshore fisheries are not currently possible. Past observer coverage of inshore fisheries was low (e.g., fewer than 2% of tows observed in 2009–10, Ramm 2012) and coverage was mainly focused on monitoring of Hector's and Maui's dolphin interactions and abundance for the Threat Management Plan. There are also practical and logistical problems with placing observers on smaller inshore vessels, and other options are being explored for the monitoring of these fisheries. This includes electronic monitoring using various configurations of video cameras, gear sensors, and position recording. Some progress has been made, but there remain some issues to surmount before electronic monitoring can provide all the information required to estimate fish and invertebrate bycatch. However for the SNA 1 fishery MPI has committed to 100% observer or camera coverage for all trawl vessels from October 1, 2015[1], and research into estimation of all fish bycatch and discards using electronic monitoring is planned for 2015–16 (ENV2015-04).

Detailed fishing event data for inshore fishing, e.g., tow-by-tow catch and effort, were not collected before 1 October 2007 unless the vessel was using the Trawl Catch Effort and Processing Return (TCEPR) used by deepwater vessels (over 28 m). Before 1 October 2007, smaller trawl (6–28 m), longline, and setnet vessels used the Catch Effort and Landing Return (CELR) to collect daily summary catch-effort and landings data by statistical area. From 1 October 2007 onwards, detailed data for each fishing event were collected using the new Trawl Catch and Effort Return (TCER), and this may support a more detailed analyses of bycatch in inshore fisheries.

8.3.2 CHATHAM RISE (CHAT)

The Chatham Rise is an important region for all the major deepwater fisheries except for southern blue whiting. Total bycatch from deepwater fisheries has ranged from about 16 000 t to about 37 000 t, with generally decreasing amounts since 2000–01 (Figure 8.2). In each year since 1995–96 the hoki/hake/ling trawl fishery has been the main contributor to total bycatch in this area. Prior to that most of the bycatch from deepwater fisheries was attributed to the orange roughy fishery. The arrow squid and scampi fisheries also contributed substantially in some years.

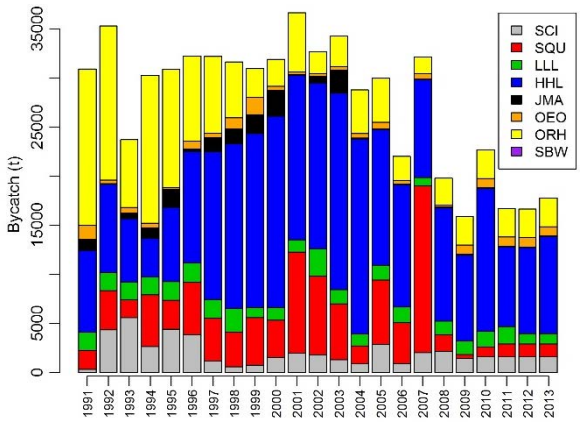

Figure 8.2: Estimated total annual bycatch (source fisheries shown by bar colouration) in Chatham Rise deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards on the Chatham Rise from deepwater fisheries has ranged from about 4 000 t to about 15 000 t, with generally lower amounts since 2003–04 (Figure 8.3). In most years the largest contributor to discards in this area was the hoki/hake/ling trawl fishery. Discards were relatively low in the orange roughy fishery compared to bycatch as a large part of the bycatch in that fishery, especially in earlier years, is likely to have been commercial species – oreos in particular.

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

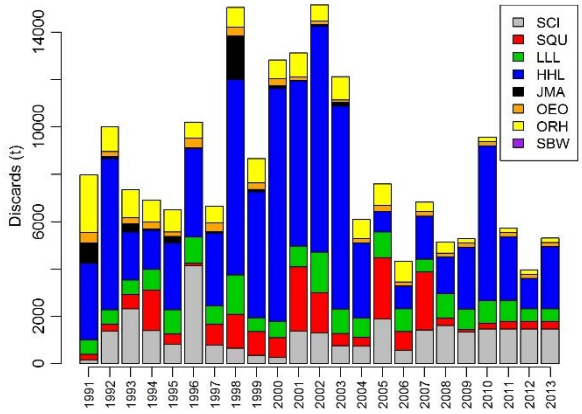

Figure 8.3: Estimated total annual discards (source fisheries shown by bar colouration) in Chatham Rise deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.3 SUBANTARCTIC (SUBA)

The sub-Antarctic is - an important region for all the major deepwater fisheries except for jack mackerel. Total bycatch from deepwater fisheries in the area has ranged from about 700 t to about 4300 t, with variable levels but generally lower since 2004–05 (Figure 8.4). In the past the main contributors have been the ling longline, southern blue whiting, orange roughy, and hoki/hake/ling fisheries. Most recently the oreo fishery has been the greatest contributor.

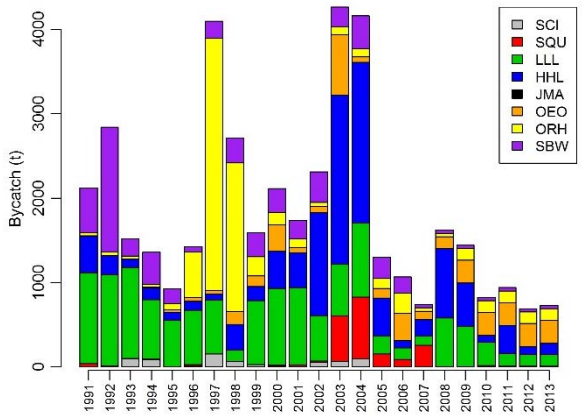

Figure 8.4: Estimated total annual bycatch (source fisheries shown by bar colouration) in sub-Antarctic deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the sub-Antarctic from deepwater fisheries has ranged from about 300 t to about 1600 t, with generally decreasing levels over time, especially after 2003–04 (Figure 8.5). Discards in the southern blue whiting fishery are high relative to bycatch due to the contribution of the target species to discard totals.

Currently total discards are evenly split between the southern blue whiting, oreo and ling longline fisheries.

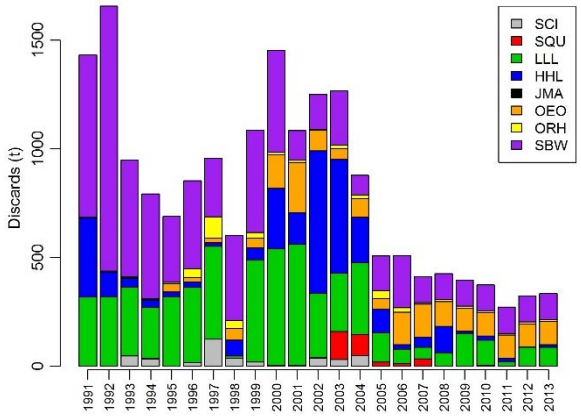

Figure 8.5: Estimated total annual discards (source fisheries shown by bar colouration) in sub-Antarctic deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.4 STEWART-SNARES SHELF (STEW)

The Stewart-Snares shelf is an important region for the jack mackerel, hoki/hake/ling and arrow squid trawl fisheries, with smaller fisheries also operating for oreo and orange roughy and ling (longline). Total bycatch in the Stewart-Snares shelf area from deepwater fisheries has ranged from about 3000 t to about 24 000 t per year, with the lowest values in the mid-1990s, and relatively steady levels since about 2002–03 (Figure 8.6). The majority of this bycatch, in all years except for 1994–95, has been in the arrow squid fishery, with most of the remainder coming from the hoki/hake/ling fishery. In a few years centred around 1999–2000 there was also a notable contribution from the jack mackerel fishery.

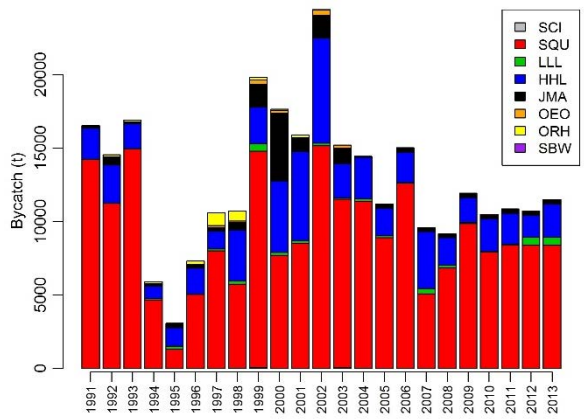

Figure 8.6: Estimated total annual bycatch (source fisheries shown by bar colouration) in Stewart-Snares shelf deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the Stewart-Snares shelf area from deepwater fisheries has ranged from about 500 t to about 6000 t, with lower values in the mid-1990s and late 2010s (Figure 8.7). Currently discarding in this area is mostly attributed to the arrow squid and hoki/hake/ling fisheries.

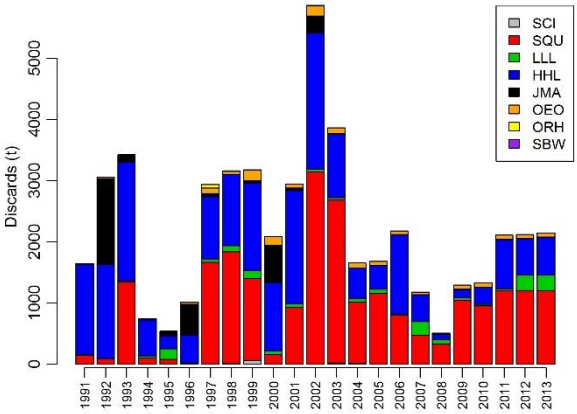

Figure 8.7: Estimated total annual discards (source fisheries shown by bar colouration) in Stewart-Snares shelf deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.5 AUCKLAND ISLANDS (AK)

The main fisheries currently operating in the Auckland Islands region are the scampi and arrow squid trawl fisheries, with smaller fisheries for hoki/hake/ling also present. An orange roughy fishery operated in the region from the mid-1990s to the early 2000s, but has been only minor in recent years. Total bycatch in the Auckland Islands area from deepwater fisheries has ranged from about 750 t to about 7500 t per year, with relatively steady levels of 2000–3000 t per year since about 1997–98 (Figure 8.8). The main contributors to bycatch in this area have been the scampi and arrow squid fisheries, as well as the orange roughy fishery during the 1990s. Currently the main contributing fishery is the arrow squid fishery.

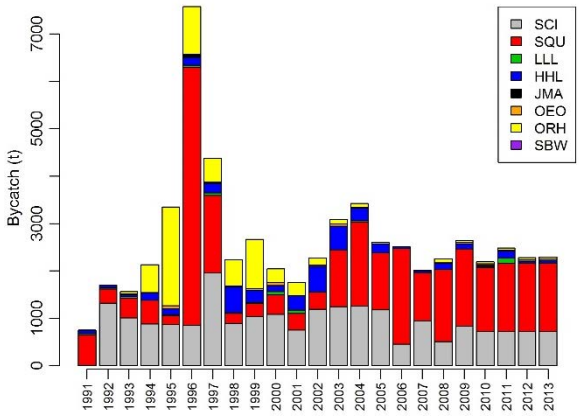

Figure 8.8: Estimated total annual bycatch (source fisheries shown by bar colouration) in Auckland Islands deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the Auckland Islands area from deepwater fisheries has ranged from about 100 t to about 1600 t per year, resulting mostly from the scampi and arrow squid fisheries (Figure 8.9). Current levels are typical of the last 20 years and can be attributed evenly to these two fisheries.

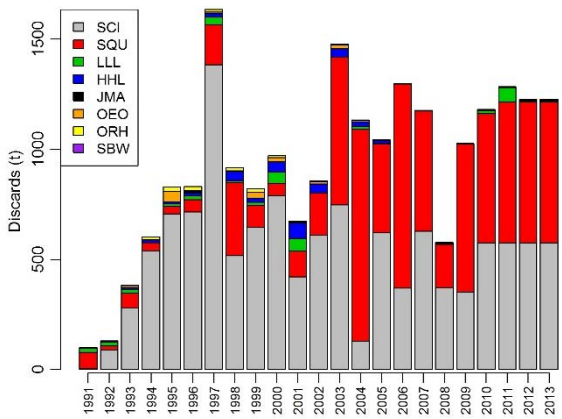

Figure 8.9: Estimated total annual discards (source fisheries shown by bar colouration) in Auckland Islands deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.6 PUYSEGUR (PUYS)

Most deepwater fisheries have operated at some time in the Puysegur area, with bycatch mainly attributed to the orange roughy fishery in the early 1990s, and to the arrow squid fishery in the early 2000s. Total bycatch in the area from deepwater fisheries has ranged from about 250 t to about 4500 t per year, with generally decreasing amounts since about 2000–01 (Figure 8.10). Annual bycatch is

currently relatively low, and attributed mostly to the hoki/hake/ling fishery, with smaller contributions from the arrow squidand orange roughy fisheries.

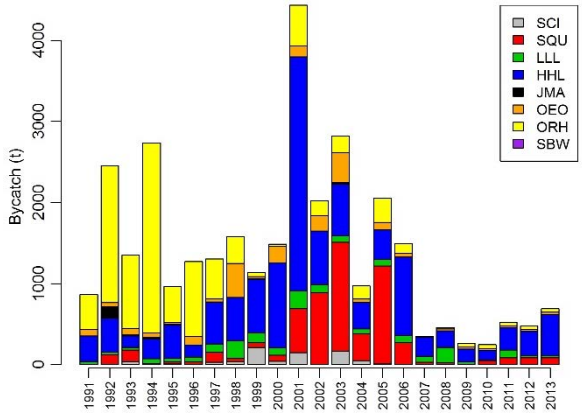

Figure 8.10: Estimated total annual bycatch (source fisheries shown by bar colouration) in Puysegur deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the Puysegur area from deepwater fisheries has ranged from about 100 t to about 1400 t per year, with lower amounts after 2004–05 (Figure 8.11). Discards were mostly attributable to the hoki/hake/ling fishery in the 1990s and in the most recent few years, and to the arrow squid fishery in the early 2000s.

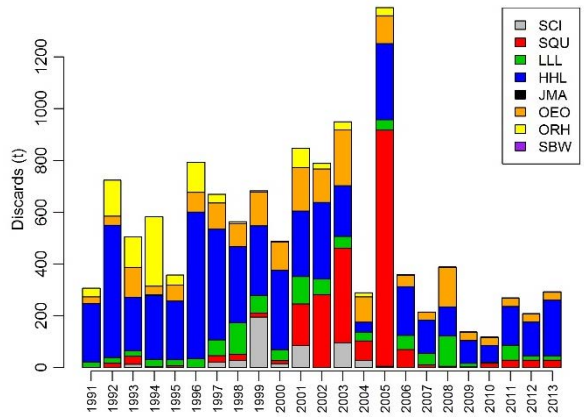

Figure 8.11: Estimated total annual discards (source fisheries shown by bar colouration) in Puysegur deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.7 WEST COAST SOUTH ISLAND (WCSI)

The main fisheries in this area are the trawl fisheries for hoki/hake/ling and jack mackerel, as well as a small ling longline fishery and, before 2000, an orange roughy fishery. Currently almost all bycatch can be attributed to the hoki/hake/ling and jack mackerel fisheries. Total bycatch in the West Coast South Island area from deepwater fisheries has ranged from about 3000 t to about 18 000 t per year, with generally decreasing amounts since about 1994–95 (Figure 8.12).

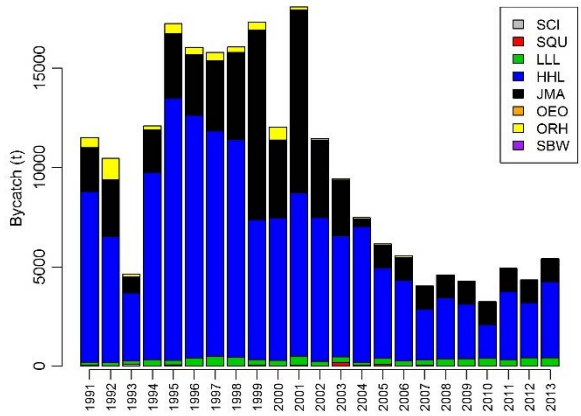

Figure 8.12: Estimated total annual bycatch (source fisheries shown by bar colouration) in West Coast South Island deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the West Coast South Island area from deepwater fisheries has ranged from about 700 t to about 9000 t per year, with generally decreasing amounts since about 1994–95 and a relatively low contribution from the jack mackerel fishery compared to bycatch (Figure 8.13). Total discards have been below 2000 t per year since 2003–04, attributed mostly to the hoki/hake/ling fishery, with a small contribution from the ling longline fishery.

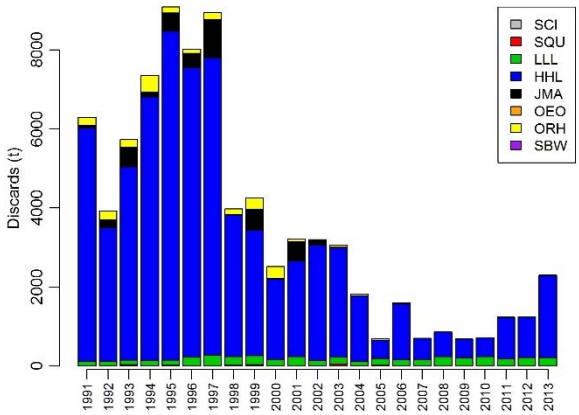

Figure 8.13: Estimated total annual discards (source fisheries shown by bar colouration) in West Coast South Island deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.8 WEST COAST NORTH ISLAND (WCSI)

The dominant deepwater fishery on the West Coast North Island region is currently the jack mackerel trawl fishery, with fisheries for orange roughy and arrow squid operating mainly before 2003–04. Total bycatch in the West Coast North Island area from deepwater fisheries has ranged from about 1100 t to about 9000 t per year, with generally stable amounts since about 2001–02 (Figure 8.14). In most years almost all of the bycatch can be attributed to the jack mackerel fishery, but with substantial contributions from the orange roughy and arrow squid fisheries in some years. Current bycatch levels are steady at about 6800 t per year, dominated by the jack mackerel fishery.

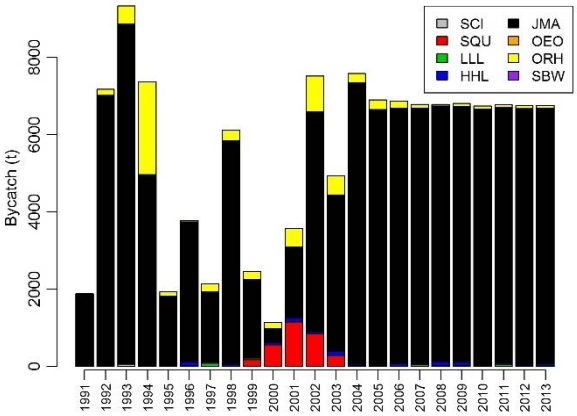

Figure 8.14: Estimated total annual bycatch (source fisheries shown by bar colouration) in West Coast North Island deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the West Coast North Island area from deepwater fisheries has ranged from about 20 t to about 1500 t per year, with generally stable levels of 100–200 t per year since 2003–04 (Figure 8.15). The jack mackerel fishery contributes relatively less to total discards than it does to bycatch but still dominates in most years.

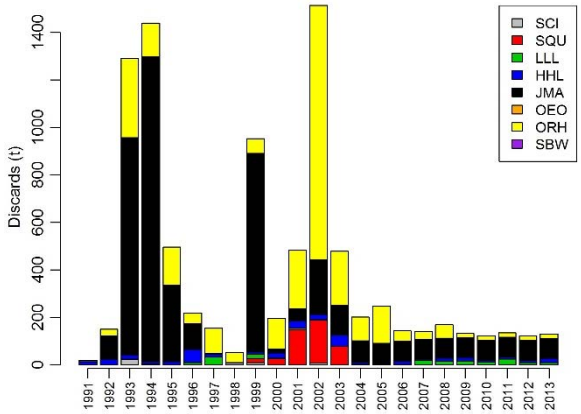

Figure 8.15: Estimated total annual discards (source fisheries shown by bar colouration) in West Coast North Island deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.9 NORTHLAND (NRTH)

Deepwater fisheries in the Northland region are mainly limited to a trawl fishery for scampi, and smaller fisheries for orange roughy and hoki/hake/ling. Total bycatch in the area from deepwater fisheries has ranged from about 600 t to about 5000 t per year, but with generally stable levels of less than 1400 t per year since about 1998–99 (Figure 8.16). In most years bycatch was mainly associated with the scampi fishery, with smaller amounts from the hoki/hake/ling fishery and a large contribution from the orange roughy fishery in 1996–97. Other deepwater fisheries are minor in this area and currently total annual bycatch is less than 1000 t, split between the scampi and hoki/hake/ling fisheries.

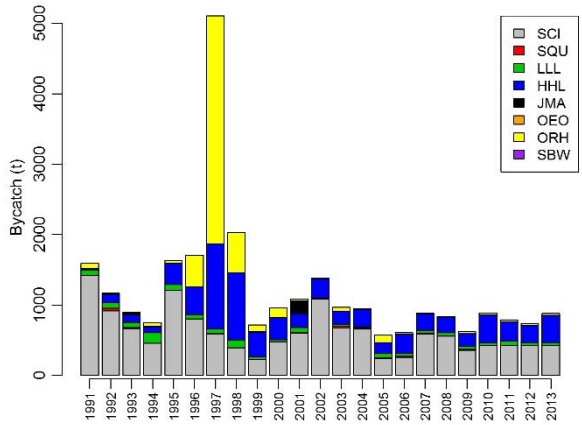

Figure 8.16: Estimated total annual bycatch (source fisheries shown by bar colouration) in Northland deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the Northland area from deepwater fisheries have ranged from about 200 t to about 1000 t per year, with levels of about 400 t per year over the last

several years (Figure 8.17). Discards in this area are dominated by the scampi fishery in all but the 1998–99 fishing year, with lesser contributions from the hoki/hake/ling and orange roughy fisheries.

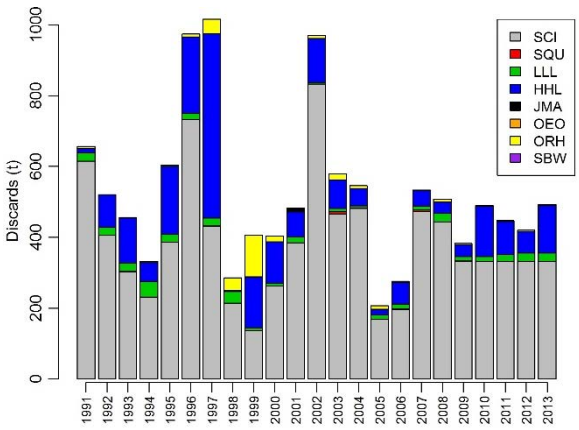

Figure 8.17: Estimated total annual discards (source fisheries shown by bar colouration) in Northland deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.10 EAST COAST NORTH ISLAND (EAST)

The main deepwater fisheries operating in the East Coast North Island are the scampi, hoki/hake/ling, and orange roughy fisheries, and the ling longline fishery. Total bycatch in the area from deepwater fisheries has ranged from about 1000 t to about 7500 t per year, with generally decreasing levels since about 1997–98 (Figure 8.18). Most of the bycatch comes from the hoki/hake/ling and scampi fisheries, with larger contributions from the orange roughy fishery before 2004–05, and an increasing proportion from the ling longline fishery over time.

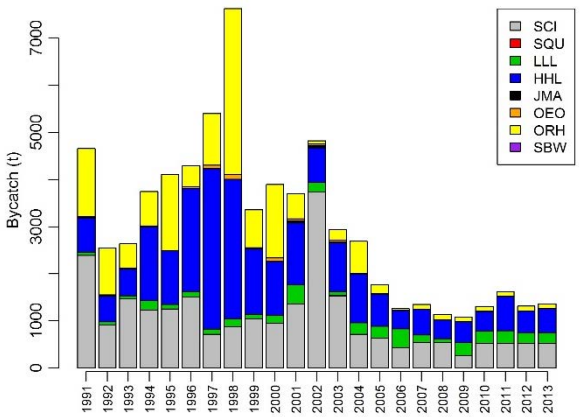

Figure 8.18: Estimated total annual bycatch (source fisheries shown by bar colouration) in East Coast North Island deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the East Coast North Island area from deepwater fisheries has ranged from about 400 t to about 2800 t per year, with generally lower levels after 2001–02 (Figure 8.19). The scampi and orange roughy fisheries contributed more to discards than to bycatch in this area, and in most years only a small proportion of total discards was attributable to the hoki/hake/ling fishery. Current annual discards are about 600 t, mostly associated with the scampi fishery.

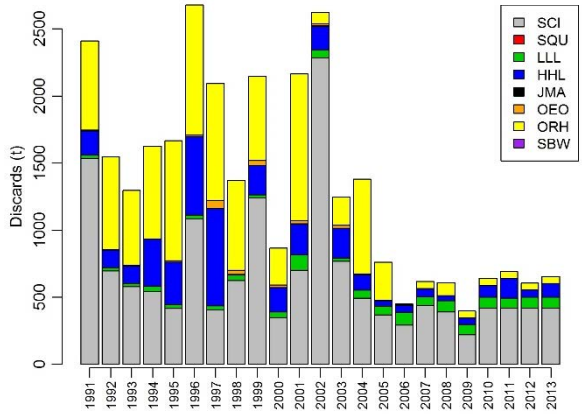

Figure 8.19: Estimated total annual discards (source fisheries shown by bar colouration) in East Coast North Island deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.11 COOK STRAIT (COOK)

The main fishery in the Cook Strait area has been the hoki/hake/ling fishery with this fishery contributing the great majority of bycatch in most years. Total bycatch in the Cook Strait area from deepwater fisheries has ranged from about 400 t to about 5000 t per year, with generally decreasing levels since about 1996–97 (Figure 8.20). The orange roughy fishery operating on the fringes of this area also contributed substantially to total annual bycatch through the early 1990s. Currently total annual bycatch is less than 1000 t, almost all from the hoki/ hake/ling fishery.

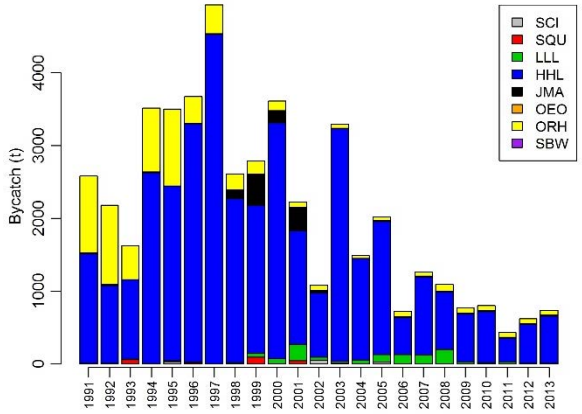

Figure 8.20: Estimated total annual bycatch (source fisheries shown by bar colouration) in Cook Strait deepwater fisheries. For fisheries abbreviations see Table X.1.

Total discards in the Cook Strait area from deepwater fisheries has ranged from about 200 t to about 4000 t per year, with generally decreasing levels since about 1995–96 (Figure 8.21). Discards in this area have virtually all been associated with the hoki/ hake/ling fishery. Current discard levels are 200–800 t per year.

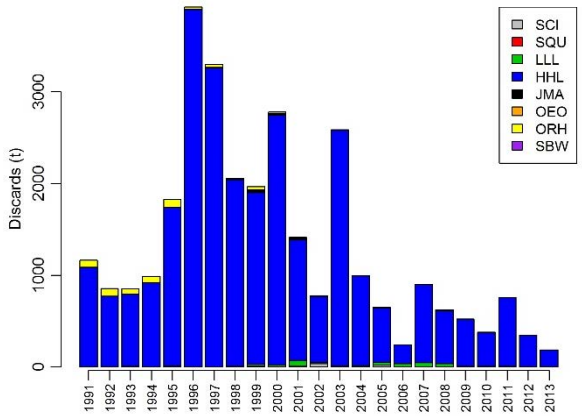

Figure 8.21: Estimated total annual discards (source fisheries shown by bar colouration) in Cook Strait deepwater fisheries. For fisheries abbreviations see Table X.1.

8.3.12 ARROW SQUID TRAWL FISHERY

Since 1990–91 the level of observer coverage in this fishery was 6–53% of the total annual catch, and was relatively high, 28–40% from 2006–07 to 2010–11 due to the management measures imposed for the protection of New Zealand sealions (*Phocarctos hookeri*)[2]. This coverage was spread across the fleet and annually 10–68% of all vessels targeting arrow squid were observed, with this fraction increasing over time. Observers covered the full size range of vessels operating in the fishery, although the smallest vessels were slightly undersampled and the largest oversampled.

The observer effort was mostly focussed on the main arrow squid fisheries around the Auckland Islands and Stewart-Snares Shelf, but the smaller fisheries on the Puysegur Bank and off Banks Peninsula were also covered, although less consistently. Observer coverage was more focussed on the central period of the arrow squid season, February to April, than the fleet was in general – with fishing in January and May slightly undersampled.

Appropriate stratification for the analyses was determined using linear mixed-effect models (LMEs) to identify key factors influencing variability in the observed rates of bycatch and discarding. This approach addressed the significant vessel-to-vessel and trip-to-trip differences in bycatch and discard rates in this fishery by treating the trip variable as a random effect (whereby the trip associated with each record was assumed to be randomly selected from a population of trips) and treated other variables as fixed effects. This process consistently identified the separate fishery areas (Auckland Islands, Stewart-Snares Shelf, Puysegur Bank, Banks Peninsula) as having the greatest influence on bycatch and discard rates (with trawl duration of secondary importance) and so fishery area was used in all cases to stratify the calculation of annual levels.

Since 1990–91, over 470 bycatch species or species groups were identified by observers in this fishery, most being non-commercial species (including invertebrate species) caught in low numbers. Arrow squid accounted for about 80% of the total estimated catch recorded by observers. The main bycatch species or species groups were the QMS species barracouta (8.5%), silver warehou (2.5%), spiny dogfish (1.7%), and jack mackerel (1.1%); and of these only spiny dogfish were generally discarded (Figure 8.22).

[2] Operational plan to manage the incidental capture of New Zealand sea lions in the Southern Squid Trawl Fishery (SQU6T); Ministry for Primary Industries, 1 October 2012. ISBN Online: 978-0-478-42003-6; ISSN Online: 2253-3923

Of the other (non-squid) invertebrate groups, crabs (0.8%), in particular smooth red swimming crab (*Nectocarcinus bennetti*) (0.5%), were caught in the greatest amounts and were mostly discarded. Smaller amounts of octopus and squid, sponges, cnidarians, and echinoderms were also often caught and discarded.

When combined into broader taxonomic groups, bony fish (excluding rattails, tuna, flatfish, and eels) contributed the most bycatch (16.5% of the total catch), followed by sharks and dogfishes (1.9%), crustaceans (0.8%), and rattails (0.2%). The combined bycatch of all other fish (tuna, rays and skates, chimaeras, flatfish, and eels) accounted for a further 0.5% of the total catch.

More than 75% of the sharks and dogfishes, rattails, and eels were discarded, whereas about half the flatfish were retained, as were most of the tuna, rays and skates, chimaeras, and other fish not in any of these groups. The fish species discarded in the greatest amounts were spiny dogfish, redbait, rattails, and silver dory. Of the invertebrates, virtually all the echinoderms, other squids, sponges, cnidarians, and polychaetes were discarded, but crustaceans, octopuses, and other molluscs were often retained.

Figure 8.23). The large majority of the bycatch comprised QMS species, with less than 1000 t of non-QMS species and invertebrate species bycatch in most years.

TRENDS IN ESTIMATED BYCATCH BY SPECIES FROM THE ARROW SQUID TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were barracouta (*Thyrsites atun*, BAR), silver warehou (*Seriolella punctata*, SWA), and combined jack mackerel species: greenback jack mackerel (*Trachurus declivis*, JMA); slender jack mackerel (*Trachurus murphyi*, JMM) and yellowtail jack mackerel (*Trachurus novaezelandiae*, JMN).

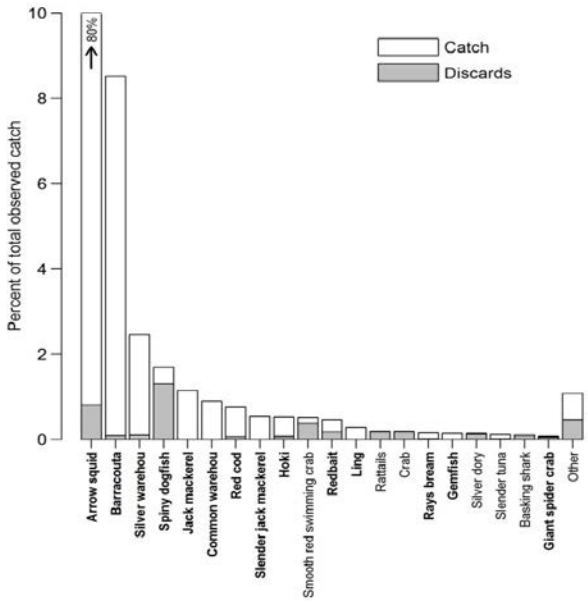

Figure 8.22: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the arrow squid fishery, and the percentage discarded, 1 October 1990 to 30 September 2011 (Anderson 2013a). The "Other" category is the sum of all bycatch species representing less than 0.05% of the total catch. QMS species are shown in bold.

Total annual bycatch in the arrow squid fishery was 4500–25 000 t, with low levels in the early 1990s and after 2007–08, and a peak in the early 2000s (

- Of the 185 bycatch species examined, 13 showed a decrease in catch over time and 18 an increase in catch.
- The species showing the greatest decline were paddle crabs (PAD), combined jack mackerel species (JMA, JMM, and JMN) and barracouta (BAR) (Figure 8.24).
- The species showing the greatest increase were silver dory (*Cyttus novaezealandiae*, SDO), giant spider crab (*Jacquinotia edwardsii*, GSC), and the smooth red swimming crab (NCB) (Figure 8.24).

Estimated total annual discards ranged from just over 200 t in 1995–96 to about 5500 in 2001–02 and, like bycatch, peaked in the early 1990s and were at relatively low levels after 2006–07 (Figure 8.25). The majority of discards were QMS species (about 62% for all years), followed by non-QMS species (19%), invertebrate species (11%), and arrow squid (7%).

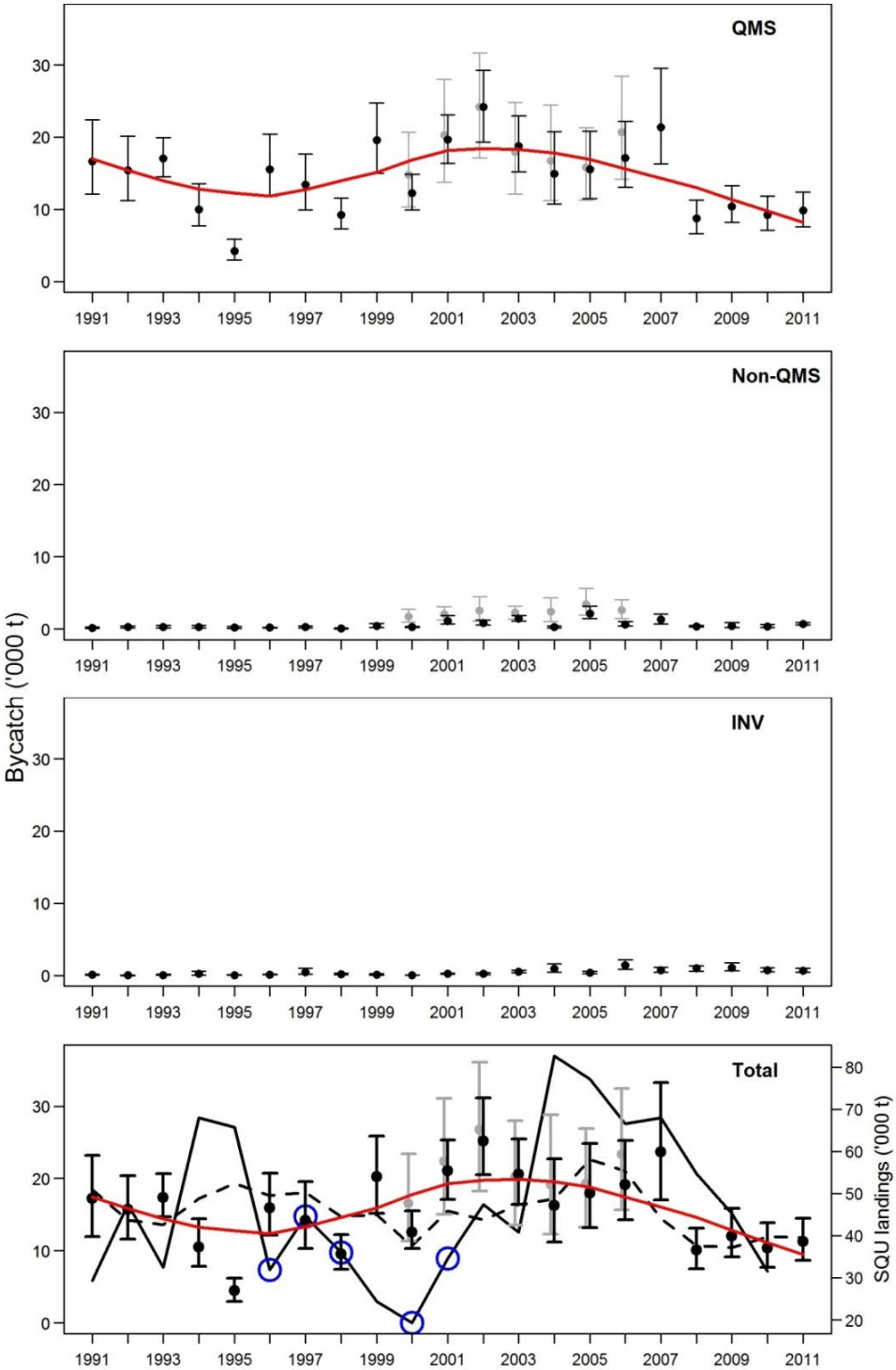

Figure 8.23: Annual estimates of bycatch in the arrow squid trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2010–11. Also shown (in grey) are estimates of bycatch in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual bycatch. In the bottom panel the solid black line shows the total annual reported trawl-caught landings of arrow squid (Ministry for Primary Industries 2013a), with circles indicating years in which the fishery closed early after reaching the sea lion FRML; and the dashed line shows annual effort (scaled to have mean equal to that of total bycatch).

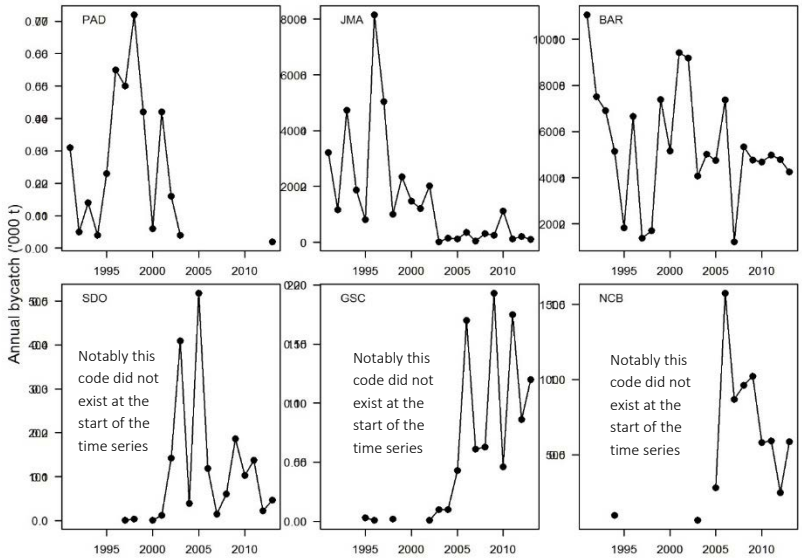

Figure 8.24: Annual bycatch estimates in the arrow squid trawl fishery for the species which had the greatest catch decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1, trawl and bottom longline fisheries subsection), and may be area-specific (see text above). See text above for species codes (from Ballara 2015).

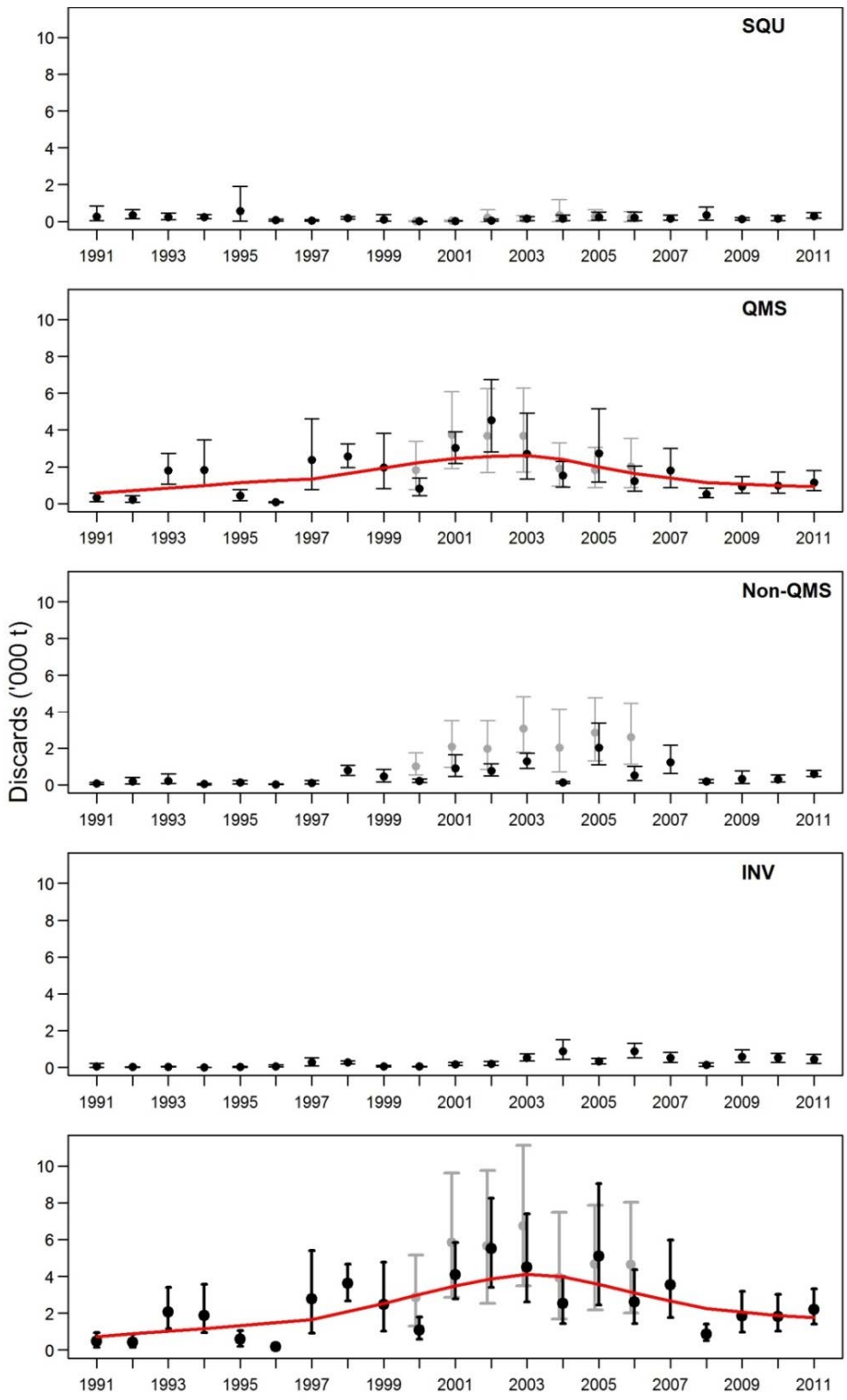

Figure 8.25: Annual estimates of discards in the arrow squid trawl fishery, for arrow squid (SQU), QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2010–11. Also shown (in grey) are estimates of discards in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual discards.

8.3.13 HOKI/HAKE/LING TRAWL FISHERY

Earlier reports were limited to the hoki target fishery and only the most recent published report has been expanded to cover bycatch and discards from hoki, hake and ling target fisheries combined—but hoki was dominant in this fishery, accounting for over 90% of the catch (Ballara et al 2010). An updated report, considering all years up to 2012–13, is due to be published in late 2015 and although not incorporated into the following summary, the raw data were used to produce a complete set of annual bycatch and discard estimates for the standardized areas used in this report.

Observer coverage in the hoki, hake, and ling trawl fishery between 2000–01 and 2006–07 was 11–21% of the annual target fishery catch, and 78 separate vessels were observed, covering the full range of vessel sizes. The annual number of observed tows decreased from 3580 in 2000–01 to 1999 in 2006–07. Coverage was spread over the geographical range of this fishery, with high sampling throughout the west coast South Island (WCSI) and Chatham Rise fishing grounds and, less frequently, in the Sub-Antarctic. Lower levels of sampling were achieved in the Cook Strait and Puysegur fisheries, and coverage was lower still around the North Island although this area accounted for very little of the overall catch. Adequate observer coverage was achieved during the hoki spawning season (July to early September), but coverage outside of this period was variable and under-representative in some months in some years, especially in the Sub-Antarctic, Chatham Rise and Puysegur fisheries.

Hoki, hake, and ling accounted for 87% (77%, 6%, and 4% respectively) of the total observed catch from trawls targeting hoki, hake, and ling between 2000–01 and 2006–07. The remaining 13% comprised a large range of species, in particular javelinfish (2.1%), silver warehou (1.7%), rattails (1.4%), and spiny dogfish (1.1%) (Figure 8.26). In total, over 470 species or species groups were identified by observers, the majority of these species are non-QMS species caught in low numbers. Chondrichthyans in general, often unspecified but including spiny dogfish and basking shark, accounted for much of the non-commercial catch. Echinoderms, squids, crustaceans, and other unidentified invertebrates were also well represented in the bycatch of this fishery.

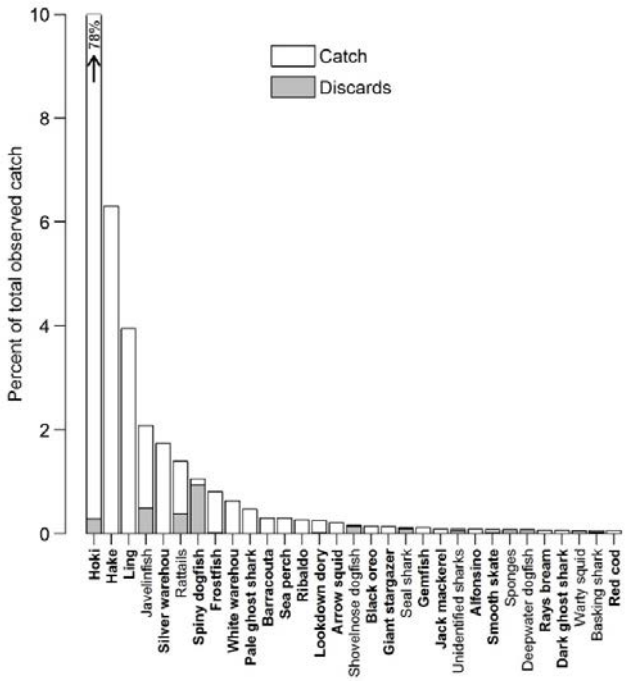

Figure 8.26: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the hoki/hake/ling 2000–01 to 2006–07 fishery, and the percentage discarded. QMS species are shown in bold.
Total bycatch in the hoki, hake, and ling fishery between 2000–01 and 2006–07 was 36 000–58 000 t per year (compared to the combined total landed catch of hoki, hake, and ling of 130 000–238 000 t). Estimates of total bycatch for 1990–91 to 1998–99 from earlier projects (for the hoki target fishery alone), were 15 000–60 000 t. Overall, total bycatch increased during the 1990s to a peak in the early 2000s, then declined slowly. Annual bycatch for the 1990–01 to 2006–07 period was also estimated for commercial species (i.e. QMS species and species which were generally retained (more than 75%) and which comprised 0.1% or more of the total observed catch) and non-commercial species, rather than QMS and non-QMS species. Roughly similar amounts of these two categories were caught overall, and each showed a similar pattern over time to total bycatch (

Figure 8.27).

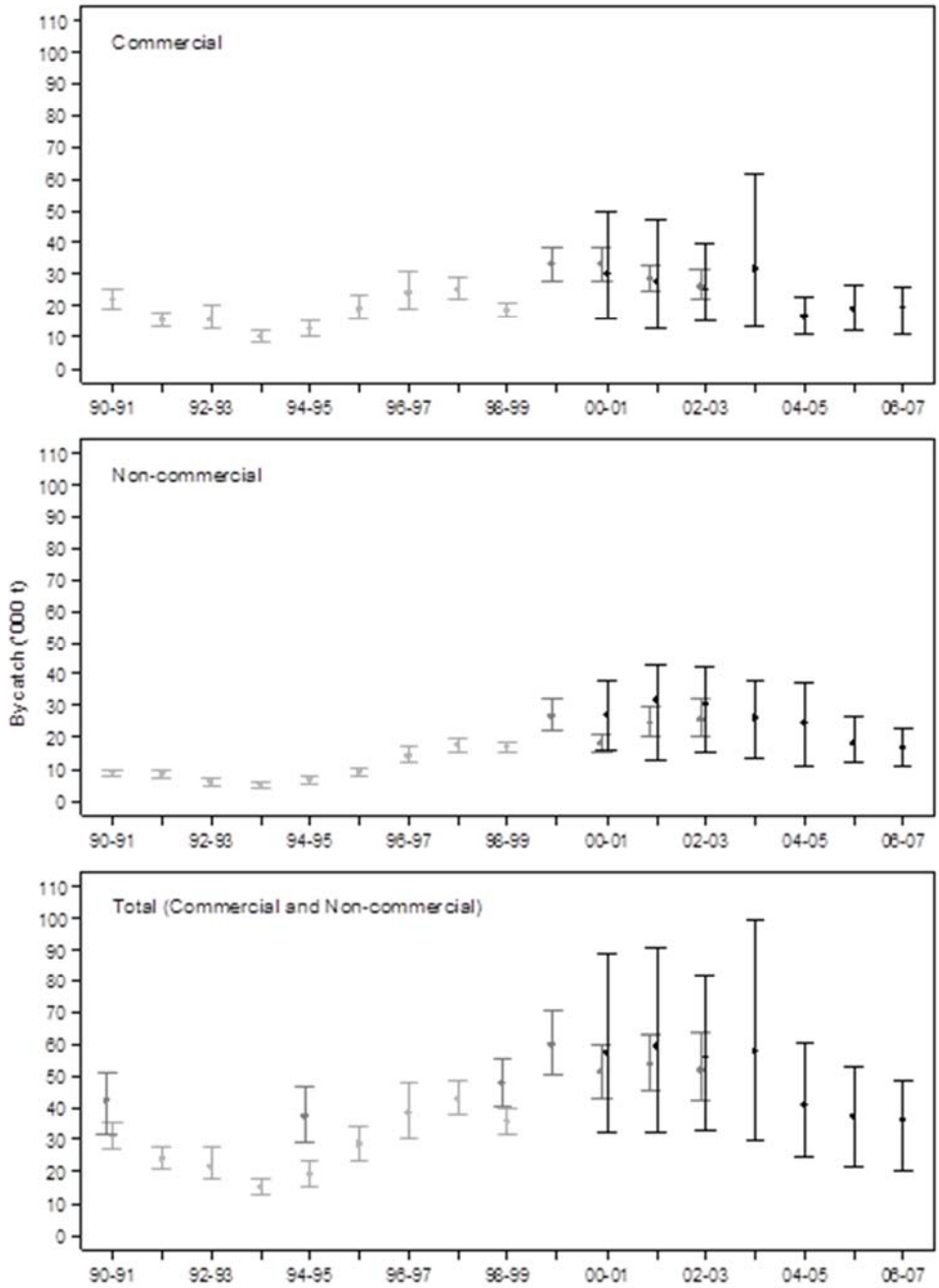

Figure 8.27: Annual estimates of fish bycatch in the target hoki, hake and ling trawl fishery, calculated for commercial species, non-commercial species, and overall for 2000–01 to 2006–07 (black). Also shown (in light grey) are the equivalent bycatch estimates calculated for 1990–91 to 1998–99 by Anderson et al (2001), and for the years 1990–91, 1994–95, 1998–99 and 1999–2000 to 2002–03 by Anderson & Smith (2005), (in dark grey). Error bars show the 95% confidence intervals.

TRENDS IN BYCATCH BY SPECIES FROM THE HOKI, HAKE, AND LING TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were silver warehou (SWA), javelinfish (JAV), and unspecified rattails (Macrouridae, RAT).

- Of the 340 bycatch species examined, 40 had a decrease in catch over time and 19 an increase in catch.
- The species showing the greatest decline were skates (SKA), combined jack mackerel species (JMA, JMM, and JMN), and dogfishes (*Etmopterus* spp., ETM) (Figure 8.28).
- The species showing the greatest increase were Tam 'o Shanter urchins (Echinothurioida, TAM), umbrella octopus (*Opisthoteuthis* spp., OPI), and floppy tubular sponge (*Hyalascus* sp., HYA) (Figure 8.28).

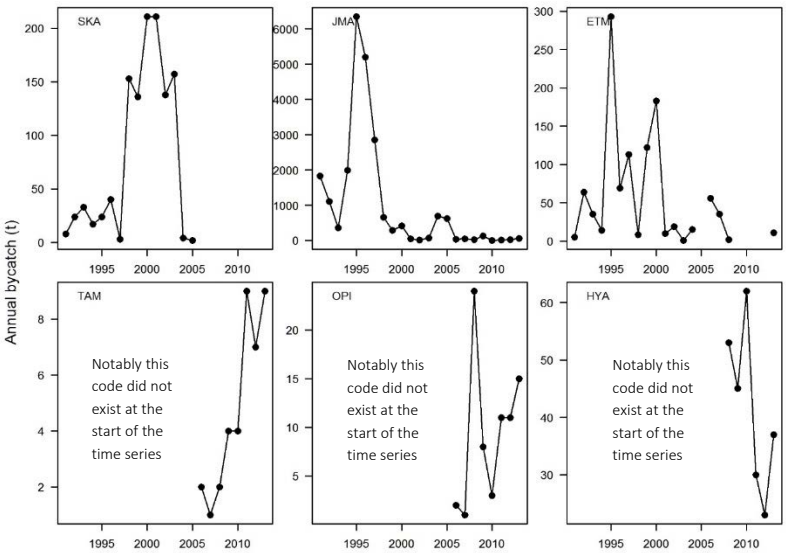

Figure 8.28: Annual bycatch estimates in the hoki, hake, and ling trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discard estimates for 2000–01 to 2006–07 were 5500–29 000 t per year with the main species discarded including spiny dogfish, rattails, javelinfish, hoki, and shovelnose dogfish. Total annual discards for 1990–91 to 1998–99 were 6600–17 900 t, and overall there was no obvious trend in total discards (Figure 8.29). The target species (hoki, hake, and ling) made up 9.7% of total observed discards. Discard rates were strongly influenced by the use of fishmeal plants on fishing vessels; discards of non-commercial species on factory vessels without meal plants were up to twice the level of discards for vessels with meal plants. The prevalence of meal plants, especially for species such as javelinfish and other rattails, was greater in recent years, mostly due many non meal plant vessels leaving NZ waters.

8.3.14 JACK MACKEREL TRAWL FISHERY

Estimates of annual bycatch in this fishery are available for 1990–91 to 2004–05 (Anderson 2007), with this fishery being reassessed in 2015. The annual level of observer coverage in this fishery was 8–27% of the target fishery catch but was usually 15–20%. For the most recent period examined in detail, 2001–02 to 2004–05, the majority of the observer effort was focussed on the main fishery, off the west coasts of the North and South Islands, with some additional coverage on the Stewart/Snares Shelf and Chatham Rise fisheries. However, in 2003–04 and 2004–05, there was a total of only 12 trawls observed outside of the western fishery. During this time the fishery was dominated by seven large trawlers and observers were able to complete a trip on each vessel in most years. The fishery occurs mostly in October–February and April–August, and although there were long periods in each year when commercial fishing effort was not observed, coverage encompassed all main fishing periods for the four years combined. More recently observer coverage was relatively high (30–88% of tows from 2006–07 to 2012–13) and should remain so given the commitment of MPI to full observer coverage on foreign charter vessels, which took over 90% of the catch in this fishery since 2002–03 (Ministry for Primary Industries 2013b).

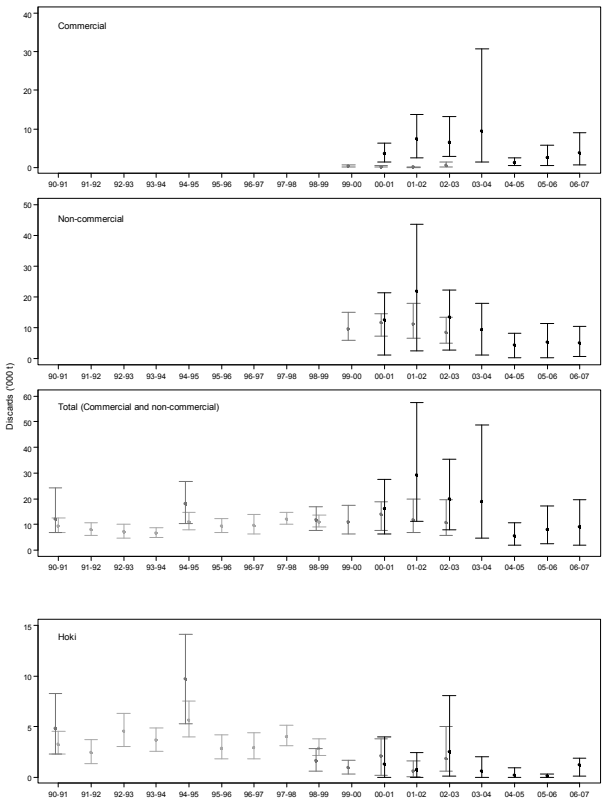

Figure 8.29: Annual estimates of fish discards in the target hoki, hake, and ling trawl fishery, calculated for commercial species, non-commercial species, overall and hoki for the period 2000–01 to 2006–07 (black). Also shown (in light grey) are the COM, OTH and TOT discard estimates calculated for the period 1990–91 to 1998–99 by Anderson et al. (2001), and COM, OTH and TOT discard estimates calculated for 1990–91, 1994–95, 1998–99 and 1999–2000 to 2002–03 by Anderson and Smith (2004), (in dark grey). Error bars show the 95% confidence intervals.

Jack mackerel species were 70% of the total estimated catch from all trawls targeting jack mackerel from 2001–02 to 2004–05. The remaining 30% mostly comprised other commercial species; especially barracouta (15.6%), blue mackerel (4.8%), frostfish (3.1%), and redbait (2.7%) (Figure 8.30). Overall about 130 species or species groups were identified by observers, and about half of these were non-commercial, non-QMS species caught in low numbers. The species most discarded was the spiny dogfish (which became a QMS species in October 2004), which comprised about 0.5% of the total catch. The bycatch of non-QMS invertebrate species has yet to be closely studied in this fishery, but species of squid, salps, and jellyfish were the most common species recorded by observers during this period.

Total bycatch in the jack mackerel trawl fishery from 2001–02 to 2004–05 was 7700–11 900 t. Estimates of total bycatch for 1990–91 to 2003–04 from earlier projects were 5400–15 500 t. After an abrupt increase in the late 1990s, annual bycatch steadily decreased to a level comparable to that of the 1990–91 to 1996–97 period. This bycatch consisted almost entirely of commercial (mainly QMS) species (Figure 8.31).

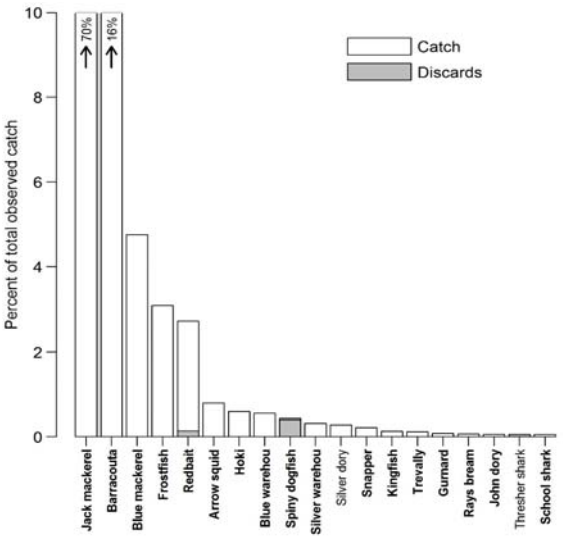

Figure 8.30: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the jack mackerel fishery, 2001–02 to 2004–05, and the percentage discarded. QMS species are shown in bold.

TRENDS IN BYCATCH BY SPECIES FROM THE JACK MACKEREL TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were barracouta (BAR), blue mackerel (*Scomber australasicus*, EMA), and frostfish (*Lepidopus caudatus*, FRO).
- Of the 110 bycatch species examined, 11 had a decrease in catch over time and 10 an increase in catch.
- The species showing the greatest decline were dark ghost shark (GSH), sea perch (*Helicolenus* spp., SPE), and carpet shark (*Cephaloscyllium isabellum*, CAR) (Figure 8.32).
- The species showing the greatest increase were silver dory (*Cyttus novaezealandiae*), kingfish (*Seriola lalandi*), and pilchard (*Sardinops sagax*). (Figure 8.32).

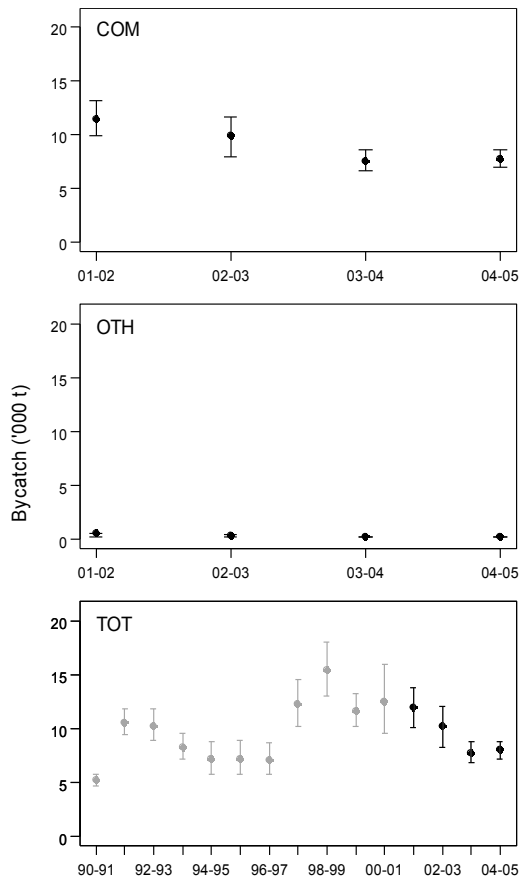

Figure 8.31: Annual estimates of fish bycatch in the target jack mackerel trawl fishery for the 2001–02 to 2004–05 fishing years (in black), calculated for commercial species (COM), non-commercial species (OTH), and overall (TOT). Also shown (in grey) are estimates of overall bycatch calculated for 1990–91 to 2000–01 by Anderson et al (2000) and Anderson (2004a). Error bars show the 95% confidence intervals.

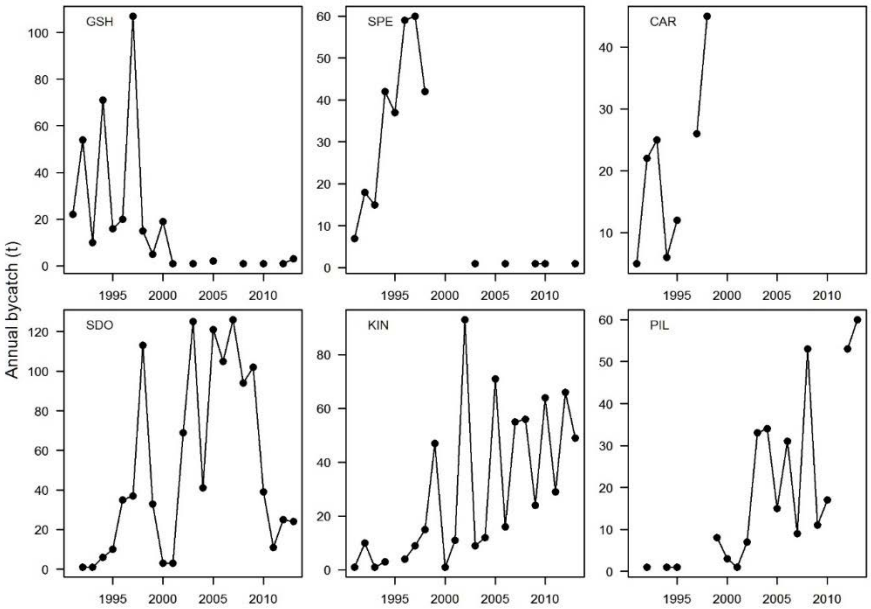

Figure 8.32: Annual bycatch estimates in the jack mackerel trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discards decreased between 2001–02 and 2004–05, continuing a trend that began in 1998–99, to a level of only 90–100 t per year. This is about 5% of the level of 1997–98 (1850 t), when annual discards were at their greatest, and is lower than in any year since 1990–91. Discards of the target species were about 200–400 t per year prior to 1998–99 but thereafter decreased to only about 10 t per year, mainly due to the absence of recorded losses of large quantities of fish through rips in the net or intentional releases of fish during landing. Discards were composed of roughly equal amounts of commercial and non-commercial species in the recent study, although commercial species discards were substantially greater in 2001–02 (Figure 8.33).

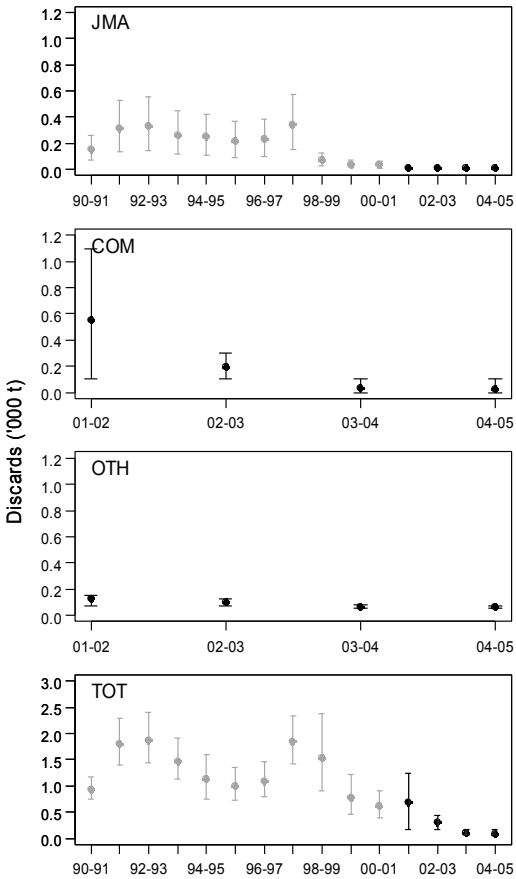

Figure 8.33: Annual estimates of fish discards in the target jack mackerel trawl fishery for the 2001–02 to 2004–05 fishing years (in black), calculated for jack mackerel (JMA), commercial species (COM), non-commercial species (OTH), and overall (TOT). Also shown (in grey) are estimates of jack mackerel and overall discards calculated for 1990–91 to

2000–01 by Anderson et al (2000) and Anderson (2004a). Error bars show the 95% confidence intervals.

8.3.15 SOUTHERN BLUE WHITING TRAWL FISHERY

In a study that covered data from 2002–03 to 2006–07, the ratio estimator used to calculate bycatch and discard rates in this fishery was based on trawl duration (Anderson 2009b). Linear mixed-effect models (LMEs) identified fishing depth as the key variable influencing bycatch rates and discard rates in this fishery, and regression tree methods were used to optimise the number of levels of this variable in order to stratify the calculation of annual bycatch and discard totals in each catch category.

The key categories of catch/discards examined were; southern blue whiting, other QMS species combined, commercial species combined (as defined above for hoki/hake/ling), non-commercial species combined, and three commonly caught individual species, hake, hoki, and ling.

The level of observer coverage represented was 22–53% of the target fishery catch from 2002–03 to 2006–07 and similar levels were reported from 1990–91 to 2001–02. The spread of observer data, across a range of variables, had no obvious shortcomings, due to a combination of the highly restricted distribution of the southern blue whiting fishery over space and time of year, a stable and uniform fleet composition, and a high level of observer effort.

Southern blue whiting were more than 99% of the total estimated catch from all observed trawls targeting southern blue whiting from 2002–03 to 2006–07. About half the remaining total catch was made up of ling (0.2%), hake (0.1%), and hoki (0.1%) (Figure 8.34). These three species, along with other QMS species, comprised over 80% of the total bycatch. In all, over 120 species or species groups were identified by observers, most were non-commercial species caught in low numbers. Porbeagle sharks (introduced into the QMS in 2004), javelinfish and other rattails, and silverside, accounted for much of the remaining bycatch. Invertebrate species (mainly sponges, crabs, and echinoderms) were also recorded by observers, but no taxon accounted for more than 0.01% of the total observed catch.

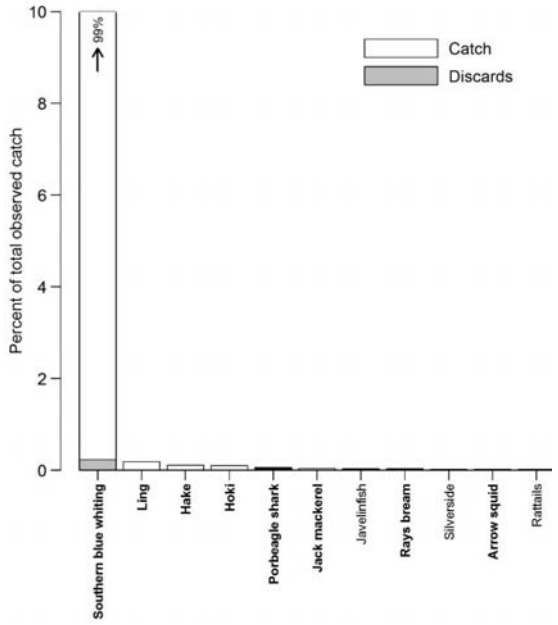

Figure 8.34: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the southern blue whiting fishery, 2002–03 to 2006–07, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch estimates from 2002–03 to 2006–07 was 40–390 t, compared with approximate target species catches in the same period of about 22 000 to 42 000 t. This bycatch was split between commercial species (55%) and non-commercial species (45%), although QMS species accounted for about 80% of the total bycatch during this period. Total annual bycatch decreased during the period, to an all-time low of 40 t in 2006–07. Total annual bycatch estimates for 1990–91 to 2001–02, from earlier reports, were mostly 60–500 t but reached nearly 1500 t in 1991–92 (Figure 8.35). This year immediately preceded the introduction of southern blue whiting into the QMS, and effort and the catch was exceptionally high.

TRENDS IN BYCATCH BY SPECIES FROM THE SOUTHERN BLUE WHITING TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were ling (*Genypterus blacodes*, LIN), hoki (*Macruronus novaezelandiae*, HOK), and hake (*Merluccius australis*, HAK).
- Of the 65 bycatch species examined, 4 had a decrease in catch over time and 11 an increase in catch.

- The species showing the greatest decline were warty squid (*Onykia* spp., WSQ), lookdown dory (*Cyttus traversi*, LDO) and arrow squid (*Nototodarus sloanii* and *N. gouldi*, SQU) (Figure 8.36).
- The species showing the greatest increase were ray's bream (*Brama brama*, RBM), pale ghost shark (*Hydrolagus bemisi*, GSP), and opah (*Lampris immaculatus,* PAH) (Figure 8.36).

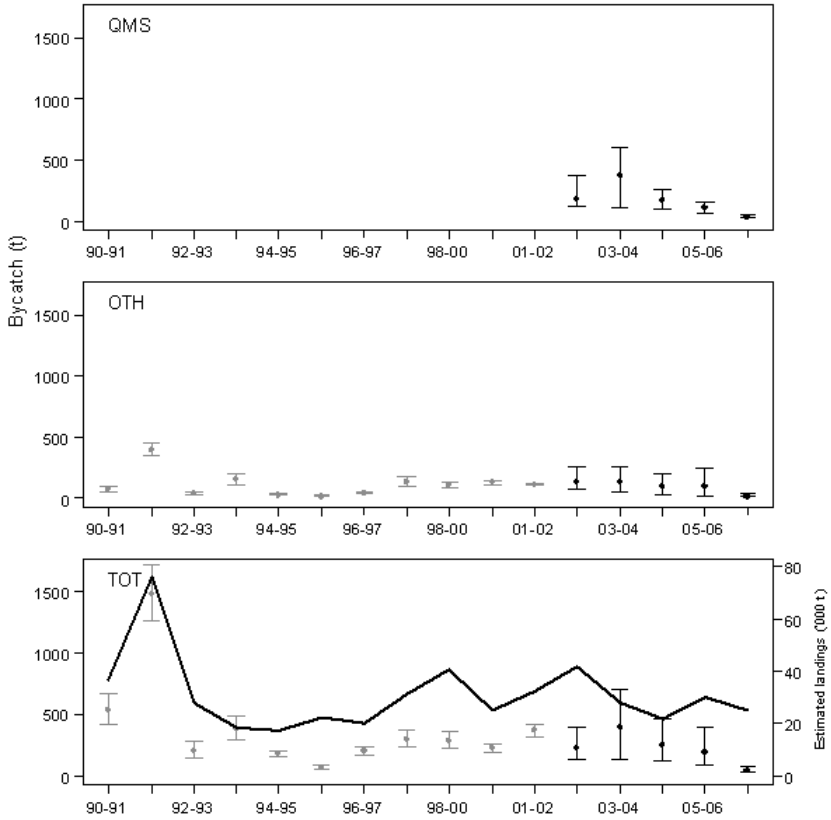

Figure 8.35: Annual estimates of fish bycatch in the southern blue whiting trawl fishery, calculated for QMS species, non-commercial species (OTH), and overall (TOT) for 2002–03 to 2006–07 (in black). Also shown (in grey) are estimates of bycatch in each category (excluding QMS) for 1990–91 to 2001–02 (Anderson 2004a). Error bars show the 95% confidence intervals. Note: the 98–00 fishing year encompasses the 18 months between September 1998 and March 2000, the transitional period between a change from an Oct–Sep to Apr–Mar fishing year. The dark line in the bottom panel shows the total annual estimated landings of SBW (Ministry for Primary Industries 2013a).

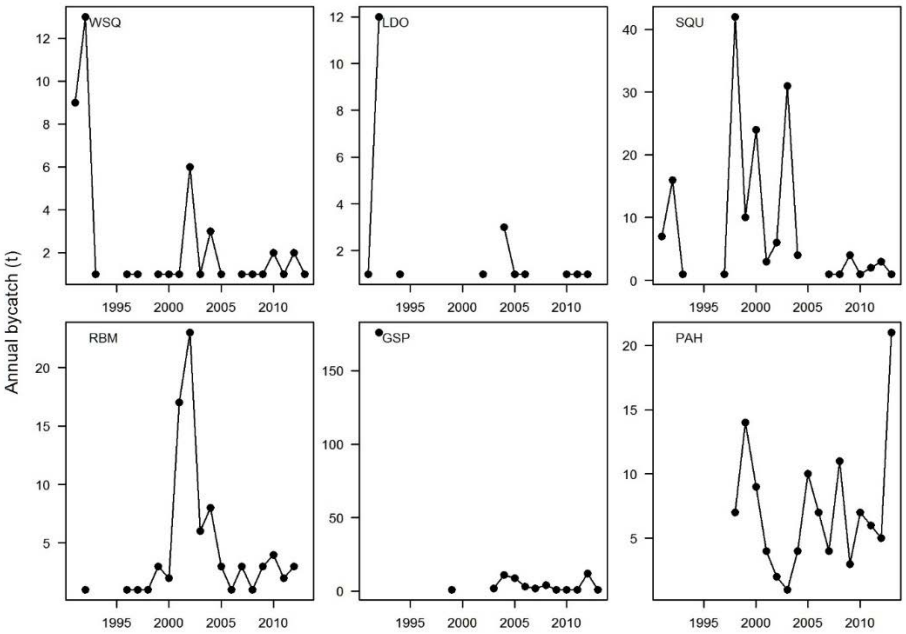

Figure 8.36: Annual bycatch estimates in the southern blue whiting trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1), and may be area-specific (see text above). See text above for species codes.

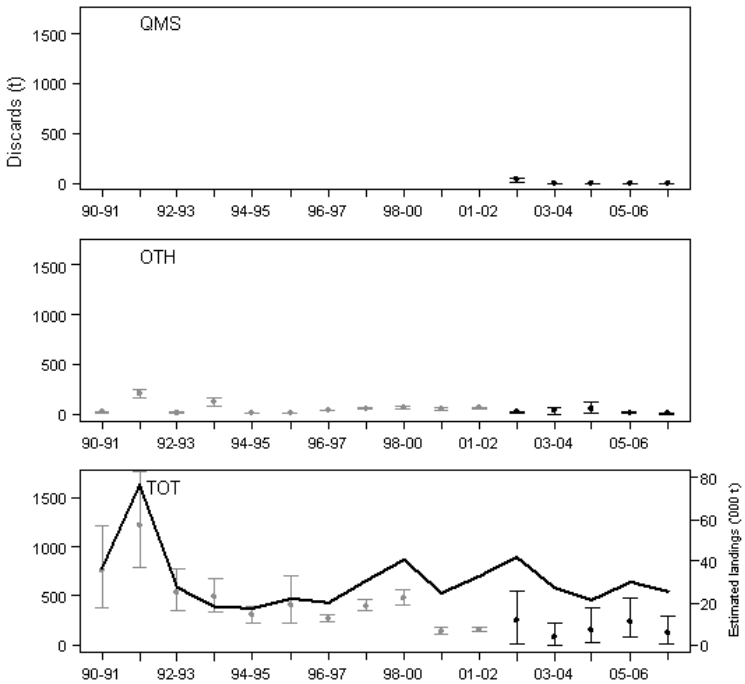

Figure 8.37: Annual estimates of fish discards in the southern blue whiting trawl fishery, calculated for the target species (SBW), QMS species, non-commercial species (OTH), and overall (TOT) for 2002–03 to 2006–07 (in black). Also shown (in grey) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2001–02 by Anderson (2004a). Error bars show the 95% confidence intervals. The dark line shows the total annual estimated landings of SBW (Ministry for Primary Industries 2013a).

Total annual discard estimates from 2002–03 to 2006–07 were 90–250 t per year. Discard amounts sometimes exceeded bycatch due to the large contribution of the target species (50–230 t per year) to total discards – the

result usually of fish losses during recovery of the trawl. Discarding of commercial species was virtually non-existent in most years and discards of non-commercial species amounted to only 10–50 t per year. The main species discarded were southern blue whiting, rattails and porbeagle sharks. Total annual discard estimates for 1990–91 to 2001–02, from earlier reports, were mostly 140–750 t but were about 1200 t in 1991–92 (Figure 8.37). Discards of southern blue whiting (and therefore total discards) decreased substantially at the end of the 1990s and remained at low levels, below 250 t per year, up to 2006–07.

8.3.16 ORANGE ROUGHY TRAWL FISHERY

A detailed analysis of this fishery from 1990–91 to 2008–09, used the ratio estimator to calculate bycatch and discard rates based on the number of trawls (Anderson 2011). Linear mixed-effect models (LMEs) identified trawl duration as the key variable influencing bycatch rates and discard rates in this fishery, and regression tree methods were used to optimise the number of levels of this variable in order to stratify the calculation of annual bycatch and discard totals in each catch category.

The key categories of catch/discards examined were; orange roughy, other QMS species (excluding oreos) combined, commercial species combined (as defined above for hoki/hake/ling), and non-commercial species combined.

The level of observer coverage in this fishery was high over the entire period of the fishery—more than 10% (in terms of the total fishery catch) in all but one year, and over 50% in some years. Observer coverage was not evenly spread across all parameters of the orange roughy fishery, the most widespread of any New Zealand fishery, with notable undersampling of smaller vessels, the east coast fisheries in QMAs ORH 2A, ORH 2B, and ORH 3A (where only small vessels are allowed to operate), and some of the earlier years of the period.

Since 2005–06, orange roughy has been about 84% of the total observed catch. Much of the remainder of the total catch (about 10%) comprised oreo species: mainly smooth oreo (8%), and black oreo (2.1%). Rattails (various species, 0.8%) and shovelnose spiny dogfish (*Deania calcea*, 0.6%) were the species most adversely affected by this fishery, with over 90% discarded (Figure 8.38). Other fish species frequently caught and usually discarded included deepwater dogfishes (family Squalidae), especially *Etmopterus* species, the most common was probably Baxter's dogfish (*Etmoptertus baxteri*), slickheads, and morid cods, especially Johnson's cod (*Halargyreus johnsonii*) and ribaldo. In total, over 250 bycatch species or species groups were observed, most were non-commercial species, including invertebrate species, caught in low numbers. Squid (mostly warty squid, *Onykia* spp.) were the largest component of invertebrate catch, followed by various groups of coral, echinoderms (mainly starfish), and crustaceans (mainly king crabs, family Lithodidae).

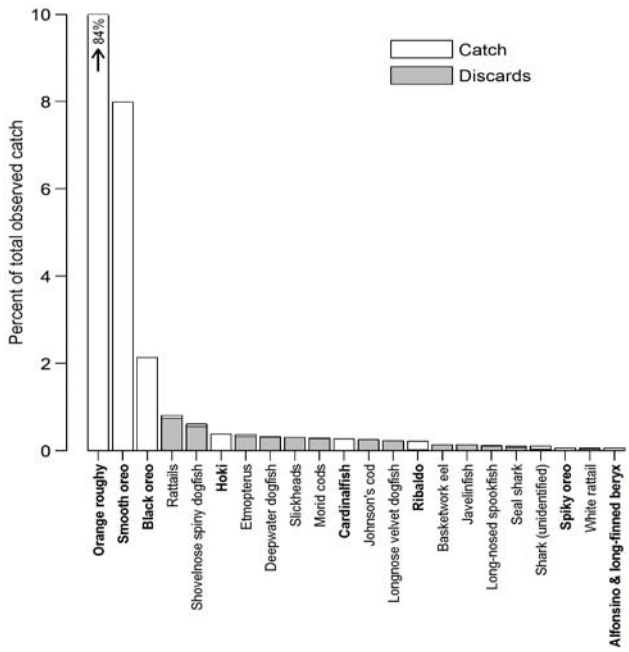

Figure 8.38: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the orange roughy fishery, 1990–91 to 2008–09 and the percentage discarded. QMS species are shown in bold.

Total annual bycatch in the orange roughy fishery since 1990–91 was 2300–27 000 t, and declined over time alongside the decline in catch and effort in this fishery to be less than 4000 t in each of the last four years estimated, 2005–06 to 2008–09 (Figure 8.39). Bycatch mostly comprised commercial species, with non-commercial species accounting for only 5–10% of the total bycatch in the recent period.

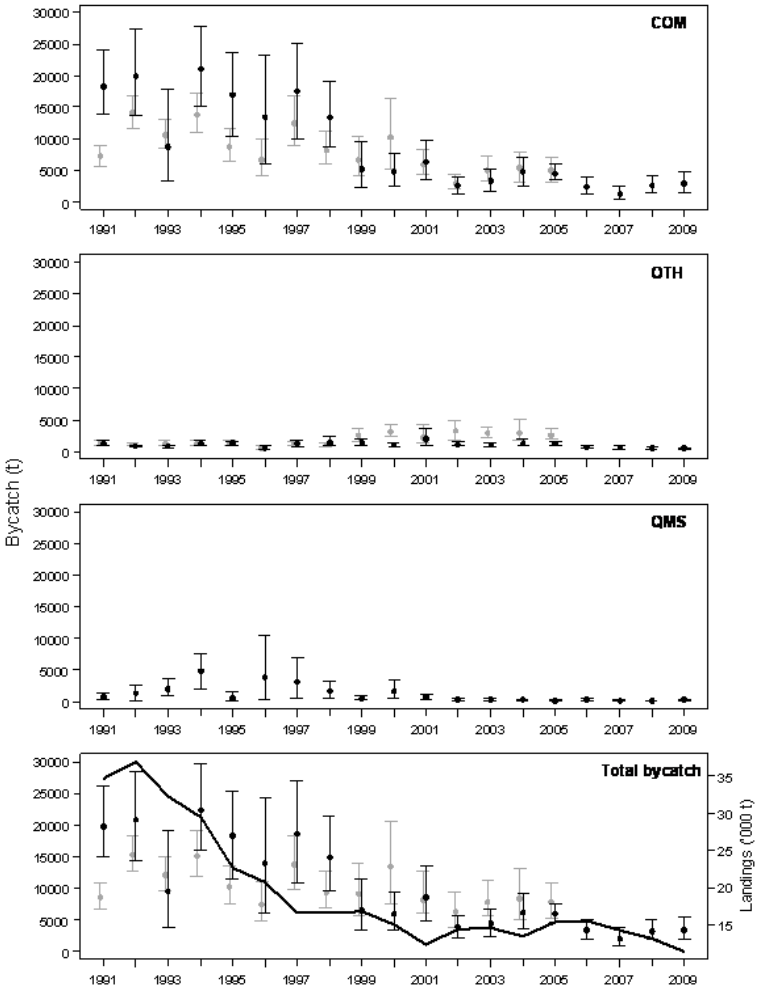

Figure 8.39: Annual estimates of fish bycatch in the orange roughy trawl fishery, calculated for commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are earlier estimates of bycatch in each category (excluding QMS) calculated for 1990–91 to 2004–05 (Anderson et al 2001, Anderson 2009a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of orange roughy (O. Anderson & M. Dunn (NIWA), unpublished data).

TRENDS IN BYCATCH BY SPECIES FROM THE ORANGE ROUGHY TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were smooth oreo (*Pseudocyttus maculatus*, SSO), black oreo (*Allocyttus niger*, BOE), and black cardinalfish (*Epigonus telescopus*, CDL).
- Of the 201 bycatch species examined, 16 had a decrease in catch over time and 26 an increase in catch.
- The species showing the greatest decline were spiny dogfish (SPD), black oreo (*Allocyttus niger*, BOE), and cardinalfishes (Epigonidae, CDL) (Figure 8.40).
- The species showing the greatest increase were morid cods (Moridae, MOD), longnose velvet dogfish (*Centroscymnus crepidater*, CYP), and bushy hard coral (*Goniocorella dumosa*, GDU; a species probably not well identified before 2005–06) (Figure 8.40).

Estimated total annual discards also decreased over time, from about 3400 t in 1990–91 to about 300 t in 2007–08 (Figure 8.41), and since about 2000 were almost entirely non-commercial, non-QMS species. Large discards of orange roughy and other commercial species, more prevalent early in the fishery, were often due to fish lost from torn nets during hauling (and are accounted for in stock assessments)

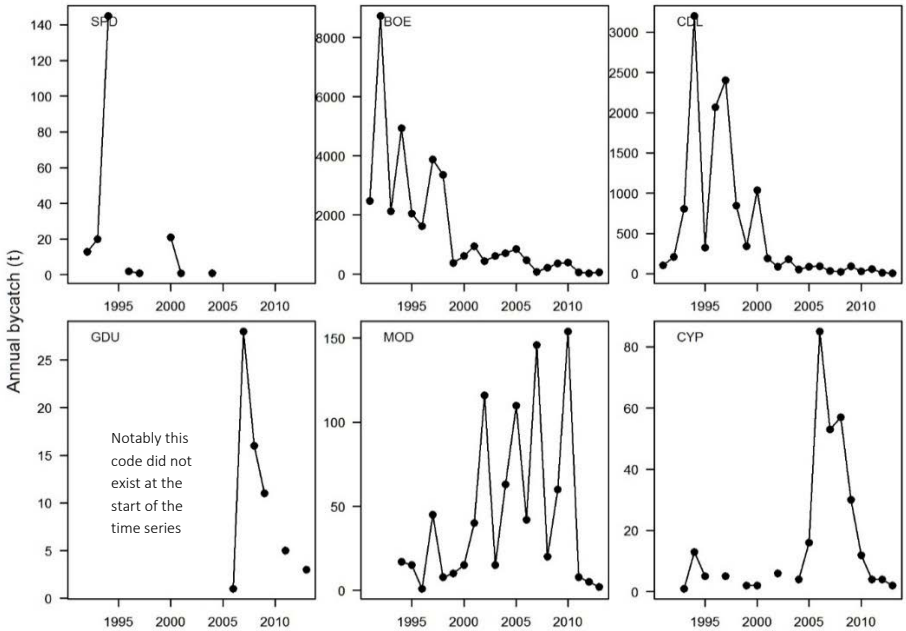

Figure 8.40: Annual bycatch estimates in the orange roughy trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1), and may be area-specific (see text above). See text above for species codes.

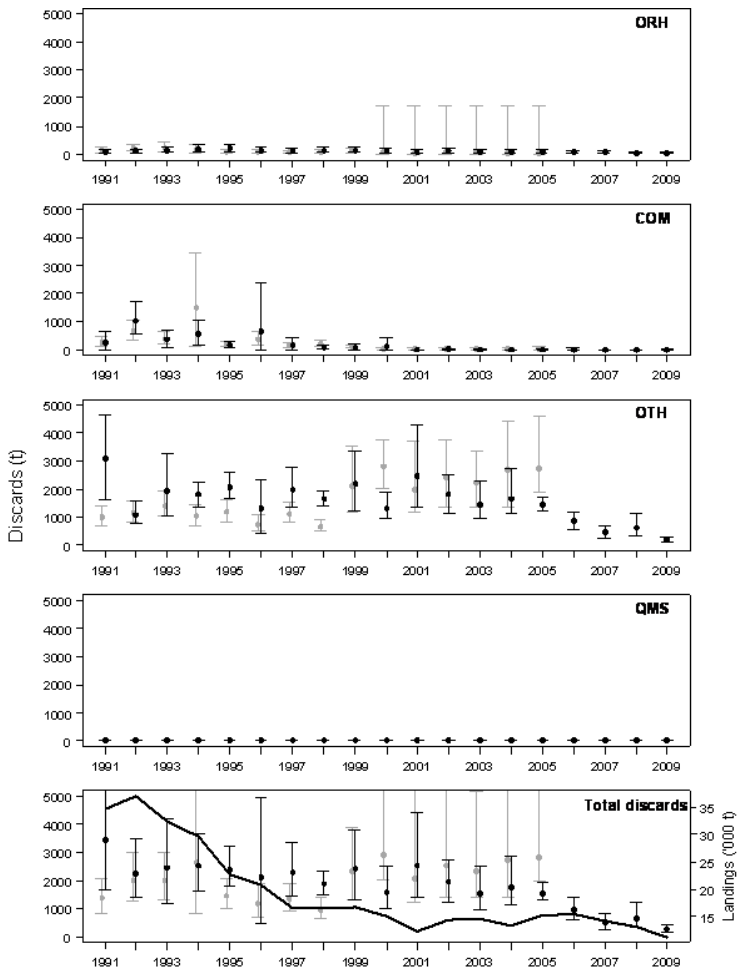

Figure 8.41: Annual estimates of fish discards in the orange roughy trawl fishery, calculated for the target species (ORH), commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2004–05 (Anderson et al 2001, Anderson 2009a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of orange roughy (O. Anderson & M. Dunn (NIWA), unpublished data).

8.3.17 OREO TRAWL FISHERY

A detailed analysis of this fishery from 1990–91 to 2008–09, used the ratio estimator to calculate bycatch and discard rates in the oreo fishery based on the number of trawls (Anderson 2011). Linear mixed-effect models (LMEs) identified trawl duration as the key variable influencing bycatch rates and discard rates in this fishery, and regression tree methods were used to optimise the number of levels of this variable in order to stratify the calculation of annual bycatch and discard totals in each catch category. The key categories of catch/discards examined were; oreos, other QMS species (excluding oreos) combined, commercial species combined (as defined above for hoki/hake/ling), and non-commercial species combined.

The oreo fishery was strongly linked to the orange roughy fishery, and only about 15% of the observed trips examined in the study predominantly targeted oreos, and nearly 30% of the observed trawls targeting oreos were from trips which predominantly targeted orange roughy. The coverage of the oreo fishery was therefore partly determined by the operations of the orange roughy fishery.

The annual number of observed trawls in the oreo fishery ranged from 30 in 1991–92 to 1006 in 2006–07 and the number of vessels observed ranged from 2 to 12. The level of coverage remained at a relatively consistent level after the mid-1990s, despite a decrease in the total catch and effort. Observer coverage was mostly restricted to the main fisheries on the South Chatham Rise and further south. Within this region, few locations were not covered by observers during the 19 years examined, but in the smaller fisheries, on the North Chatham Rise, Louisville Ridge, and the east coast from Kaikoura to East Cape, coverage was minimal. The match of observer coverage to commercial effort was relatively good, especially compared with the orange roughy fishery. Some oversampling on the south Chatham Rise occurred in some periods, e.g., 2001–2005 and 2008–09, and undersampling in the Pukaki/Bounty

fisheries in 2005–06 and 2008–09, but elsewhere, and at other times, the spread of coverage was nearly ideal. The full range of vessel sizes (mainly between 300 t and 3000 t) was covered by observers, although small vessels were underrepresented and large vessels overrepresented. The fleet reduced in recent years and the remaining vessels were observed more regularly, with 30–60% of the fleet hosting observers annually since 2002–03.

Oreo species accounted for about 92% of the total estimated catch from all observed trawls targeting oreos after 1 October 2002. Orange roughy (3.5%) was the main bycatch species, with no other species or group of species accounting for more than 0.6% of the total catch. Hoki were the next most common bycatch species, followed by rattails, deepwater dogfish (especially Baxter's dogfish and seal shark (*Dalatias licha*)), slickheads, and basketwork eel (*Diastobranchus capensis*), all of which were usually discarded (Figure 8.42). Ling were also frequently caught, but only comprised about 0.25% of the total catch. In total, over 250 species or species groups were identified by observers in the target fishery, including numerous invertebrates. As in the orange roughy fishery, corals, squids and octopuses, king crabs, and echinoderms were the main groups caught. Coral, in particular, was a substantial part of the bycatch, accounting for almost 0.4% of the total catch.

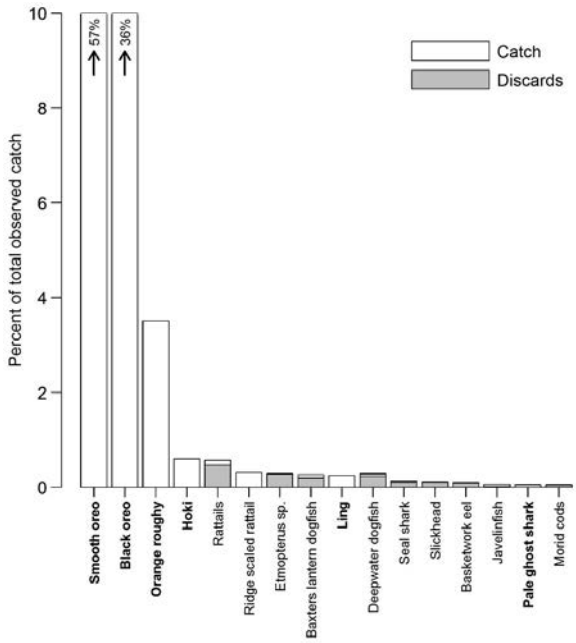

Figure 8.42: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the oreo fishery, 1990–91 to 2008–09, and the percentage discarded. QMS species are shown in bold.

Total annual bycatch in the oreo fishery since 1990–91 was 270–2200 t and, apart from some higher levels in the late 1990s, showed no obvious trends (Figure 8.43). Bycatch was split almost evenly between commercial and non-commercial species overall, although after 2002 about 60% of the bycatch comprised commercial species.

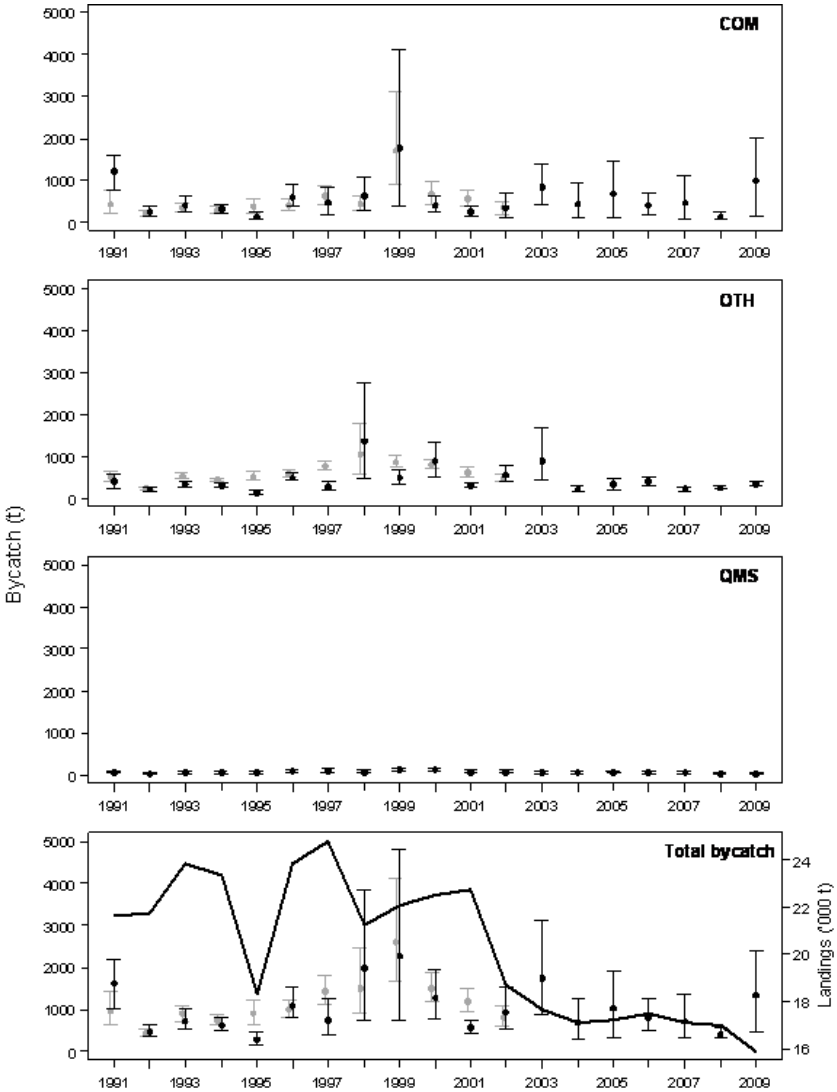

Figure 8.43: Annual estimates of fish bycatch in the oreo trawl fishery, calculated for commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of bycatch in each category (excluding QMS) calculated for 1990–91 to 2001–02 (Anderson 2004a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of oreos (Ministry for Primary Industries 2013a).

TRENDS IN BYCATCH BY SPECIES FROM THE OREO TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were orange roughy (*Hoplostethus atlanticus*, ORH), unspecified shark (SHA), and hoki (HOK).
- Of the 116 bycatch species examined, 19 had a decrease in catch over time and 8 an increase in catch.
- The species that showed the greatest decline were dark ghost shark (GSH) and unspecified shark (SHA), although both trends may be influenced by improving taxonomic resolution over time; and ling (LIN) (Figure 8.44).
- The species that showed the greatest increase were ridge-scaled rattail (*Macrourus carinatus*, MCA), Baxter's lantern dogfish (*Etmopterus baxteri*, ETB), and pale ghost shark (GSP), (Figure 8.44).

Discards in the oreo fishery remained relatively stable over time, ranging from about 260 t to 750 t per year, with higher levels in the late 1990s than in the early 1990s or 2000s (Figure 8.45). Discards mainly comprised non-commercial, non-QMS species, but also included a significant component of the target species in most years.

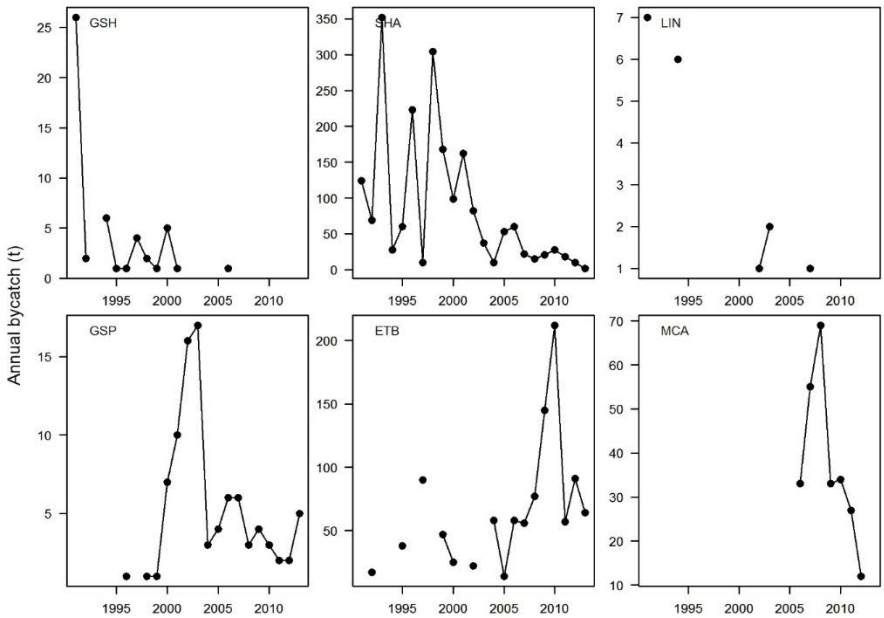

Figure 8.44: Annual bycatch estimates in the oreo trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1). See text above for species codes.

8.3.18 SCAMPI TRAWL FISHERY

A detailed analysis of this fishery from 1990–91 to 2009–10 used the ratio estimator to calculate bycatch and discard rates in the scampi fishery based on the number of trawls (Anderson 2012). Linear mixed-effect models (LMEs) identified fishery area as the key variable influencing bycatch rates and discard rates.

The key categories of catch/discards examined were; all QMS species combined, all non-QMS species combined, all invertebrate species combined, javelinfish, and all other rattail species combined.

Observer coverage in the scampi fishery has been relatively low compared with most of the other fisheries assessed. The long-term level of observer coverage in the orange roughy, oreo, arrow squid, southern blue whiting, and ling longline fisheries is greater than 18% of the target fishery catch (and over 40% for southern blue whiting) whereas in the scampi fishery (and also in the jack mackerel fishery) long-term coverage has only been about 11–12%. However, annual coverage in the scampi fishery was greater than 10% in most years and fell below 5% only once (in 2000–01).

The annual number of observed trawls in the fishery ranged from 142 to 797, but has been over 300 trawls in most years. The number of vessels observed in each year ranged from 3 to 8 (equivalent to 33–66% of the fleet) and was very constant—5 or 6 vessels in most years. Analysis of the spread of observer effort compared with that of the scampi fishery as a whole, across a range of variables, indicated that this coverage was reasonably well spread. Although some less important regions of the fishery received little or no coverage (e.g. the central Chatham Rise, where commercial scampi fishing has only recently developed

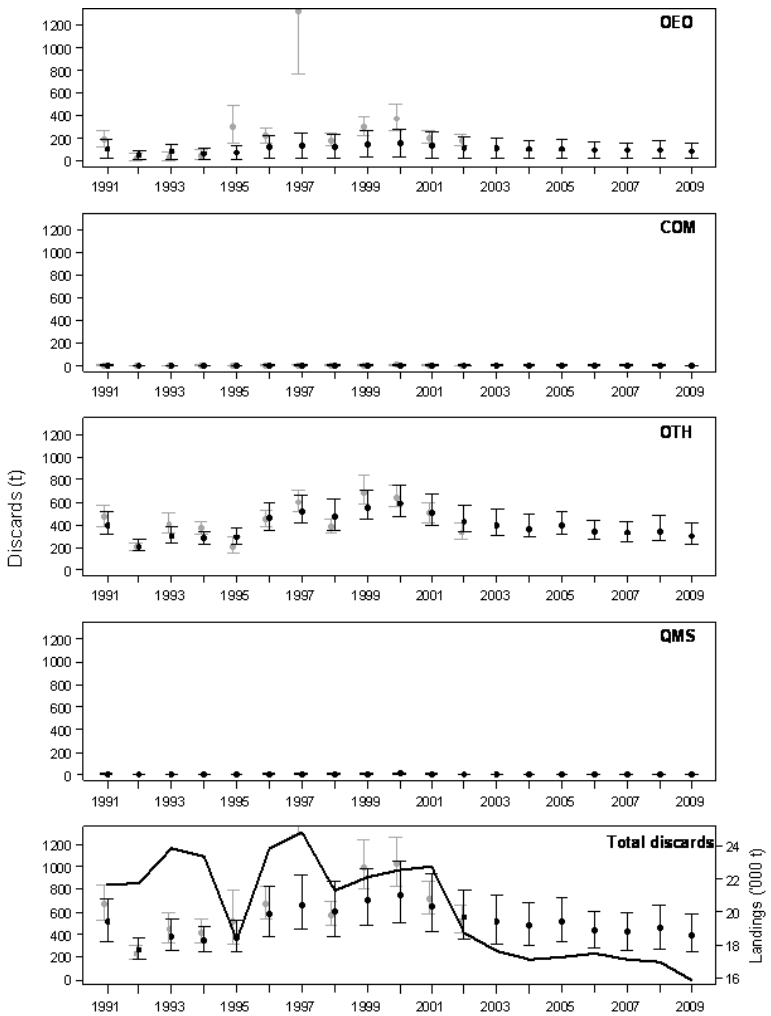

Figure 8.45: Annual estimates of fish discards in the oreo trawl fishery, calculated for the target species (OEO), commercial species (COM), non-commercial species (OTH), QMS species, and overall for 1990–91 to 2008–09 (black points). Also shown (grey points) are estimates of discards in each category (excluding QMS) calculated for 1990–91 to 2001–02 (Anderson 2004a). Error bars show the 95% confidence intervals. The black line in the bottom panel shows the total annual estimated landings of oreos (Ministry for Primary Industries 2013a).

(after 2001–02), and west coast South Island), the main scampi fisheries were consistently sampled throughout the period examined. Vessels were mostly of a similar size, and the small amount of effort by larger vessels was adequately covered, as was the full depth range of the fishery and (despite highly intermittent sampling in several years) all periods of the year.

Over 450 bycatch species or species groups were observed in the scampi target fishery catch, most being non-commercial species, including invertebrate species, caught in low numbers. Scampi accounted for only about 17% of the total estimated catch from all observed trawls targeting scampi since 1 October 1990. The main bycatch species or species groups were javelinfish (16%), other (unidentified) rattails (13%), sea perch (*Helicolenus* spp., 8.4%), ling (7.5%), and hoki (6.1%). The first three of these bycatch groups were mostly discarded (Figure 8.46). Of the other invertebrate groups, unidentified crabs (1.1%) and unidentified starfish (0.8%) were caught in the greatest amounts. When combined into broader taxonomic groups, bony fish (excluding rattails) contributed the most to total bycatch (40%), followed by rattails (29%), rays and skates (3.5%), sharks and dogfish (2.3%), crustaceans (2.2%), chimaeras (2.0%), echinoderms (1.6%), and cnidarians (0.6%). A large percentage of the bycatch in these groups was discarded, and was less than 85% only for bony fish (excluding rattails) (33%), rays and skates (67%), and chimaeras (28%).

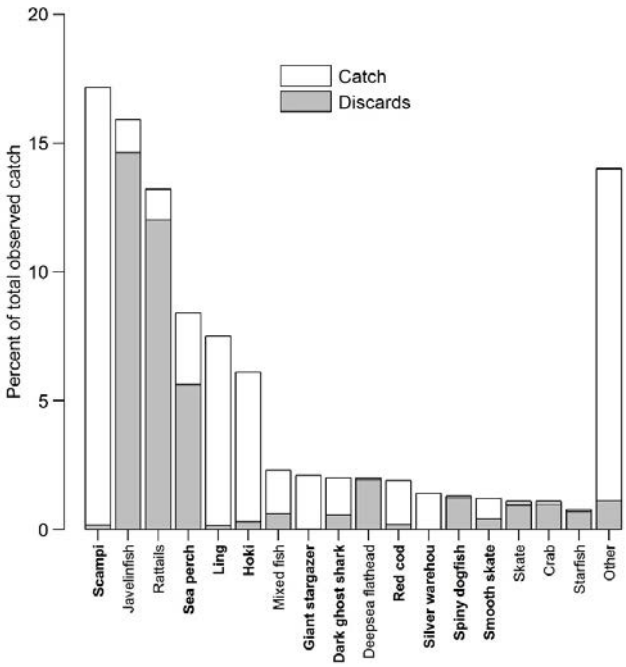

Figure 8.46: Percentage of the total catch contributed by the main bycatch species (those representing 1% or more of the total catch) in the observed portion of the scampi fishery, 1990–91 to 2009–10, and the percentage discarded. The "Other" category is the sum of all other bycatch species (fish and invertebrates) representing less than 1% of the total catch. QMS species are shown in bold.

Total annual bycatch since 1990–91 ranged from about 2100 t to 9200 t and although highly variable showed a significant decline over the past 20 years – driven mainly by a decline in the bycatch of QMS species (Figure 8.47). This decline may be partly due to modifications to the top of the trawl to reduce fish bycatch, introduced across the fleet after 2002–03 (Tuck, 2013). Annual bycatch has generally been an even mixture of QMS and non-QMS species, with invertebrate species (although showing a significant increase over time) accounting for only about 7% of the total bycatch for the whole period. Rattails (split evenly between javelinfish and all other species combined) accounted for 30–80% of the annual non-QMS bycatch. Comparison of bycatch rates with relative biomass estimates from trawl surveys to test for similarity of trends over time was possible for the Chatham Rise and Auckland Islands fishery areas, but these were inconclusive.

TRENDS IN BYCATCH BY SPECIES FROM THE SCAMPI TRAWL FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1990–91 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were javelinfish (*Lepidorhynchus denticulatus*, JAV), unspecified rattails (Macrouridae, RAT), and sea perch (*Helicolenus* spp., SPE).
- Of the 267 bycatch species examined, 16 had a decrease in catch over time and 12 an increase in catch.
- The species that showed the greatest decline were skates (*Rajidae* and *Arhynchobatidae*, SKA; although identification of skates beyond this generic code may have improved after 2002–03), bluenose (*Hyperoglyphe antarctica*, BNS; a species not present at the Auckland Islands) and alfonsino (*Beryx* spp., BYX; a species not found south of the Chatham Rise; the use of the specific code BYS may have increased) (Figure 8.48).
- The species showing the greatest increase were Geometric star (*Psilaster acuminatus*, PSI), frilled crab (*Trichopeltarion fantasticum*, TFA), and spiny masking crab (*Teratomaia richardsoni*, SMK) (Figure 8.48).

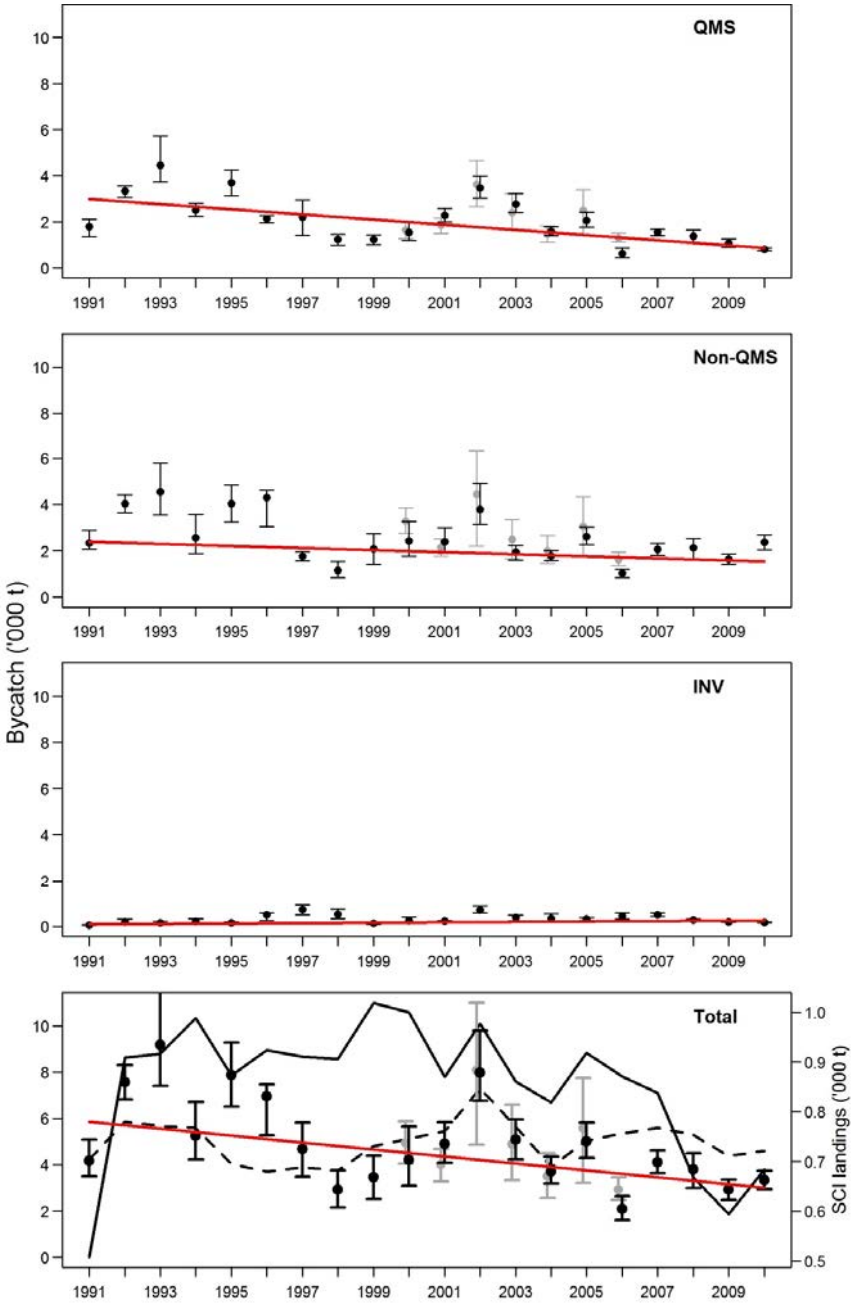

Figure 8.47: Annual estimates of bycatch in the scampi trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2009–10. Also shown (in grey) are estimates of bycatch in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The straight lines show the fit of a weighted regression to annual bycatch. In the bottom panel the solid black line shows the total annual reported landings of scampi (Ministry for Primary Industries 2013a) and the dashed line shows annual effort (scaled to have mean equal to that of total bycatch).

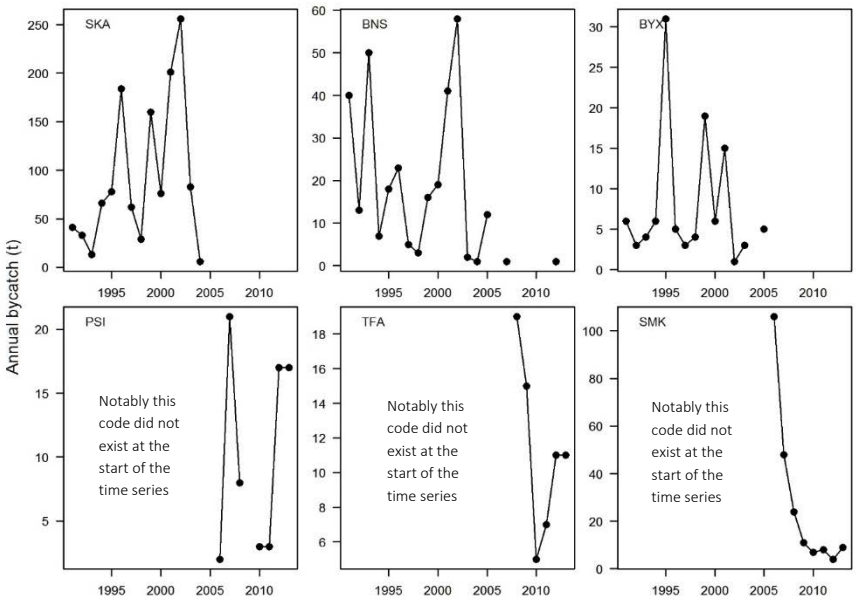

Figure 8.48: Annual bycatch estimates in the scampi trawl fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1990–91 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1), and may be area-specific (see text above). See text above for species codes.

Total annual discards ranged from 6790 t in 1995–96 to 1430 t in 2005–06 and, although there was a general decrease since 2001–02, there was no significant trend in overall discard levels since 1990–91 (Figure 8.49). Discards were dominated by non-QMS species (overall about 75%) followed by QMS species (16%) and invertebrates (9%). Rattail species accounted for nearly 60% of the non-QMS discards and about 45% of all discards.

8.3.19 LING LONGLINE FISHERY

The first analysis of bycatch and discards in this fishery covered the period from 1990–91 to 1997–98 (Anderson et al 2000), and a later analysis extended this to 2005–06 (Anderson 2008). The analysis was further updated in 2014, re-estimating annual bycatch and discards for all fishing years up to 2011–12, within the standard species categories (QMS, non-QMS, and Invertebrate) (Anderson 2014).

The ratio estimator used in these analyses to calculate bycatch and discard rates was based on the number of hooks set. The ratios were applied to hook number totals calculated from commercial catch-effort data to make annual estimates for the target fishery as a whole.

Linear mixed-effect models (LMEs) were used to identify key factors influencing variability in the observed rates of bycatch and discarding, resulting in an area based stratification for the calculations.

Between 1992–93 and 2011–12 only 9% of the vessels operating in this fishery were observed (24 vessels) but these tended to be the main operators (including most of the larger autoliners) and accounted for up to 52% (by catch) and 60% (by effort) of the total fishery, although coverage was low (less than 10%) prior to 1999–2000).

Ling were 68% of the total estimated catch from all observed sets targeting ling between 1992–93 and 2011–12, and spiny dogfish (much of which was discarded) about a further 13% (Figure 8.50). About half of the remaining 19% of the catch comprised other commercial species; especially ribaldo (*Mora moro*) (2.9%), smooth skates (*Dipturus innominatus*) (1.8%), red cod (*Pseudophycis bachus*), (1.7%), rough skates (*Zearaja nasuta*, 1.7%), and sea perch (*Helicolenus* spp.) (1.2%). Altogether, 93% of the observed catch was comprised of QMS species. Over 230 species or species groups were identified by observers, the majority being non-commercial species caught in low numbers, especially Chondrichthyans, often unspecified but including shovelnose spiny dogfish (*Deania calcea*), *Etmopterus* species, and seal sharks (*Dalatias licha*). A large number of echinoderms, especially starfish (of which about 39 t were observed caught during the period), anemones, crustaceans, and other invertebrates were also recorded by observers.

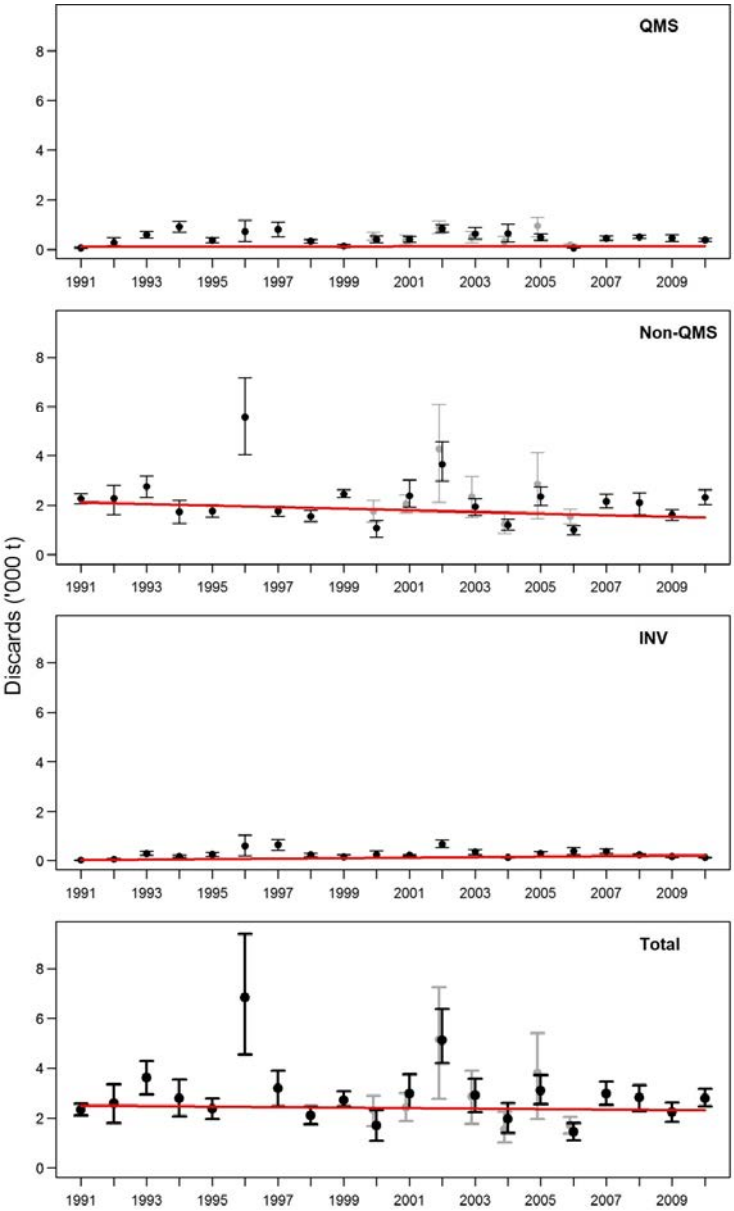

Figure 8.49: Annual estimates of discards in the scampi trawl fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1990–91 to 2009–10. Also shown (in grey) are estimates of discards in each category (excluding INV) calculated for 1999–2000 to 2005–06 (Ballara & Anderson 2009). Error bars indicate 95% confidence intervals. The straight lines show the fit of the weighted regression to annual discards.

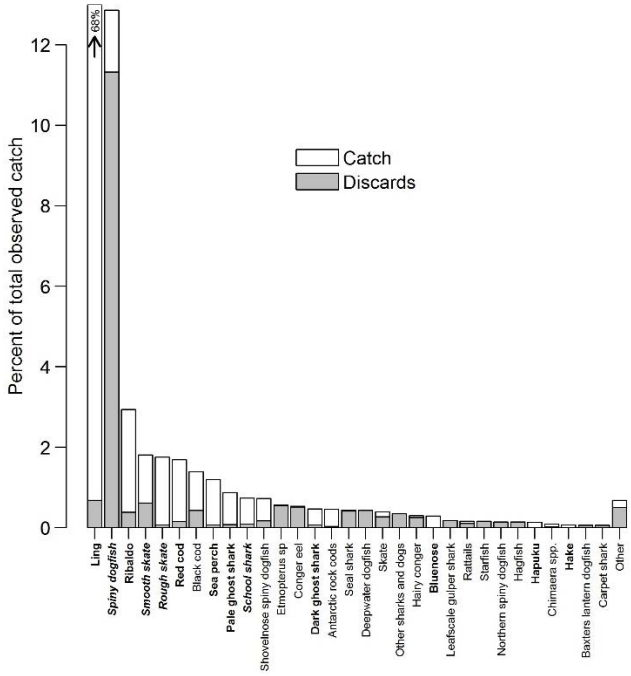

Figure 8.50: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the ling longline fishery, 1992–93 to 2011–12 and the percentage discarded. QMS species are shown in bold.

Total annual bycatch estimates for 1992–93 to 2011–12 were 2100–3900 t, compared with approximate target species catches in the same period of 3500–9800 t. Bycatch weights decreased slowly during the period, in line with decreasing effort in the fishery (Figure 8.51).

TRENDS IN BYCATCH BY SPECIES FROM THE LING BOTTOM LONGLINE FISHERY

Ballara (2015) estimated the level of individual fish and invertebrate species bycatch in each fishing year from 1992–93 to 2012–13. The following conclusions were made:

- The most commonly caught bycatch species were spiny dogfish (SPD), ribaldo (*Mora moro*, RIB), and smooth skate (*Dipturus innominatus*, SSK).
- Of the 104 bycatch species examined, 5 have shown a decrease in catch over time and 9 an increase in catch.
- Among the species showing the greatest decline were bluenose (*Hyperoglyphe antarctica*, BNS), Ray's bream (*Brama brama*, RBM), and hapuku (*Polyprion oxygeneios*, HAP) (Figure 8.52).
- The species showing the greatest increase were the hairy conger (HCO), hagfish (*Eptratretus cirrhatus*, HAG), and pale ghost shark (*Hydrolagus bemisi*, GSP) (Figure 8.52).

Total annual discard estimates for 1992–93 to 2011–12 were 1200–2500 t, and generally decreased during the period (Figure 8.53). About 45–70% of these discarded fish were quota species, mainly spiny dogfish, the remainder being non-quota, generally non-commercial, species. Ling were discarded in small amounts (40–250 t per year), these generally being attributable to fish being lost on retrieval or predated by marine mammals and birds.

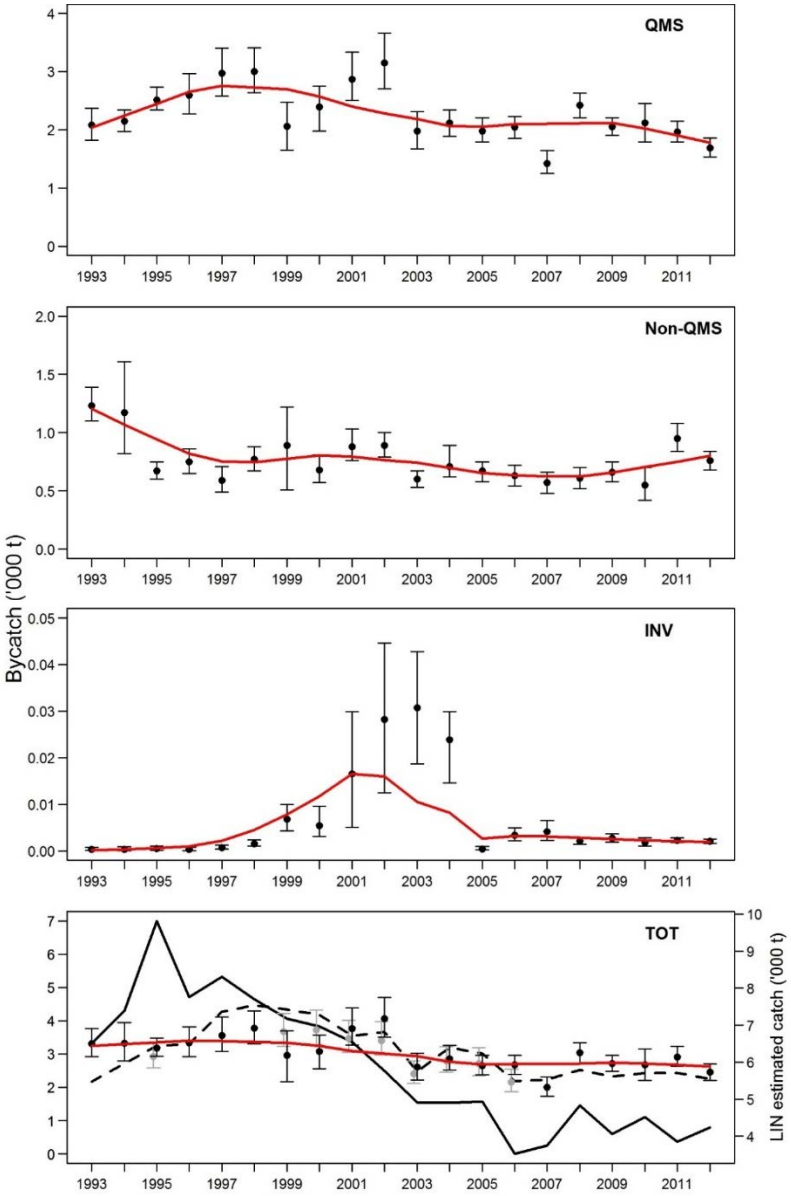

Figure 8.51: Annual estimates of bycatch in the ling longline fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1992–93 to 2011–12. Also shown (in grey) are earlier estimates of total bycatch calculated for 1994–95 and 1998–99 to 2005–06 (Anderson 2008). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual bycatch. In the bottom panel the solid black line shows the total annual estimated commercial longline-catch of ling, and the dashed line shows annual effort (number of hooks), scaled to have mean equal to that of total bycatch.

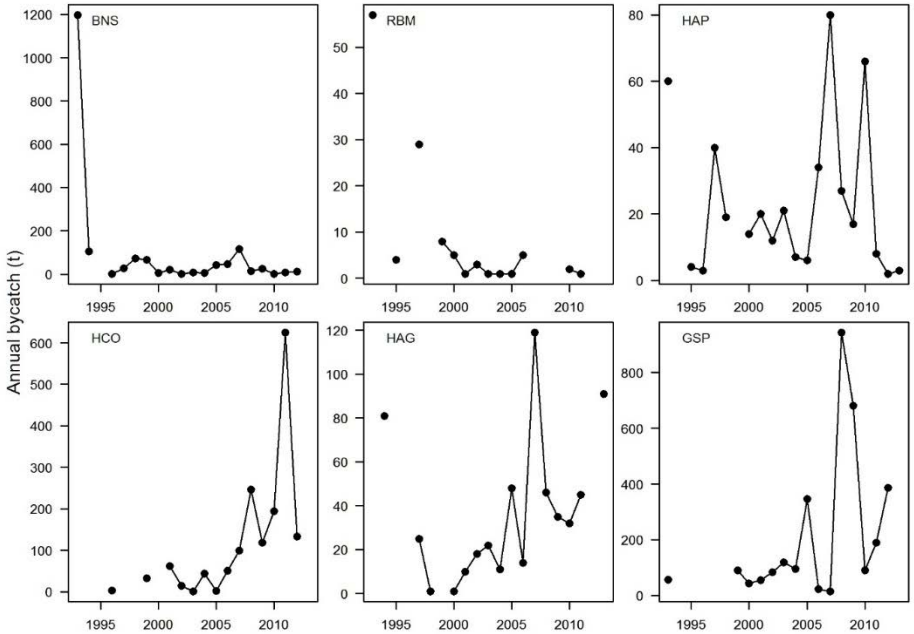

Figure 8.52: Annual bycatch estimates in the ling longline fishery for the species which had the greatest decrease (top) and greatest increase (bottom) between 1992–93 and 2012–13. Some apparent changes in bycatch may be due to improvements in observer identifications (see Section 8.3.1). See text above for species codes.

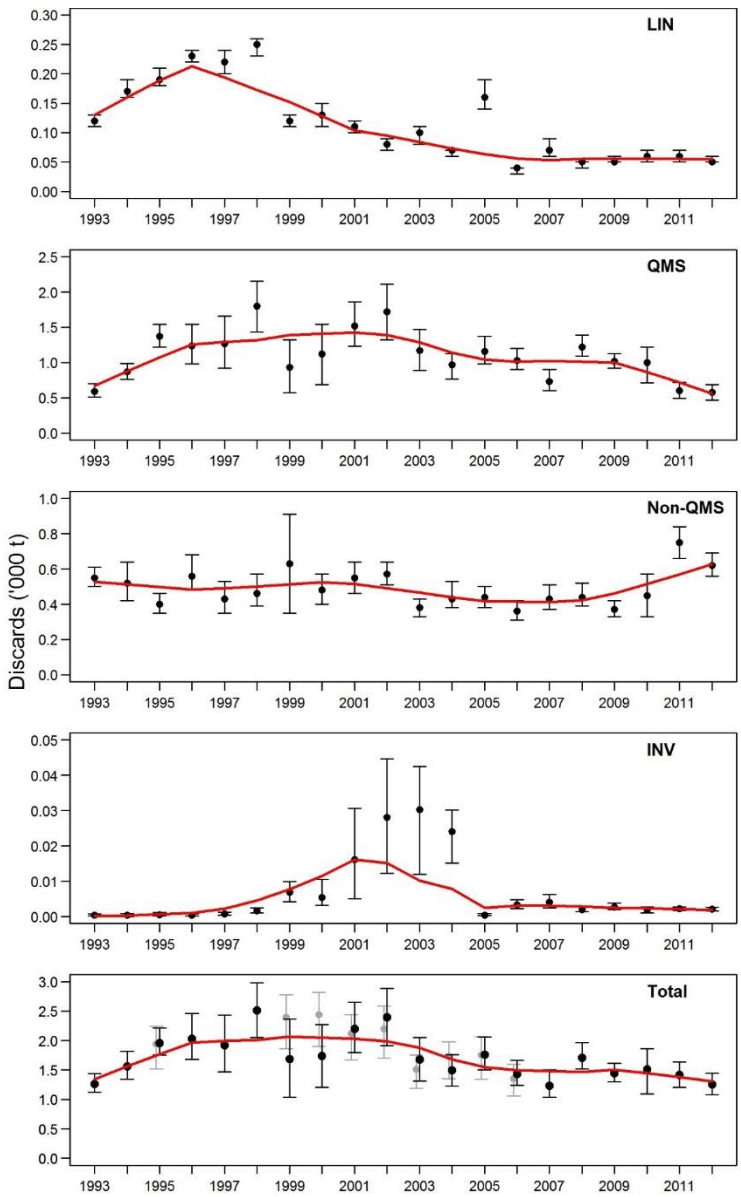

Figure 8.53: Annual estimates of discards in the ling longline fishery, for ling (LIN), QMS species, non-QMS species, invertebrates (INV), and overall for 1992–93 to 2011–12. Also shown (in grey) are earlier estimates of total discards calculated for 1994–95 and 1998–1999 to 2005–06 (Anderson 2008). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual discards.

8.3.20 TUNA LONGLINE FISHERY

The New Zealand tuna longline fishery was dominated by the foreign licensed vessels during the 1980s, but is now comprised of chartered Japanese vessels and New Zealand domestic vessels. The domestic fishing fleet dominated the fishery since 1993–94 (Figure 8.54).

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

A detailed analysis of fish bycatch in tuna longline fisheries covered the 2006–07 to 2009–10 fishing years (Griggs & Baird 2013)

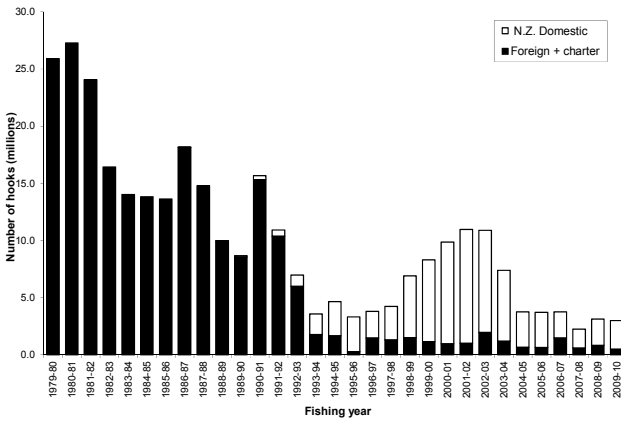

Figure 8.54: Effort (hooks set) in the tuna longline fishery. Black bars are Foreign and Charter vessels, white bars are NZ domestic vessels.

During 2006–07 to 2009–10, 111 074 fish and invertebrates from at least 62 species or species groups were observed. Most species were rarely observed, with only 37 species (or species groups) exceeding 100 observations between 1988–89 and 2009–10. The most commonly observed species over all years were blue shark, albacore tuna, and Ray's bream, these three making up nearly 70% of the catch by numbers. Blue shark and Ray's bream were the most abundant and second most abundant species in each of the four fishing years 2006–07 to 2009–10 (Table 8.2). Other important non-target species were albacore, lancetfish, bigscale pomfret, dealfish, porbeagle shark, swordfish, moonfish, mako shark, deepwater dogfish, sunfish, and oilfish. The catch composition varied with fleet and area fished.

QMS bycatch species caught were blue shark, mako shark, porbeagle shark, school shark, moonfish, Ray's bream, and swordfish. Swordfish was also sometimes targeted.

Table 8.2: Species composition of observed tuna longline catches. Number of fish observed are shown for 2006–07 to 2009–10 and all fish observed since 1988–89. Top 30 species.

	Species	Scientific Name	2006–07 to 2009–10	Total number
1	Blue shark	*Prionace glauca*	38 162	182 628
2	Albacore tuna	*Thunnus alalunga*	9 854	101 316
3	Rays bream	*Brama brama*	25 277	98 205
4	Southern bluefin tuna	*Thunnus maccoyii*	10 373	43 291
5	Porbeagle shark	*Lamna nasus*	2 235	19 011
6	Dealfish	*Trachipterus trachypterus*	2 304	17 185
7	Lancetfish	*Alepisaurus ferox* & *A. brevirostris*	5 661	14 383
8	Moonfish	*Lampris guttatus*	1 683	9 134
9	Deepwater dogfish	Squaliformes	1 600	9 112
10	Swordfish	*Xiphias gladius*	2 213	8 286
11	Big scale pomfret	*Taractichthys longipinnis*	2 954	7 818
12	Oilfish	*Ruvettus pretiosus*	711	7 542
13	Mako shark	*Isurus oxyrinchus*	1 676	6 162
14	Rudderfish	*Centrolophus niger*	373	4 907
15	Butterfly tuna	*Gasterochisma melampus*	617	4 469
16	Escolar	*Lepidocybium flavobrunneum*	643	4 422
17	Bigeye tuna	*Thunnus obesus*	1 240	4 390
18	School shark	*Galeorhinus galeus*	419	3 620
19	Yellowfin tuna	*Thunnus albacares*	97	3 342
20	Sunfish	*Mola mola*	1 000	2 755
21	Pelagic stingray	*Pteroplatytrygon violacea*	585	2 398
22	Hoki	*Macruronus novaezelandiae*	265	2 021
23	Thresher shark	*Alopias vulpinus*	169	1 400
24	Skipjack tuna	*Katsuwonus pelamis*	38	1 151
25	Dolphinfish	*Coryphaena hippurus*	134	608
26	Flathead pomfret	*Taractes asper*	158	516
27	Striped marlin	*Tetrapturus audax*	59	468
28	Black barracouta	*Nesiarchus nasutus*	51	386
29	Barracouta	*Thyrsites atun*	10	357
30	Pacific bluefin tuna	*Thunnus orientalis*	34	222

Most blue, porbeagle, mako, and school sharks were processed in some way, either being finned or retained for their flesh, but there were significant fleet differences. Blue sharks were mainly just finned. Most albacore, swordfish, yellowfin tuna, moonfish and Ray's bream were retained. Most bigscale pomfret, escolar, oilfish and rudderfish were discarded, with some year and fleet differences. Almost all deepwater dogfish, dealfish, and lancetfish were discarded.

8.3.21 ALBACORE TUNA TROLL FISHERY

This fishery was carried out by small domestic vessels fishing over the summer months mainly on the west coast of the North and South Island, especially WCSI.

Observers began to go to sea on troll vessels in 2007. The first two years were a trial period with one trip observed in each year. Targets were set in 2009. Coverage was 0.5–1.5% of days fished for the 2009–10 to 2012–13 fishing years.

Albacore was 94.4% of the observed catch over the past seven years, followed by Ray's bream (2.7%), Skipjack tuna (1.7%), and small numbers (less than 1%) of a few other species (Table 8.3).

Table 8.3: Species composition of observed albacore troll catches, 2006–07 to 2012–13.

Species	Scientific name	Number of fish caught							
		2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	Total of 7 years
Albacore tuna	*Thunnus alalunga*	1 684	1 776	1 755	5 403	4 905	2 772	3 881	22 176
Rays bream	*Brama brama*		18	12	537	35	7	15	624
Skipjack tuna	*Katsuwonus pelamis*	1	2	26	20	359	2		410
Barracouta	*Thyrsites atun*			1		24	13	23	61
Kahawai	*Arripis trutta*			6		3	14	14	37
Kingfish	*Seriola lalandi*			2	4	4			10
Dolphinfish	*Coryphaena hippurus*				1				1
Mako shark	*Isurus oxyrinchus*						1	1	2
Unidentified		2			174				176

8.3.22 SKIPJACK TUNA PURSE SEINE FISHERY

Skipjack tuna was 98.5% of the catch observed on purse seine vessels in New Zealand waters (Anon 2013).

Catch composition from six observed purse seine trips operating within New Zealand fisheries waters in 2011 and 2012 can be seen in Table 8.4.

Table 8.4: Catch composition from six observed purse seine trips operating within New Zealand fisheries waters in 2011 and 2012. [Continued on next page]

Common name	Scientific name	Observed catch (2011 & 2012)	
		weight (kg)	% of total
Skipjack tuna	*Katsuwonus pelamis*	4 360 758	98.50
Jack mackerel	*Trachurus* spp.	37 207	0.84
Blue mackerel	*Scomber australasicus*	17 760	0.40
Sunfish	*Mola mola*	4 516	0.10
Spine-tailed devil ray	*Mobula japanica*	1 990	0.04
Striped marlin	*Tetrapturus audax*	1 320	0.03
Frigate tuna	*Auxis thazard*	1 090	0.02
Albacore tuna	*Thunnus alalunga*	683	0.02

Table 8.4 [Continued]: Catch composition from six observed purse seine trips operating within New Zealand fisheries waters in 2011 and 2012.

Common name	Scientific name	Observed catch (2011 & 2012)	
		weight (kg)	% of total
Jellyfish	Scyphozoa	459	0.01
Mako shark	*Isurus oxyrinchus*	418	0.01
Thresher shark	*Alopias vulpinus*	275	0.01
Swordfish	*Xiphias gladius*	150	<0.01
Hammerhead shark	*Sphyrna zygaena*	145	<0.01
Bronze whaler shark	*Carcharhinus brachyurus*	80	<0.01
Ray's bream	*Brama brama*	80	<0.01
Frostfish	*Lepidopus caudatus*	74	<0.01
Flying fish	Exocoetidae	71	<0.01
Slender tuna	*Allothunnus fallai*	50	<0.01
Porcupine fish	*Allomycterus pilatus*	47	<0.01
Moonfish	*Lampris guttatus*	40	<0.01
Stingray	Dasyatidae	40	<0.01
Blue shark	*Prionace glauca*	30	<0.01
Discfish	*Diretmus argenteus*	25	<0.01
Snapper	*Pagrus auratus*	15	<0.01
Electric ray	*Torpedo fairchildi*	14	<0.01
Pufferfish	*Sphoeroides pachygaster*	9	<0.01
Octopus	Octopoda	7	<0.01
Squid	Teuthoidea	7	<0.01
Garfish	*Hyporhamphus ihi*	5	<0.01
Starfish	Asteroidea & ophiuroidea	3	<0.01
Salp	*Doliolum* spp.	3	<0.01
Paper nautilus	*Argonauta nodosa*	2	<0.01
Pelagic ray	*Pteroplatytrygon violacea*	2	<0.01
John dory	*Zeus faber*	2	<0.01
Leatherjacket	*Meuschenia scaber*	2	<0.01
Rudderfish	*Centrolophus niger*	2	<0.01
Smooth skate	*Dipturus innominatus*	2	<0.01
Gurnard	*Chelidonichthys kumu*	1	<0.01
Jack mackerel	*Trachurus murphyi*	1	<0.01
Natant decapod	Decapoda	1	<0.01
Pipefish	Syngnathidae	1	<0.01

8.4 INDICATORS AND TRENDS

A standard measure that can be used to characterise a fishery is the level of annual discards as a fraction of the catch of the target species. The most recent estimates (mean of last 4 years) are provided in Table 8.5 for those fisheries where the necessary data were available. The largest mean discard fraction was from the scampi trawl fishery where 4.2 kg of bycatch was discarded for every kilogram of scampi caught, and the smallest discard fraction was in the southern blue whiting fishery (0.005 kg).

Comparison of estimates of total bycatch over time from all the deepwater trawl fisheries (Figure 8.55) shows the substantial total bycatch from the large hoki/hake/ling fisheries (2015–16 hoki total TACC of 160 000 t) even though the relative amounts of *discards* from these fisheries are low (see Table 8.5). This also shows the relatively large bycatch from the scampi fishery (2015–16 scampi total TACC of 1224 t) and the arrow squid fishery (2015–16 arrow squid total trawl TACC of 77 120 t).

Some general trends were identified in some fisheries, especially those examined in recent MPI projects where the determination of trends in the rates and levels of bycatch over time was an explicit objective (Table 8.6).

Table 8.5: Fishery efficiency. Kilograms of discards per kilogram of target species catch. The numbers are the most recent estimate (mean of the most recent 4 years available) from published reports.

Fishery	Discards/target species catch (kg)
Arrow squid trawl	0.05
Ling longline	0.34
Hoki/hake/ling trawl	0.03
Jack mackerel trawl	0.011
Southern blue whiting trawl	0.005
Orange roughy trawl	0.04
Oreo trawl	0.03
Scampi trawl	4.2

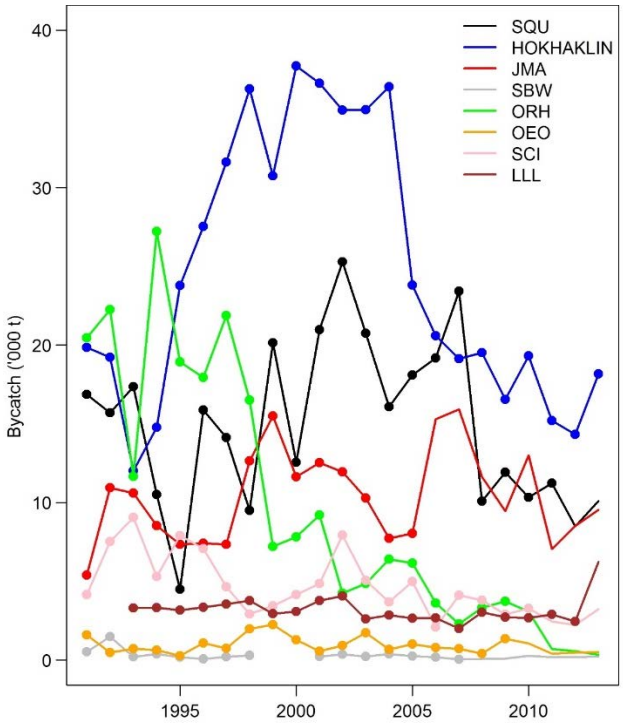

Figure 8.55: Comparison of total estimated bycatch for all the deepwater trawl fisheries 1990–91 to 2012–13. Dots are precision based estimates; no dots are coarse based estimates (see Ballara 2015 for more details). For species codes see Table 8.1).

Table 8.6: Trends in non-protected species bycatch from recent MPI projects where trend determination was an objective.

Fishery	Trends
Arrow squid trawl	Linear regression modelling of observer catch data indicated increased bycatch rates over time (positive slopes) in all species categories and areas except for QMS species in the Stewart-Snares Shelf and Banks Peninsula fisheries. These trends were statistically significant (p<0.05) for non-QMS species in the Stewart-Snares Shelf fishery and for invertebrate species in all areas. Bycatch quantities for the fishery as a whole also increased over time in each species category, and this increase was significant (p<0.05) for invertebrates. Discard rates increased over time in all species categories and areas except for arrow squid in the Banks Peninsula fishery. These trends were statistically significant (p<0.05) for QMS species in the Auckland Islands fishery, non-QMS species in the Stewart-Snares Shelf fishery, and for invertebrate species in the Auckland Islands and Banks Peninsula fisheries. Discard quantities for the fishery as a whole increased over time in all species categories, and this increase was significant (p<0.05) for non-QMS species discards and total discards.
Orange roughy trawl	Increased non-commercial species bycatch quantities between the mid-1990s and mid-2000s were shown to strongly correlate with an overall increase in mean trawl length in the fishery resulting from increased effort away from undersea features (Anderson 2009).
Scampi trawl	Linear regression modelling of observer catch data indicated significant trends of decreased bycatch quantities over time for QMS species and total species bycatch and a significant trend of increased bycatch quantities for invertebrates (Figure 8.26). A significant trend of increased discard quantities over time was shown for invertebrates, both rattail categories, and for rattails overall (Figure 8.28). Recent fleet-wide alterations to the nets that provided escape gaps for larger unwanted fish species (e.g., skates) may be responsible for the above trends. These escape gaps allow for longer tows, as the nets fill up less rapidly.
Ling longline	Linear regression modelling of observer catch data indicated increasing bycatch rates (kg/hook) for both QMS species and

	non-QMS species in LIN 2, and for QMS species in COOK; and decreasing bycatch rates for both QMS species and non-QMS species in BNTY, and QMS species in LIN 4. There were also decreasing discard rates of ling and QMS species in some areas, notably the Bounty and Campbell Plateaus, and increasing discard rates for both QMS species and non-QMS species in LIN 2.

Ballara (2015b) analysed temporal (1990–91 to 2012–13) bycatch trends for individual species or species groups for seven Deepwater trawl and one bottom longline (ling) fisheries. A summary of the bycatch regression slope coefficients for each species and fishery is provided in graphical form in Appendix 17.10, and broken down by area in Appendix 17.11-12. This showed a consistent increase (in six or more of the eight fisheries) for deepsea skates (*Notoraja* spp.), Baxters lantern dogfish (*Etmopterus baxteri*), pale ghost shark (*Hydrolagus bemisi*), and javelinfish (*Lepidorhynchus denticulatus*); and consistent decline for bluenose (*Hyperoglyphe antarctica*), dark ghost shark (*Hydrolagus novaezealandiae*), and skates (*Rajidae* and *Arhynchobatidae*). Some of the trends may be attributable to changes in reporting behaviour, e.g., increased reporting of specific skates and reduced use of the generic skate category. It seems likely that a bycatch decline for well-known species such as bluenose may represent a change in availability, abundance or distribution of that species.

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9 CHONDRICHTHYANS (SHARKS, RAYS AND CHIMAERAS)

Scope of chapter	This chapter outlines the relevant biology of New Zealand chondrichthyans, the nature of any fishing interactions, the management approach, and trends in key indicators of fishing effects. This chapter covers Quota management System (QMS), non-QMS and protected sharks.
Area	All of the New Zealand EEZ and Territorial Sea.
Focal localities	This differs depending upon the species or fishery examined
Key issues	Sustainability of fisheries extractions
Emerging issues	Risk assessment of fisheries extractions
MPI Research (current)	POS2013-01 Abundance indicators for blue, porbeagle and mako sharks SEA2014-03 Shark fin and dressed weight conversion factors for selected sharks SEA2013-16 Shark, ray and chimaera qualitative risk assessments SEA2013-10 Porbeagle shark movements from tagging HMS2013-02 Catch composition of porbeagle sharks in tuna longline fisheries HMS2014-02 Catch composition of mako sharks in tuna longline fisheries HMS2014-05 Stable isotope analysis of highly migratory species SEA2013-11 Trends in blue shark catch rates in tuna longline fisheries ZBD2011-01 Diets of highly migratory species ZBD2011-01 Factors affecting the distribution of highly migratory species HHS2013-01 Hammerhead shark movements estimated by tagging INS2014-01 Abundance indicators for 8 sharks and chimaeras ENV2014-02 Age and growth of 7 sharks and rays SPO2015-01 Characterisation and CPUE of rig stocks
Other Govt Research (current)	DOC CSP Research: MIT2013-04 Basking shark mitigation: detection and avoidance. MIT2011-01 Protected rays – mitigate captures and assess survival of live-released animals. DOC14304 Review of fishery interactions and biology of oceanic whitetip shark MBIE project (C01X0905): Conservation of New Zealand's threatened iconic marine megafauna.
University research	Biological and behavioral research is currently being carried out at Waikato, Otago, Victoria and Auckland universities on a variety of species (including white shark, Lucifer's dogfish, longnose spookfish, Pacific spookfish, prickly dogfish, broadnose sevengill shark, blue shark) and on mitigating the bycatch of sharks on longlines. This list may not include all university research.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
Related issues/chapters	See the Non-protected species (fish and invertebrates) bycatch chapter. More detail is provided for QMS species in the stock assessment plenary (MPI 2015).

Note: This chapter was revised for the AEBAR 2015.

9.1 CONTEXT

Chondrichthyans (cartilaginous fishes) comprise all fish species (except lampreys and hagfish) that lack true bone in their skeletons, specifically sharks, rays, skates and chimaeras. In New Zealand, seven chondrichthyans are totally protected under the Wildlife Act (1953). The impacts of fishing on chondrichthyans are managed under the Fisheries Act (1996), with eleven species subject to the Quota Management System (QMS) and two species prohibited as target species. The management policy framework is contained in Fisheries Plans developed for Deepwater, Highly Migratory, and Inshore fisheries (see Chapter 1 for fuller descriptions and web links).

New Zealand has international obligations to collaborate with other countries in the assessment and management of shared and migratory chondrichthyan stocks. New Zealand participates in a number of Regional Fisheries Management Organisations that have some responsibility for chondrichthyans, including Western and Central Pacific Fisheries Commission (which manages tuna fisheries and the associated species), Commission for the Conservation of Southern Bluefin Tuna (southern bluefin tuna), Commission for the Conservation of Antarctic Marine Living Resources (toothfish), and the South Pacific Regional Fisheries Management Organisation (multiple non-Highly Migratory Species). New Zealand is also a signatory to conventions that play a role in the management of some species, including the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the Convention on the Conservation of Migratory Species of Wild Animals.

To address global concerns about the management of chondrichthyans[1], the Food and Agriculture Organisation of the United Nations (FAO) developed an International Plan of Action for the Conservation and Management of Sharks (IPOA)[2]. The IPOA builds upon the FAO Code of Conduct for Responsible Fisheries and was endorsed by the FAO Council in June 1999 and subsequently adopted by the November 1999 FAO Conference. The overarching goal of the IPOA is: 'to ensure the conservation and management of sharks and their longterm sustainable use.' To achieve this goal the IPOA suggests that each member state of FAO that regularly catches sharks, either as target or incidental catch, should develop a National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks).

New Zealand developed an NPOA–Sharks that came into effect in October 2008 (Ministry of Fisheries 2008), this has since been superseded by the NPOA-Sharks 2013 (Ministry for Primary Industries 2013). The purpose of the NPOA-Sharks 2013 is:

> "To maintain the biodiversity and the long-term viability of all New Zealand shark populations by recognising their role in marine ecosystems, ensuring that any utilisation of sharks is sustainable, and that New Zealand receives positive recognition internationally for its efforts in shark conservation and management."

It aims to achieve this purpose by identifying goals and five-year objectives in the following key areas:

- Biodiversity and long-term viability of shark populations;
- Utilisation, waste reduction and the elimination of shark finning;
- Domestic engagement and partnerships;
- Non-fishing threats;
- International engagement;
- Research and information.

It is a comprehensive plan to focus efforts to improve our research and information on shark populations, and base conservation and management actions on an assessment of risks.

The NPOA-Sharks applies to all chondrichthyans that are found within New Zealand's Exclusive Economic Zone (EEZ) and Territorial Sea (New Zealand fisheries waters), migratory species that frequent New Zealand fisheries waters, and species taken by New Zealand-flagged vessels fishing on the High Seas (including the Ross Sea, Antarctica). Appendix 9.1 provides a list of all 117 known New Zealand chondrichthyans, along with their management class and IUCN and Department of Conservation threat classes.

9.2 BIOLOGY

The population dynamics of chondrichthyans differ markedly from those of bony fishes. Chondrichthyans have a mammal-like reproductive strategy of producing a small number of well-developed young, rather than spawning large numbers of undeveloped eggs as do most bony fishes. Chondrichthyans either lay large yolky eggs on the seabed

or give birth to live young, but in both reproductive modes the number of young produced annually is usually in single digits or in the low tens. A few species may produce more

[1] In the IPOA and in the NPOA–Sharks, 'sharks' are defined to include all chondrichthyans, viz. sharks, rays and chimaeras. However, in this chapter, we use the terms chondrichthyans, sharks, rays, chimaeras in their strict sense to avoid confusion. Skates are a type of ray and are grouped with rays.

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

than 100 young per litter (e.g. blue shark has up to 135 young (Last & Stevens 2009)) but even in these more fecund species, large litter sizes are exceptional and the average number of young per female is much lower (30–40 in the blue shark (Last & Stevens 2009)). Gestation periods and reproductive cycles last 10 months to two years in many species, and may be as high as three years (e.g. school shark, mako shark (Mollet et al 2000, Walker 2005)). Fecundity may increase with the size of females (e.g. rig and school shark (Francis & Mace 1980, Walker 2005)) so if human activities reduce the average size of females in a population (as often happens in fisheries) the reproductive output may decline faster than the rate of population decline. These characteristics mean that chondrichthyans have a much closer, potentially almost linear, relationship between population size and recruitment. They also have limited potential for density-dependent compensatory mechanisms that might boost reproductive output at low population sizes.

Many cartilaginous fishes are also long-lived and slow growing, further reducing their capacity for recovering from population declines. Many species have ages at maturity greater than 10 years and longevities in excess of 20 years, although some are faster growing and are therefore more productive (e.g. rig (Francis & Ó Maolagáin 2000)). The combination of low reproductive rate and low growth rate makes chondrichthyans particularly vulnerable to overfishing (Camhi et al 1998, Smith et al 1998, Dulvy et al 2003, Pikitch et al 2008, Simpfendorfer & Kyne 2009).

Six feeding studies have been carried out in the last few years on a suite of middle depth to deepwater chondrichthyans, mainly using stomach content data collected during Chatham Rise trawl surveys (Jones 2008, 2009, Dunn et al 2010a, 2010b, Forman & Dunn 2012, Dunn et al 2013). The diets of blue, porbeagle and mako sharks have been analysed using samples collected by observers on tuna longline vessels (Horn et al 2013). Fish and squid were the primary prey of shark species, with chimaeras having a diet dominated by benthic invertebrates, and skates also feeding on benthic and natant invertebrates. There was evidence of both depth- and diet-related niche separation. In one study, DNA testing was used to identify stomach contents. The importance of discards in the diet of some sharks and rays was highlighted. In a seventh study, juvenile rig were found to feed mainly on benthic crustaceans such as mud crabs and snapping shrimps in estuaries around New Zealand (Getzlaff 2012).

9.3 GLOBAL UNDERSTANDING OF FISHERIES INTERACTIONS

There are numerous examples worldwide of chondrichthyan stocks collapsing under fishing pressure, and until recently little attention has been focused on their management. This situation reflects the generally low importance of chondrichthyans in terms of quantity and value in commercial catches, and the consequent low research and management priority accorded to them. However the rapid increase in demand for, and value of, shark fins over the last two decades has resulted in a rapid increase in chondrichthyan fishing mortality throughout the world, although there is evidence of a sharp decline in the shark fin trade since 2011 (Dent & Clarke 2015), and many chondrichthyan populations are now believed to be severely depleted. There is also widespread public opposition to shark 'finning', in which only the fins are kept and the rest of the shark is discarded at sea, because of concerns about sustainability, wastage, and finning of live sharks. (Live shark finning is an offence under the Animal Welfare Act 1999). Shark finning was banned in New Zealand in October 2014. The results of this ban are expected to become apparent in the next fishing year.

Chondrichthyans are caught by most fishing methods, although trawling, netting and lining are the most important. Chondrichthyans are caught in nearly all parts of the world, ranging from tropical to arctic/antarctic waters, and from estuaries and shallow coastal waters to the deepest areas fished. Historically, most chondrichthyan catches worldwide have been taken as bycatch in fisheries for other target species. However, the increased value of shark fins has driven a move towards target fishing for some shark species elsewhere in the world, and increased utilisation of incidentally caught sharks. Consequently reported global landings of chondrichthyans increased steadily up to almost 900 000 t in the early 2000s but have been declining since then (Worm et al 2013). However unreported catches are undoubtedly substantial so the true extent of chondrichthyan catches remains unclear (Bonfil 1994, Camhi et al 1998, Clarke et al 2006, Worm et al 2013). Furthermore, the survival of discarded chondrichthyans has rarely been quantified: measures of mortality rates of chondrichthyans at the time they are hauled to a fishing vessel are available for some species (Francis et al 1999a, Campana et al 2009, Griggs & Baird 2013), but estimates of subsequent survival of live releases are rare (Moyes et al

2006, Campana et al 2009, Musyl et al 2011, Hutchinson et al 2013).

Despite these uncertainties, there is ample evidence that many chondrichthyan populations are now over-fished and that fishing effort is still expanding in habitats containing some of the most vulnerable species, especially deepwater chondrichthyans (Kyne & Simpfendorfer 2007, Simpfendorfer & Kyne 2009, Rice & Harley 2012a, 2012b). Management measures have been implemented by many countries, particularly for targeted species, and Regional Fisheries Management Organisations are paying greater attention to the need to manage species that occur in international waters or straddle the national waters of multiple countries. Efforts are also focusing on reducing shark finning, particularly in fisheries catching pelagic sharks, by requiring fins to be attached to sharks at the point of landing, or to comprise no more than 5% of the landing by weight. However it is not clear that this requirement has been effective in reducing catches (Clarke et al 2012, Worm et al 2013).

9.4 STATE OF KNOWLEDGE OF FISHERIES INTERACTIONS IN NEW ZEALAND

A total of 117 chondrichthyans are known from New Zealand waters (including the Ross Sea), however that number is expected to grow slightly as taxonomic studies continue on deepwater species. Of these species, 12 are chimaeras, 30 are skates and rays, and 75 are sharks. Many New Zealand species also occur elsewhere in the world (some have worldwide distributions) but a high percentage (30%) are endemic to New Zealand. New Zealand's chondrichthyan fauna is small compared with that in Australia, which has more than 322 species (Last & Stevens 2009), but that partly reflects New Zealand's lack of tropical environments. The high percentage of endemic species makes New Zealand's fauna unique and distinctive.

The largest threat to chondrichthyan populations is from fishing activities, although other potential impacts include underwater noise, dredging, sonar surveys, electromagnetic fields generated by power stations and undersea cables, loss of habitat, eutrophication and sedimentation, entrapment by aquaculture facilities, and shark ecotourism (Francis & Lyon 2013, Jones et al 2015). More than 70 of New Zealand's chondrichthyan species are caught (deliberately or incidentally) by fishers (Ministry for Primary Industries 2013). Eleven chondrichthyans are managed under the QMS (Ministry for Primary Industries 2013, 2015), seven are fully protected (Francis & Lyon 2012), two cannot be targeted, and the remainder are Non-QMS species (Appendix 9.1). Due to reporting requirements commercial landings of chondrichthyans are relatively well known, but less is known about recreational and customary catches.

A nationwide survey from 1 October 2011 to 30 September 2012 provides the most reliable estimates of recreational chondrichthyan catches (Table 9.1) (Wynne-Jones et al 2014). The majority of the recreational catch is from inshore QMS species; mako is the only shark listed that is not normally considered an inshore species. 'Stingray' is likely to include more than one species and 'sand shark' is likely to refer mainly to rig or school shark. Mako sharks are also targeted/bycatch in the gamefish charter boat fishery, so estimates for mako are potentially underestimates as the survey was not designed to sample gamefishers on charter boats. Estimates in tonnes are only available for rig and spiny dogfish and these constitute 4.0% and 0.4% percent respectively of the reported commercial landings in the same year for those species. All subsequent data reported in this chapter are from the commercial fishery.

Commercial catches of chondrichthyan species during the five-year period 2009–10 to 2013–14 are shown in Table 9.1 and Figure 9.1. Spiny dogfish produced by far the greatest catches, followed by school shark. Dark ghost shark, rough skate, rig and elephantfish formed a second tier of species, and blue shark, pale ghost shark, smooth skate, carpet shark and seal shark formed a third tier; the remaining species had relatively low catches (less than 215 t per year on average). Unspecified sharks and unspecified dogfish were both important categories, indicating that fishers were not accurately recording all catches to species level. Reported discards in 2012–13 to 2013–14 were significant for spiny dogfish, seal shark, carpet shark, shovelnose dogfish and other deepwater and unspecified sharks (Table 9.3). Live releases of seven specified chondrichthyans are permitted under Schedule 6 of the Fisheries Act, and from 2006–07 such releases were not counted against quota (Table 9.4). Spiny dogfish may also be discarded dead, but are be counted against a fisher's Annual Catch Entitlement (ACE) and the total allowable catch limit for that species against quota. Live releases in 2012–13 to 2013–14 were significant for blue, porbeagle and mako sharks, and smooth skates (Table 9.3). The conditions of Schedule 6 releases have been amended for mako, porbeagle, and blue shark. From 1 October 2014, fishers were allowed to return these three species to the

sea both alive and dead, although the status must be reported accurately. Those returned to the sea dead are counted against a fisher's Annual Catch Entitlement (ACE) and the total allowable catch limit for that species. The survival rate of discarded and released sharks is unknown, and probably varies enormously with species, fishing method, handling, and other factors.

9.4.1 QMS SPECIES

The eleven chondrichthyans managed under the QMS are shown in Table 9.4 with their Total Allowable Commercial Catches (TACCs) and 2013–14 landings. Landings of all but two species (rough skate and elephantfish) were below the TACCs.

QMS chondrichthyans are treated in detail in MPI's annual Fisheries Assessment Plenary reports (Ministry for Primary Industries 2014, 2015) and that material is not repeated here. Quantitative stock assessments have been attempted for only three chondrichthyan stocks (rig in SPO 3 and SPO 7, and elephantfish in ELE 3) but only the assessment for SPO 7 was accepted and adopted by the MPI Southern Inshore Working Group. The status of other stocks has been estimated from trends in standardised CPUE and trawl surveys.

A summary of the status of the stocks of QMS chondrichthyans is given in Appendix 9.2. Stock status has been estimated for six of the 11 QMS chondrichthyans, and 18 of the 45 stocks. None of the stocks was considered to be below the 'hard limit' reference point, one stock (SPO 7) was considered unlikely (<40%) to be below the 'soft limit'. No stocks were considered to be in an 'overfishing' state; the remainder of the stocks were considered to be in a favourable state.

9.4.2 PROTECTED SPECIES

Seven chondrichthyans are currently protected in New Zealand fisheries waters: white shark (also known as white pointer shark) was protected in 2007; spinetail devilray, manta ray, whale shark, deepwater nurse shark and basking shark in 2010; and oceanic whitetip shark in 2013.

Under-reporting of protected species by commercial fishers introduces a major bias into estimates of fishery interactions (Francis & Lyon 2012), but good observer coverage can go a long way to overcoming these biases. Observer coverage has been reasonably good over the last decade (2002-03 to 2012-13) or more in some large valuable fisheries (e.g. trawl fisheries for hoki (9.3 – 38.7% per year) and orange roughy (11.6 – 43.9% per year), and on licensed foreign fishing vessels (e.g. in the southern bluefin longline fishery (32.3 – 56.6% per year)). Some trawl fisheries around southern New Zealand and skipjack tuna purse seine fisheries in northern New Zealand also had reasonable coverage over about the last decade (southern blue whiting (25.2 – 99.9% per year), squid (12.9 - 85.9% per year) and tuna (12 – 29.1% per year 2005-06 to 2012-13), providing good information on captures of basking sharks, white sharks and spinetail devilrays. However, observer coverage has not always been representative of the spatial and temporal distribution of these fisheries. Inshore fisheries, notably set net, bottom longline, and trawl fisheries, have received only sparse observer coverage. These fisheries may have unobserved and unrecorded mortality of some protected species, especially basking shark, white shark and deepwater nurse shark.

BASKING SHARK

Basking sharks are frequently taken as bycatch around southern New Zealand (Francis & Lyon 2012). The main capture locations are the east coast South Island off Banks Peninsula (FMA 3), the west coast South Island between Westport and Hokitika, Puysegur (FMA 7), the shelf edge south and east of Stewart Island (FMA 5) and the Snares Islands, and around the Auckland Islands (FMA 6). Captures (and sightings) of basking sharks also occurred around North Island but were relatively uncommon (Francis & Duffy 2002, Francis & Sutton 2012).

Most basking shark records came from trawl fisheries. The sharks were caught mainly by vessels targeting barracouta and hoki off east coast South Island, hoki off west coast South Island, and arrow squid off Southland-Auckland Island. Basking sharks are also caught in set nets (Francis & Duffy 2002) but have rarely been reported by fishers since they were protected in 2010 (Francis & Lyon 2012). The observer coverage of this fleet has been low, so the set net bycatch cannot be quantified. Basking sharks are rarely entangled in surface longlines (Francis & Duffy 2002).

Table 9.1: Recreational harvest estimates for New Zealand chondrichthyan species for the 2011–12 fishing year. Mean fish weights are only available for two species, otherwise only the counts are shown. Mgmt class = Management class, QMS is shown, all others are Non-QMS and non-protected species; CV = Coefficient of variation of the estimate to the left. Reproduced in part from Wynne-Jones et al (2014).

Species	Mgmt class	Fishers (n)	Events (n)	Harvest (n)	CV	Mean Weight (kg)	Harvest (tonnes)	CV
Rig	QMS	159	241	47 718	0.14	1.09	52.05	0.14
School Shark	QMS	95	160	30 555	0.17	-	-	-
Spiny Dogfish Shark	QMS	97	119	22 200	0.19	1.02	22.60	0.19
Stingray		46	59	11 053	0.40	-	-	-
Elephant Fish	QMS	24	47	6 198	0.34	-	-	-
Sand Shark		10	18	3 719	0.54	-	-	-
Hammerhead Shark		10	12	1 429	0.34	-	-	-
Bronze Whaler Shark		5	5	570	0.52	-	-	-
Mako Shark	QMS	5	6	529	0.51	-	-	-
Carpet Shark		3	5	452	0.67	-	-	-

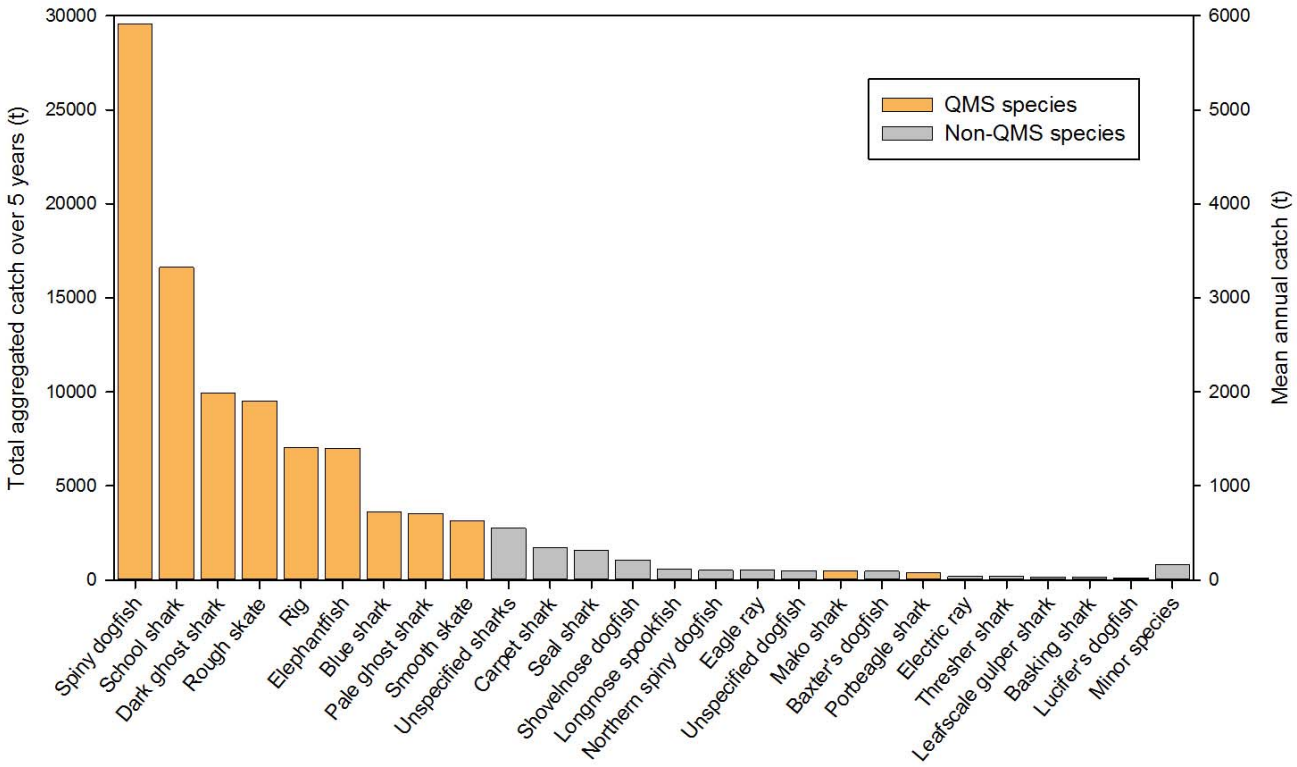

Figure 9.1: Reported total catches (landings, discards and live releases) for chondrichthyan species aggregated across 2009–10 to 2013–14. The average annual catches are shown on the right axis. Source: Ministry for Primary Industries catch-effort database.

Table 9.2: Reported total catches (tonnes, including discards and live releases) for chondrichthyan species from 2009–10 to 2013–14, arranged in descending order of total catch. Only species with more than 5 t of aggregated catch are included. The management class is also shown (blanks indicate Non-QMS species). Source: Ministry for Primary Industries catch-effort database. (NB: Catches of QMS species differ from landings in Table 9.4 because they include discards and releases, and came from a different source.) * Total 5-year catches of protected species (basking shark and spinetail devilray) were estimated and scaled up from numbers of animals reported on protected species forms for the four years 2010–11 to 2013–14 (see text for details).

Species	Mgmt class	Code	2009-10	2010-11	2011-12	2012-13	2013-14	Total
Spiny dogfish	QMS	SPD	6626	6250	5704	5020	5945	29546
School shark	QMS	SCH	3389	3618	3315	3165	3144	16631
Dark ghost shark	QMS	GSH	2070	2326	2095	1712	1760	9963
Rough skate	QMS	RSK	1961	1937	1553	1919	2147	9517
Rig	QMS	SPO	1439	1457	1445	1311	1394	7045
Elephantfish	QMS	ELE	1386	1412	1382	1427	1401	7008
Blue shark	QMS	BWS	746	804	1054	740	302	3646
Pale ghost shark	QMS	GSP	799	632	695	700	719	3545
Smooth skate	QMS	SSK	581	649	580	646	708	3164
Unspecified sharks		OSD	609	597	697	586	275	2763
Carpet shark		CAR	296	349	336	340	396	1717
Seal shark		BSH	386	325	277	315	283	1587
Shovelnose dogfish		SND	192	186	145	182	367	1072
Longnose spookfish		LCH	131	97	101	117	126	572
Northern spiny dogfish		NSD	88	123	102	93	110	516
Eagle ray		EGR	81	105	108	92	130	515
Unspecified dogfish		DWD	234	98	78	35	63	508
Mako shark	QMS	MAK	76	95	160	87	56	474
Baxter's dogfish		ETB	46	47	30	41	303	467
Porbeagle shark	QMS	POS	68	77	60	94	100	400
Electric ray		ERA	30	37	38	41	48	194
Thresher shark		THR	30	38	38	37	44	187
Leafscale gulper shark		CSQ	20	14	9	30	96	169
Basking shark	Protected	BSK						165*
Lucifer's dogfish		ETL	26	17	25	32	21	121
Broadnose sevengill shark		SEV	17	18	19	20	21	95
Slender smoothhound		SSH	5	27	10	35	10	87
Short-tailed stingray		BRA	11	16	13	14	29	83
Bronze whaler shark		BWH	18	14	16	11	13	72
Long-tailed stingray		WRA	10	9	12	13	20	64
Hammerhead shark	Non-target	HHS	8	15	13	10	11	56
Unspecified stingray		STR	8	20	9	3	8	48
Longnose velvet dogfish		CYP	0	0	0	8	38	46
Giant chimaera		CHG	1	6	19	13	3	42
Deepwater spiny skate		DSK	11	13	0	8	1	33
Prickly dogfish		PDG	6	7	4	4	4	25
Spinetail devilray	Protected	MJA						24*
Unspecified skates		OSK	2	1	2	10	7	22
Unspecified rays		RAY	4	1	3	12	1	21
Unspecified chimaeras		CHI	2	11	1	2	2	17
Owston's dogfish		CYO	1	3	3	3	3	13
Longnose deepsea skate		PSK	7	2	1	1	1	11
Numbfish		BER	1	3	2	3	1	10
Plunket's shark		PLS	0	0	0	3	7	10
Sixgill shark		HEX	0	0	0	4	3	7
Softnose skate		LSK	2	1	1	1	1	5

Table 9.3: Percentages of reported total catches that were landed, discarded and released alive for chondrichthyan species from 2012–13 to 2013–14, arranged in descending order of total catch. NB: Species order differs from that in Table 9.2 because the two tables cover different time periods. Protected species are not included. Source: Ministry for Primary Industries catch-effort database.

Species	Code	Catch (t)	Landed %	Discarded %	Released %
Spiny dogfish	SPD	10965.0	39.0	61.0	0.0
School shark	SCH	6309.5	99.7	0.1	0.2
Rough skate	RSK	4065.9	97.9	0.2	1.9
Dark ghost shark	GSH	3471.6	97.8	2.2	0.0
Elephantfish	ELE	2828.6	100.0	0.0	0.0
Rig	SPO	2705.3	99.1	0.0	0.9
Pale ghost shark	GSP	1419.1	99.5	0.5	0.0
Smooth skate	SSK	1354.0	89.3	0.2	10.5
Blue shark	BWS	1042.7	75.8	4.6	19.6
Unspecified sharks	OSD	860.6	53.5	46.5	0.0
Carpet shark	CAR	735.4	10.6	89.4	0.0
Seal shark	BSH	598.5	75.4	24.6	0.0
Shovelnose dogfish	SND	549.8	71.0	29.0	0.0
Baxter's dogfish	ETB	343.2	84.3	15.7	0.0
Longnose spookfish	LCH	242.5	85.8	14.2	0.0
Eagle ray	EGR	222.1	62.5	37.5	0.0
Northern spiny dogfish	NSD	203.4	62.0	38.0	0.0
Porbeagle shark	POS	194.2	70.6	6.1	23.3
Mako shark	MAK	143.0	89.5	0.8	9.7
Leafscale gulper shark	CSQ	125.7	54.3	45.7	0.0
Unspecified dogfish	DWD	97.9	73.1	26.9	0.0
Electric ray	ERA	89.3	9.2	90.8	0.0
Thresher shark	THR	80.3	43.2	56.8	0.0
Lucifer's dogfish	ETL	52.7	50.2	49.8	0.0
Longnose velvet dogfish	CYP	45.9	76.9	23.1	0.0
Slender smoothhound	SSH	44.5	23.5	76.5	0.0
Short-tailed stingray	BRA	43.3	2.7	97.3	0.0
Broadnose sevengill shark	SEV	41.0	57.2	42.8	0.0
Long-tailed stingray	WRA	32.7	10.3	89.7	0.0
Bronze whaler shark	BWH	23.1	84.6	15.4	0.0
Hammerhead shark	HHS	20.9	95.8	4.2	0.0
Unspecified skates	OSK	16.9	12.2	87.8	0.0
Giant chimaera	CHG	16.6	20.5	79.5	0.0
Unspecified rays	RAY	13.5	1.5	98.5	0.0
Unspecified stingray	STR	10.5	3.8	96.2	0.0
Plunket's shark	PLS	10.3	19.3	80.7	0.0
Deepwater spiny skate	DSK	9.0	3.6	96.4	0.0
Prickly dogfish	PDG	7.9	9.3	90.7	0.0
Sixgill shark	HEX	6.6	6.3	93.7	0.0
Owston's dogfish	CYO	5.6	22.0	78.0	0.0
Numbfish	BER	4.1	0.9	99.1	0.0
Unspecified chimaeras	CHI	4.0	0.4	99.6	0.0
Longnose deepsea skate	PSK	1.6	1.5	98.5	0.0
Unspecified catshark	APR	1.4	86.9	13.1	0.0
Softnose skate	LSK	1.4	11.6	88.4	0.0

Table 9.4: TACCs and 2013–14 landings (tonnes) of the eleven chondrichthyans managed under the QMS. Also shown are the date of entry of each species into the QMS, and date of addition to Schedule 6 of the Fisheries Act that allows release of fish into the sea. Source: Monthly Harvest Returns (Ministry for Primary Industries 2014, 2015). (NB: Landings differ from the catches in previous table because the latter include discards and releases, and came from a different source.)

Species	Code	TACC (tonnes)	2013-14 landings	Entry into QMS	Addition to Schedule 6
Spiny dogfish	SPD	12660	5864	2004	2004
School shark	SCH	3436	3136	1986	2013
Rough skate	RSK	1986	2122	2003	2003
Dark ghost shark	GSH	3047	1817	1998	
Elephantfish	ELE	1304	1394	1986	
Rig	SPO	1941	1386	1986	2012
Pale ghost shark	GSP	1780	727	1999	
Smooth skate	SSK	849	641	2003	2003
Blue shark	BWS	1860	117	2004	2004
Porbeagle shark	POS	110	71	2004	2004
Mako shark	MAK	200	44	2004	2004

Most additional commercial records came from the early 2000s, but reporting rates appeared to be very low before 2000 (Francis & Lyon 2012). Francis & Sutton (2012) found a highly significant association between the numbers of basking sharks caught and vessel nationality in each of the three main fishery areas. This was due to relatively large numbers of sharks being caught by Japanese owned trawlers in the late 1980s and early 1990s. Other operational fleet variables and environmental variables examined were not correlated with shark catch rates. Reasons for the high catch rates by Japanese trawlers are unknown, but may relate to targeting of the sharks for their liver oil, or a relatively high abundance of sharks in the late 1980s and early 1990s (Francis & Sutton 2012).

Annual catch weights up to 2009-10 reported by commercial fishers ranged from 3 t to 150 t per year. Catch weights before 1999–2000 were undoubtedly under-reported. Since 2010, protected species bycatch has been reported on Non-Fish / Protected Species Catch Returns (NF/PSCR) . Over the four fishing years 2010-11 to 2013-14, 37 basking sharks were reported on those forms. At an average weight of 3-4 tonnes per shark (estimated weights from observers), this represents about 110-150 tonnes of total catch, or 27-37 tonnes per year. Few sharks were returned to the sea alive, and even fewer were likely to have survived their release.

WHITE SHARK

White shark captures were reported from throughout mainland New Zealand and as far south as the Auckland Islands, but not from around the other outlying islands (Francis & Lyon 2012). Regions with multiple captures included the west coast South Island off Hokitika, the southern edge of the Stewart–Snares Shelf, and the Auckland Islands Shelf. White sharks were mainly caught in FMAs 1, 5, 6 and 7.

Most white shark records came from trawl and set net fisheries with few captures reported from surface and bottom longlines. Observer coverage of the set net and bottom longline fleet has been low, so the bycatch in these fisheries is likely to have been under-estimated.

Three white sharks observed on surface longlines were recorded as struck off the line or lost. One white shark observed caught in a set net in 2009 was retained, whereas another shark was released alive. The life status of sharks observed caught on bottom longlines and in trawls was never recorded.

A maximum of 6.3 t was reported landed in 1990, but catches reported in other years have been low (and often zero). Catches of white sharks are considered to be under-reported.

WHALE SHARK

No captures of whale sharks have been reported by fishers or observers in New Zealand waters (Francis & Lyon 2012). However, a single individual was caught by a coastal trawler off South Canterbury in the late 1970s (as communicated to C. Duffy in Duffy 2005). This is exceptional, as whale sharks are typically only seen in northeastern North Island waters during summer and they are rare (Duffy 2002).

DEEPWATER NURSE SHARK (SMALLTOOTH SANDTIGER SHARK)

Deepwater nurse sharks have been reported frequently by fishers and observers from along the edge of the continental shelf between Otago Peninsula and south of the Snares Islands (Francis & Lyon 2012). Clusters of records are also available from the Chatham Islands, and off Banks Peninsula and Farewell Spit. However, the southern limit of the known distribution of deepwater nurse sharks in New Zealand is a line from Cape Kidnappers in Hawke Bay to Cape Egmont. Given that most of the records are from south of that range, and that many ODO weights were implausibly small, most records of this species are erroneous, probably owing to use of an incorrect species code. Plausible commercial and observer database records of deepwater nurse shark captures include three from FMA 2 and one from the Louisville Seamount Chain (Francis & Lyon 2012).

There are other published records of deepwater nurse sharks being caught in set nets off New Plymouth (Stewart 1997, Fergusson et al 2008), trawl in Hawke Bay, and by the NIWA research trawl vessel *Tangaroa* on the Norfolk Ridge (Garrick 1974, Stewart 1997, Fergusson et al 2008), confirming that the species is occasionally caught in northern waters. Duffy (2005) cited anecdotal information that deepwater nurse sharks were "not uncommon" bycatch in a set net fishery operating around White Island and Volkner Rocks in the eastern Bay of Plenty, but noted that this fishery had ceased. Duffy (2005) and Fergusson et al (2008) also reported the capture of deepwater nurse sharks from the same location for display at Kelly Tarlton's Sealife Aquarium from the mid 1980s to the early 2000s, but all of the sharks died and the practice was discontinued.

SPINETAIL DEVILRAY AND MANTA RAY

Spinetail devilrays and manta rays occur mainly in north-eastern North Island waters during summer (Duffy & Abbott 2003). Most if not all mobulid rays reported caught in commercial fisheries were likely to have been spinetail devilrays (Paulin et al 1982); no manta rays have been confirmed caught in New Zealand waters (Duffy 2005, Jones & Francis 2012). However, it is possible that manta rays are occasionally caught in purse seines along the north-east coast of North Island although observer coverage between 2005 and 2014 in FMA 1 skipjack tuna (0 - 31.8% per year) and mackerel purse seine fisheries (0 – 25.8% per year) have not confirmed any captures.

All commercial and observer records of mobulid rays were from the northern North Island in FMAs 1 and 9, and most records came from purse seine vessels (Francis & Lyon 2012, Jones & Francis 2012). Most observer records were from the edge of the continental shelf between the Bay of Islands and Great Barrier Island. Commercial purse seine records are available from the eastern Bay of Plenty, and there are a few commercial and observer records from the North Taranaki Bight. Three devilrays have been reported caught on surface longlines, mainly near the 1000 m depth contour. Observer and commercial records were not available before 2001–02, although devilray bycatch in purse seine catches was documented between 1975 and 1981 by Paulin et al (1982). All observed devilrays were returned to the sea by fishers. The three rays caught on surface longlines were alive when retrieved, but the life status of rays caught in purse seines was not recorded. Over the four fishing years 2010-11 to 2013-14, 153 spinetail devilrays were reported on Non-Fish / Protected Species Catch Returns. At an average weight of about 125 kg per ray (observer estimated weights), this represents about 19.1 tonnes of total catch, or about 4.8 tonnes per year.

OCEANIC WHITETIP SHARK

The oceanic whitetip shark is a tropical species that enters northern New Zealand waters only in summer, and possibly only in summers that are warmer than normal (Francis et al 1999b). Only 19 observer and two commercial fishery records are known (one of which occurred in both datasets) (Francis & Lyon 2014). All records came from surface longlines set in the Kermadec Fisheries Management Area or off the northeastern coast of North Island. Most (84%) of the observed sharks were alive when hauled to the vessel, and about half were processed in some way with the remainder being discarded (those captures pre-dated protection of the species in 2013). Given the low commercial reporting rate (1 out of 19 observed sharks) and the low observer coverage of domestic surface longliners, the interaction of the surface longline fisheries

with oceanic whitetips is considered substantially under-estimated (Ministry for Primary Industries 2012, Francis & Lyon 2014).

9.4.3 NON-QMS SPECIES

More than 50 species of Non-QMS chondrichthyans are known to be caught by fishers in New Zealand waters. However, most of them are rarely caught, rarely reported, or both). The main species known to be caught by commercial fishers (Table 9.5) can be grouped into five categories: inshore rays, inshore sharks, deepwater chimaeras, deepwater sharks and deepwater skates (Table 9.5). No analysis has been done of the interactions of most of these species with fisheries, but the presumed important fishing methods that catch these species are indicated in Table 9.5.

Inshore rays and sharks are caught by a variety of fishing methods. Closures of strips of inshore waters to set netting and trawling to protect Hector's and Maui's dolphin on the north-west coast of North Island and around much of South Island may have benefitted shark and ray species that occur there, and their habitats and nursery areas. However most of these species are highly vulnerable to trawl, set net and bottom longline, and have nurseries in shallow coastal waters and harbours that are still fished by set nets and longline, and to a lesser extent trawls. Little is known about the fishery interactions of these species (but for an analysis of hammerhead shark captures see Francis (2010)). Similarly, there is little information on the biological productivity of most of the species, but many (all of the rays and thresher shark) have very low reproductive output (a few young per year) and are therefore highly susceptible to overfishing.

Deepwater chondrichthyans are caught incidentally in deepwater trawl tows, some species in considerable quantities (Table 9.5; Blackwell 2010). Seven species of squaloid deepwater sharks, shovelnose dogfish, Baxter's dogfish, lucifer dogfish, Owston's dogfish, longnose velvet dogfish, leafscale gulper shark, and seal shark commonly occur over the middle and lower continental slope in depths greater than 600 m. Shovelnose dogfish has a wider distribution, as it also occurs on the upper and middle slope (400–600 m in depth). These seven shark species are commonly taken as bycatch in the middle depths and deepwater fisheries for hoki, orange roughy, and oreos. They are either discarded at sea, or processed for their fins and livers (Blackwell 2010). Catches of seal shark and shovelnose dogfish increased through the early 1990s, peaked in the early 2000s, and then declined, but these increases may have been affected by improved identification and reporting of deepwater shark catches (Blackwell 2010; Table 9.5). Historical data are available from the MPI Observer Programme (Figure 9.2), but coverage of the distribution of deepwater sharks has been unrepresentative.

Some species that are not caught or reported in quantities sufficient to be included in Table 9.5 may also be vulnerable to overfishing. These include endemic species with limited geographic and/or depth ranges that overlap in space with the operations of deepwater trawlers, for example Dawson's catshark (Francis 2006), and some of the rarer deepwater skates and chimaeras. Their low catch weights probably reflect their rarity.

Table 9.5: Main Non-QMS chondrichthyans caught by commercial fishers, classified by species group and depth range. Only species with more than 5 t of aggregated catch between 2009–10 and 2013–14 are included. The main fishing methods thought to catch these species are also indicated (Source: M. Francis, pers. comm.).

			Method		
Species group	Species	Code	Trawl	Bottom longline	Set net
Inshore rays	Eagle ray	EGR	+	+	+
	Electric ray	ERA	+	+	+
	Long-tailed stingray	WRA	+	+	+
	Short-tailed stingray	BRA	+	+	+
	Unspecified stingray	STR	+	+	+
	Unspecified rays	RAY	+	+	+
Inshore sharks	Bronze whaler shark	BWH		+	+
	Carpet shark	CAR	+	+	+
	Hammerhead shark	HHS		+	+
	Broadnose sevengill shark	SEV		+	+
	Thresher shark	THR	+		+
	Basking shark	BSK	+		+
Deepwater chimaeras	Giant chimaera	CHG	+		
	Longnose spookfish	LCH	+		
	Unspecified chimaeras	CHI	+		
Deepwater sharks	Baxter's dogfish	ETB	+		
	Leafscale gulper shark	CSQ	+		
	Longnose velvet dogfish	CYP	+		
	Lucifer's dogfish	ETL	+		
	Northern spiny dogfish	NSD	+		
	Owston's dogfish	CYO	+		
	Plunket's shark	PLS	+		
	Prickly dogfish	PDG	+		
	Seal shark	BSH	+		
	Shovelnose dogfish	SND	+		
	Sixgill shark	HEX	+		
	Slender smoothhound	SSH	+		
	Unspecified dogfish	DWD	+		
	Deepwater spiny skate	DSK	+		
	Longnose deepsea skate	PSK	+		
Deepwater skates	Numbfish	BER	+		
	Softnose skate	LSK	+		
	Unspecified skates	OSK	+		

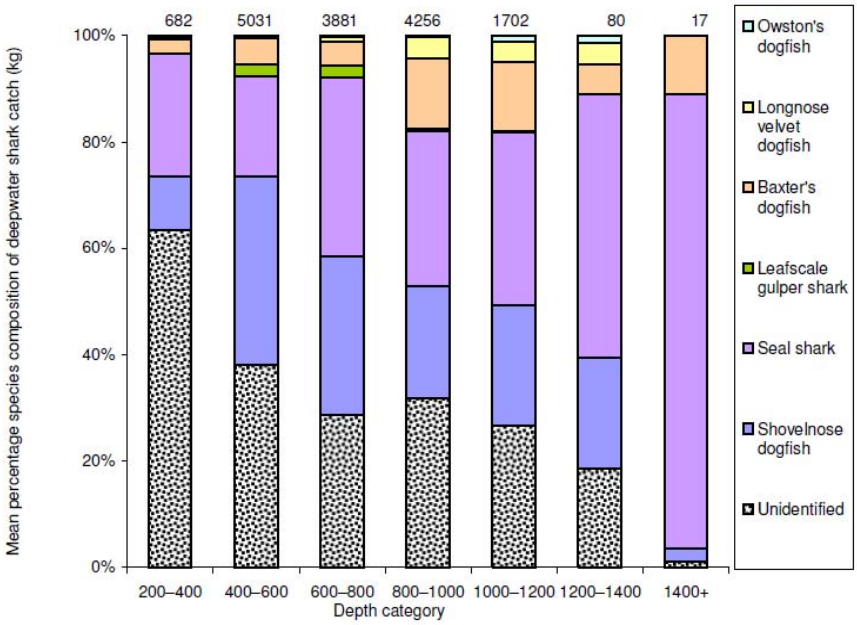

Figure 9.2: Mean catch composition of deepwater chondrichthyans reported from the Observer Programme database, all years 2001–02 to 2005–06, by major depth category (number of observations shown above bars). Source: Blackwell (2010).

9.5 INDICATORS AND TRENDS

RISK ASSESSMENT

One of the objectives of the 2013 NPOA-Sharks was to establish a risk-based approach to prioritising management actions. MPI hosted a workshop in November 2014 that produced a qualitative (level 1) risk assessment (RA) for all New Zealand chondrichthyan taxa (except for species with uncertain taxonomy) from commercial fishing. This is expected to be followed by a more quantitative (level 2) RA prior to the next review of the NPOA-Sharks in 2017.

The qualitative RA used a modified Scale Intensity Consequence Analysis approach (Ford et al. 2015). Before the workshop, data on catches, effort, distribution, abundance, and biological productivity were collated for all species and summarised to inform the RA. An expert panel then scored the relative risk to each taxon from commercial fishing, based on fishing information from the last five years, on an EEZ-wide scale. This process scored intensity and consequence of the fishery to the shark taxa, and the rationales for the scores were documented. These intensity and consequence scores were then multiplied together to get a total risk score (Ford et al. 2015). Results were reported within the three management classes of chondrichthyans - QMS, Non-QMS and Protected species.

Carpet shark (Non-QMS) and rough skate (QMS) attained the highest total risk scores, and the highest scoring protected species was basking shark (Appendix 9.3). The panel did not consider available information suggested that commercial fishing is currently causing, or in the near future could cause, serious unsustainable impacts to any sharks, rays or chimaera population examined. However, out of the 84 taxa considered, the panel had low confidence in the risk scores for 43 taxa and consensus was not reached for 3 taxa.

The risk assessment was designed to help prioritise actions to conserve chondrichthyans, noting that protected species are also given priority under the NPOA–Sharks (2013). The panel made a number of recommendations for research on high-risk or protected species. These included more use of existing data , grooming or analysis to improve inputs to assessment scores, better taxonomy and education to improve the identification of chondrichthyans, and collection of more biological information to improve our understanding of productivity (especially the ability of a taxon to recover from fishing impacts) (Ford et al. 2015).

QMS SPECIES

Standardised CPUE analyses have been carried out to monitor trends in the relative abundance of some stocks of 7 of the 11 QMS chondrichthyans species (rig, school sharks, elephantfish, pale ghost shark, blue shark, porbeagle shark and mako shark) (Table 9.6. 9.7). For all 20 of the stocks that are monitored, stock size is stable or increasing in recent years.

For blue, porbeagle and mako sharks, other abundance indicators have been developed in addition to standardized CPUE. They include high-CPUE (the proportion of half-degree rectangles having unstandardised CPUE greater than a specified threshold); proportion-zeroes (the proportion of half-degree rectangles having zero reported catches in a fishing year); geometric mean index (the geometric mean of the species abundances in catches; proportion of males in the catch; and median lengths of males and females (Francis et al 2014). None of the indicators for the period 2005−2013 suggested that any of the three shark species were declining. In fact, some of the indicators suggested positive trends for all three species.

Trawl survey relative abundance indices are used to monitor the populations of rig, school shark, spiny dogfish, elephantfish, rough and smooth skates, and pale and dark ghost sharks (Table 9.6, 9.7). For 20 out of 22 species/FMA combinations, abundance is stable or increasing in recent years; however smooth skate and pale ghost shark in FMA 4 have downward trends.

PROTECTED SPECIES

Of the seven protected chondrichthyan species, only the basking shark has any form of population monitoring and that is limited to assessing trends in relative abundance from incidental captures. Observer-based unstandardised CPUE analyses of trawl catches in three trawl fisheries (East Coast South Island EC, West Coast South Island WC, and Southland–Auckland Island SA) are shown in Figure 9. (Francis & Sutton 2012). Inter-annual variation was large, with peak observer records occurring in 1987–92, 1997–2000 and 2003–05 depending on the region. Some years had very low or zero CPUE. Francis & Smith (2010) used Bayesian predictive hierarchical models to estimate catches and catch rates in the three trawl fisheries from observer data between 1994–95 and 2007–08. The predicted strike rates showed no overall trend since 1994–95 in any of the three areas. A total of 95 sharks were observed in 49 165 tows in the 14-year period, an overall unstandardised capture rate of 1.9 per 1000 tows. The overall predicted capture rate was 2.5 sharks per 1000 tows, with area-specific rates of 3.9 (EC), 2.0 (WC), and 1.9 (SA) per 1000 tows. The total predicted number of captures from 1987 to 2012 was 922 individuals with a CV of 19%. Predicted captures peaked in 1997–98 and then declined steadily to low numbers. Much of the recent decline in basking shark bycatch was probably attributable to a decline in fishing effort of about 50% between 2002–03 and 2006–08 in the three areas (Francis & Smith 2010). However, unstandardised catch rates from observer data were much higher in 1988–92 than at any time since. Those high rates may be attributable to targeting by Japanese vessels (Francis & Sutton 2012). However, the very low (often zero) CPUE since then, and lack of large numbers and aggregations of basking sharks observed in Department of Conservation aerial surveys for dolphins around Banks Peninsula during the last decade (C. Duffy, DOC, pers. comm.), are cause for concern. There may not have been large aggregations of basking sharks in New Zealand waters since 1992. Whether such a long period without large aggregations is part of a long-term, natural cycle, or evidence of a decline in population abundance, cannot yet be determined (Francis & Smith 2010).

Table 9.6: Trends in abundance of QMS species monitored by standardised CPUE analysis and trawl surveys. Changes in trends through time are indicated by forward slashes, and multiple substocks or multiple indices within QMAs are separated by commas. Blanks, none or unreliable. Source: Ministry for Primary Industries (2014, 2015) unless otherwise indicated. "Recent years' refers to the last five years, but may be longer for long time series.

CPUE indices		QMA 1	QMA 2	QMA 3	QMA 4	QMA 5	QMA 6	QMA 7	QMA 8	Source
Rig	SPO	Nil, Down/ Nil, Nil	Up/Nil/Up	Nil				Down/Up, Nil	Down/Up, Nil	
School shark	SCH	Nil, Up	Nil	Nil	Nil	Nil		Nil/Up	Nil	
Elephantfish	ELE			Nil		Nil		Nil		
Pale ghost shark	GSP	Nil				Up				MacGibbon & Fu (2013)
Blue shark	BWS	Up								
Porbeagle shark	POS	Up								
Mako shark	MAK	Up								
Trawl survey indices				FMA 3	FMA 4	FMA 5	FMA 6	FMA 7		
Rig	SPO			Up/Nil				Nil		
School shark	SCH			Nil	Up					FMA 4: O'Driscoll et al. (2011)
Spiny dogfish	SPD			Nil	Nil	Nil	Nil	Nil		FMAs 5&6: Bagley et al. (2013)
Elephantfish	ELE			Nil						
Rough skate	RSK			Up/Nil	Nil			Down/Up		
Smooth skate	SSK			Up/Nil	Up/Down			Down/Up		
Dark ghost shark	GSH			Up	Up/Nil	Nil		Nil		
Pale ghost shark	GSP				Nil/Down	Up				
Legend:										
	Trend up in recent years									
	Stable in recent years									
	Trend down in recent years									

NON-QMS SPECIES

Some Non-QMS deepwater chondrichthyans have been monitored by trawl surveys on the Chatham Rise and Sub-Antarctic (Campbell Plateau) over a period of almost two decades. Trends in relative abundance indices and mean length were provided by O'Driscoll et al (2011) and Bagley et al (2013) and are summarised in Table 9.7. These survey series covered only a small part of the known distributions of these species, and it is not known how representative the results are. Most species showed no trends in biomass or mean length. However, on the Chatham Rise prickly dogfish increased and then declined. In the Sub-Antarctic, leafscale gulper shark, Baxter's dogfish and shovelnose dogfish all increased.

Anderson (2013) analysed trends in bycatch quantities caught in eight deepwater trawl fisheries from 1990–91 to 2010–11. Some species showed consistent declines or increases across six or more of the eight fisheries. Deepsea skates, Baxter's dogfish, and lucifer dogfish all increased while two groupings (unspecified sharks and unspecified skates) decreased. These trends appear to be a direct result of better reporting of deepwater sharks and skates by species code rather than by an unspecified generic code, and should not be interpreted as trends in abundance of the species.

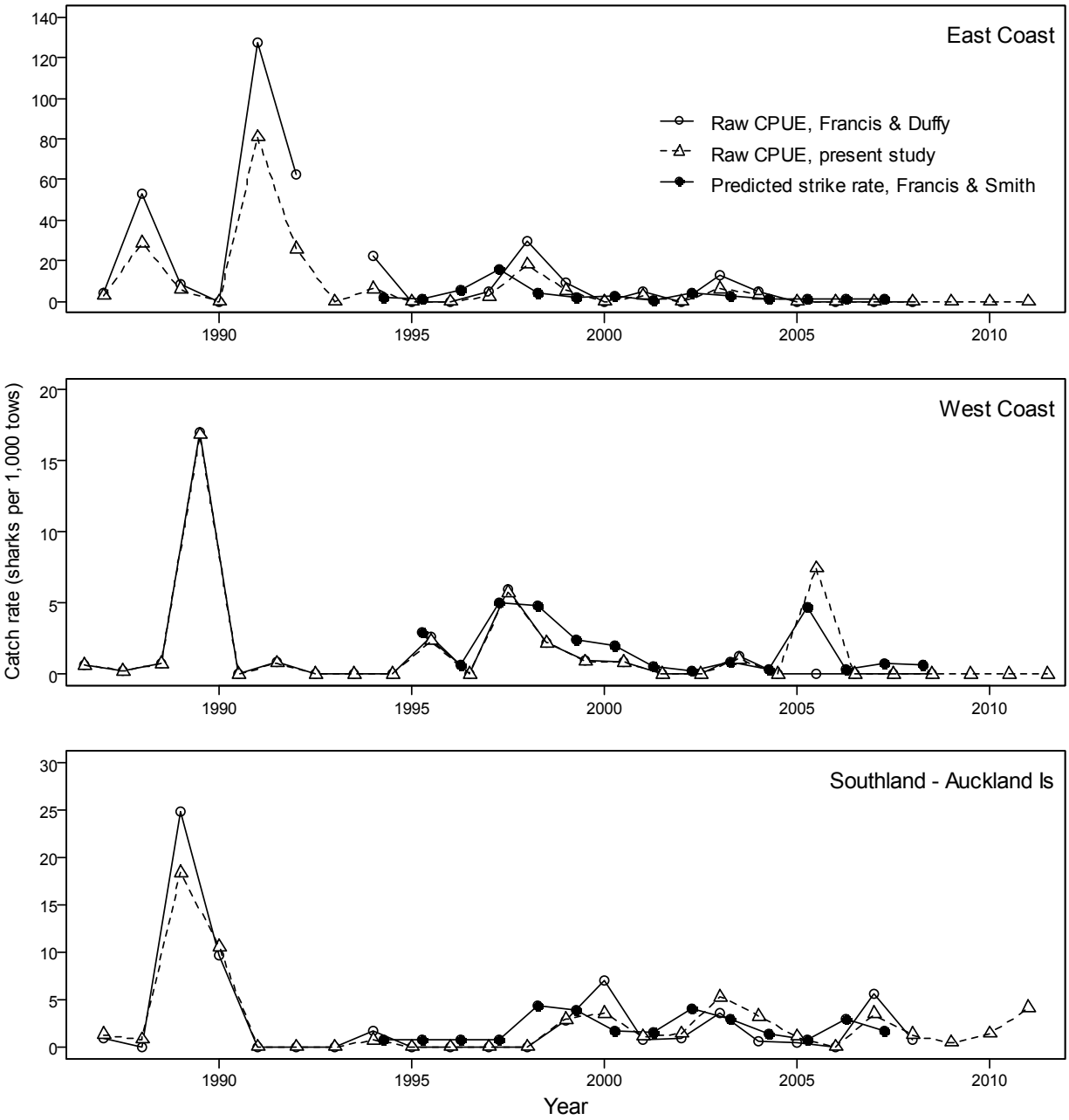

Figure 9.3: Basking shark catch rate indices for three fishery areas. For raw CPUE indices, years are calendar years for West Coast and July–June years (labelled as the greater of the two years) for East Coast and Southland-Auckland Is. For predicted strike rate, years are fishing years (labelled as the greater of the two years). Source: Francis & Sutton (2012).

Table 9.7: Trends in relative biomass and mean length determined from time series of research bottom trawl surveys of the Chatham Rise and the Sub-Antarctic (Campbell Plateau). Sources: O'Driscoll et al (2011), Bagley et al (2013).

Code	Species	Quality of biomass estimate	Biomass trend	Mean length trend
Chatham Rise, 1992-2010				
BSH	Seal shark	moderate	no change	
CYP	Longnose velvet dogfish	poor		no change
ETB	Baxter's dogfish	moderate	no change	no change
ETL	Lucifer's dogfish	very good	no change	no change
GSH	Dark ghost shark	very good	increase	decrease
GSP	Pale ghost shark	very good	no change	decrease
LCH	Longnose spookfish	very good	no change	no change
PDG	Prickly dogfish	moderate	increase then decrease	
SCH	School shark	moderate	increase	
SKA	Unspecified skates	good	no change	
SND	Shovelnose dogfish	good	no change	no change
SPD	Spiny dogfish	very good	increase	increase then decrease
SSK	Smooth skate	good	increase	no change
Subantarctic, 1991-1993 and 2000-2009				
BTH	Bluntnose deepwater skates	moderate	no change	
CSQ	Leafscale gulper shark	moderate	increase	increase
CYP	Longnose velvet dogfish	moderate	no change	no change
ETB	Baxter's dogfish	good	increase	no change
ETL	Lucifer's dogfish	good	no change	decrease
GSH	Dark ghost shark	poor		no change
GSP	Pale ghost shark	very good	no change	no change
LCH	Longnose spookfish	good	no change	no change
SND	Shovelnose dogfish	good	increase	no change
SPD	Spiny dogfish	good	no change	decrease

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9.7 APPENDICES

Appendix 9.1: List of New Zealand chondrichthyans, with details of their fisheries management classification, and IUCN and Department of Conservation threat classes. IUCN threat classes: EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient. The regional red list class is given for *Squalus acanthias* (LC) because it differs from the global class of VU. DOC threat classes: GD, Gradual Decline; RR, Range restricted; SP, Sparse; NOT, Not Threatened; MI, Migrant; VA, Vagrant. DOC qualifiers: CD, Conservation Dependent; DP, Data Poor; RC, Recovering; SO, Secure Overseas; TO, Threatened Overseas. Sources: IUCN Redlist classes as at July 2013 (L. Harrison, Shark Specialist Group IUCN, pers. comm.); DOC threat classes 2005 (Hitchmough et al 2007).

Group	Family	Species	Common name	Code	Manage-ment class	IUCN redlist class	DoC threat class	DoC qualifier
Chimaera	Callorhinchidae	*Callorhinchus milii* Bory de St Vincent, 1823	Elephantfish	ELE	QMS	LC	NOT	CD,RC
Chimaera	Rhinochimaeridae	*Harriotta haeckeli* Karrer, 1972	Smallspine spookfish	HHA	Non-QMS	DD	NOT	DP,SO
Chimaera	Rhinochimaeridae	*Harriotta raleighana* Goode & Bean, 1895	Longnose spookfish	LCH	Non-QMS	LC	NOT	SO
Chimaera	Rhinochimaeridae	*Rhinochimaera pacifica* (Mitsukuri, 1895)	Pacific spookfish	RCH	Non-QMS	LC	NOT	SO
Chimaera	Chimaeridae	*Chimaera carophila* Kemper, Ebert, Naylor & Didier 2014	Brown chimaera, longspine chimaera	CHP	Non-QMS		NOT	
Chimaera	Chimaeridae	*Chimaera lignaria* Didier, 2002	Purple chimaera, giant chimaera	CHG	Non-QMS	DD	NOT	SO
Chimaera	Chimaeridae	*Chimaera panthera* Didier, 1998	Leopard chimaera	CPN	Non-QMS	DD	NOT	
Chimaera	Chimaeridae	*Hydrolagus bemisi* Didier, 2002	Pale ghost shark	GSP	QMS	LC	NOT	
Chimaera	Chimaeridae	*Hydrolagus homonycteris* Didier 2008	Black ghost shark	HYB	Non-QMS	DD	NOT	SO
Chimaera	Chimaeridae	*Hydrolagus novaezealandiae* (Fowler, 1910)	Dark ghost shark	GSH	QMS	LC	NOT	
Chimaera	Chimaeridae	*Hydrolagus trolli* Didier and Seret, 2002	Pointynose blue ghost shark	HYP	Non-QMS	DD	NOT	SO
Chimaera	Chimaeridae	*Hydrolagus* sp. D [Didier]	Giant black ghost shark	HGB	Non-QMS		DD	
Shark	Chlamydoselachidae	*Chlamydoselachus anguineus* Garman, 1884	Frill shark	FRS	Non-QMS	NT	SP	DP,SO
Shark	Hexanchidae	*Heptranchias perlo* (Bonnaterre, 1788)	Sharpnose sevengill shark	HEP	Non-target	NT	SP	DP,SO
Shark	Hexanchidae	*Hexanchus griseus* (Bonnaterre, 1788)	Sixgill shark	HEX	Non-QMS	NT	SP	DP,SO
Shark	Hexanchidae	*Notorynchus cepedianus* (Peron, 1807)	Broadnose sevengill shark	SEV	Non-QMS	DD	NOT	DP,SO
Shark	Echinorhinidae	*Echinorhinus brucus* (Bonnaterre, 1788)	Bramble shark	BRS	Non-QMS	DD	SP	DP,SO
Shark	Echinorhinidae	*Echinorhinus cookei* Pietschmann, 1928	Prickly shark	ECO	Non-QMS	NT	SP	DP,SO
Shark	Squalidae	*Cirrhigaleus australis* White, Last & Stevens, 2007	Southern mandarin dogfish	MSH	Non-QMS	DD	SP	DP,TO
Shark	Squalidae	*Squalus acanthias* Linnaeus, 1758	Spiny dogfish	SPD	QMS	LC	NOT	SO
Shark	Squalidae	*Squalus griffini* Phillipps, 1931	Northern spiny dogfish	NSD	Non-QMS	LC	NOT	SO
Shark	Squalidae	*Squalus raoulensis* Duffy & Last, 2007	Kermadec spiny dogfish		Non-QMS	LC	DD	
Shark	Squalidae	*Squalus* sp. 5	Green-eye dogfish		Non-QMS		DD	
Shark	Centrophoridae	*Centrophorus harrissoni* McCulloch, 1915	Harrisson's dogfish		Non-QMS	EN	DD	TO
Shark	Centrophoridae	*Centrophorus squamosus* (Bonnaterre, 1788)	Leafscale gulper shark	CSQ	Non-QMS	VU	NOT	
Shark	Centrophoridae	*Deania calcea* (Lowe, 1839)	Shovelnose dogfish	SND	Non-QMS	LC	NOT	SO
Shark	Centrophoridae	*Deania histricosa* (Garman, 1906)	Rough longnose dogfish	SNR	Non-QMS	DD		
Shark	Centrophoridae	*Deania quadrispinosa* (McCulloch, 1915)	Longsnout dogfish	DEQ	Non-QMS	NT	DD	SO
Shark	Etmopteridae	*Centroscyllium* sp. cf. *kamoharai*	Fragile dogfish		Non-QMS		DD	
Shark	Etmopteridae	*Etmopterus granulosus* (Günther, 1880)	Baxter's dogfish	ETB	Non-QMS	LC	NOT	SO
Shark	Etmopteridae	*Etmopterus lucifer* Jordan & Snyder, 1902	Lucifer's dogfish	ETL	Non-QMS	LC	NOT	SO
Shark	Etmopteridae	*Etmopterus molleri* (Whitley, 1939)	Moller's lantern shark	EMO	Non-QMS	LC	NOT	SO
Shark	Etmopteridae	*Etmopterus pusillus* (Lowe, 1839)	Smooth lantern shark	ETP	Non-QMS	LC	SP	DP,SO
Shark	Etmopteridae	*Etmopterus* cf. *unicolor*	Bristled lantern shark		Non-QMS		NOT	SO
Shark	Etmopteridae	*Etmopterus viator* Straube 2012	Blue-eye lantern shark	EVI	Non-QMS			

Appendix 9.1 (continued)

Group	Family	Species	Common name	Code	Manage-ment class	IUCN redlist class	DoC threat class	DoC qualifier
Shark	Somniosidae	*Centroscymnus coelolepis* Bocage & Capello, 1864	Portuguese dogfish	CYL	Non-QMS	NT	NOT	
Shark	Somniosidae	*Centroscymnus owstonii* Garman, 1906	Owston's dogfish	CYO	Non-QMS	LC	NOT	
Shark	Somniosidae	*Centroselachus crepidater* (Bocage & Capello, 1864)	Longnose velvet dogfish	CYP	Non-QMS	LC	NOT	
Shark	Somniosidae	*Scymnodalatias albicauda* Taniuchi & Garrick, 1986	Whitetail dogfish	SLB	Non-QMS	DD	SP	DP,SO
Shark	Somniosidae	*Scymnodalatias sherwoodi* (Archey, 1921)	Sherwood's dogfish	SHE	Non-QMS	DD	SP	
Shark	Somniosidae	*Scymnodon macracanthus* Regan 1906	Roughskin dogfish		Non-QMS			
Shark	Somniosidae	*Scymnodon plunketi* (Waite, 1910)	Plunket's shark	PLS	Non-QMS	NT	NOT	
Shark	Somniosidae	*Scymnodon ringens* Bocage & Capello, 1864	Knifetooth dogfish	SRI	Non-QMS		DD	SO
Shark	Somniosidae	*Somniosus antarcticus* Whitley, 1939	Southern sleeper shark	SOP	Non-QMS	DD	SP	DP,SO
Shark	Somniosidae	*Somniosus longus* (Tanaka, 1912)	Little sleeper shark	SOM	Non-QMS	DD	DD	SO
Shark	Somniosidae	*Zameus squamulosus* (Günther, 1877)	Velvet dogfish	ZAS	Non-QMS	DD	SP	DP,SO
Shark	Oxynotidae	*Oxynotus bruniensis* (Ogilby, 1893)	Prickly dogfish	PDG	Non-QMS	DD	NOT	DP,SO
Shark	Dalatiidae	*Dalatias licha* (Bonnaterre, 1788)	Seal shark, black shark	BSH	Non-QMS	NT	NOT	SO
Shark	Dalatiidae	*Euprotomicrus bispinatus* (Quoy & Gaimard, 1824)	Pygmy shark	EBI	Non-QMS	LC	NOT	SO
Shark	Dalatiidae	*Isistius brasiliensis* (Quoy & Gaimard, 1824)	Cookie cutter shark	IBR	Non-QMS	LC	NOT	SO
Shark	Heterodontidae	*Heterodontus portusjacksoni* (Meyer, 1793)	Port Jackson shark	PJS	Non-QMS	LC	VA	SO
Shark	Rhincodontidae	*Rhincodon typus* (Smith, 1828)	Whale shark	WSH	Protected	VU	MI	SO
Shark	Odontaspidae	*Odontaspis ferox* (Risso, 1810)	Deepwater (smalltooth) sand tiger shark	ODO	Protected	VU	SP	TO
Shark	Pseudocarchariidae	*Pseudocarcharias kamoharai* (Matsubara, 1936)	Crocodile shark.	CRC	Non-QMS	NT	DD	SO
Shark	Mitsukurinidae	*Mitsukurina owstoni* Jordan, 1898	Goblin shark	GOB	Non-QMS	LC	SP	DP,SO
Shark	Alopiidae	*Alopias superciliosus* (Lowe, 1839)	Bigeye thresher	BET	Non-QMS	VU	NOT	TO
Shark	Alopiidae	*Alopias vulpinus* (Bonnaterre, 1788)	Thresher shark	THR	Non-QMS	VU	NOT	TO
Shark	Cetorhinidae	*Cetorhinus maximus* (Gunnerus, 1765)	Basking shark	BSK	Protected	VU	GD	TO
Shark	Lamnidae	*Carcharodon carcharias* (Linnaeus, 1758)	White shark, white pointer	WPS	Protected	VU	GD	TO
Shark	Lamnidae	*Isurus oxyrinchus* Rafinesque, 1810	Mako shark, shortfin mako	MAK	QMS	VU	NOT	SO
Shark	Lamnidae	*Lamna nasus* (Bonnaterre, 1788)	Porbeagle shark	POS	QMS	VU	NOT	TO
Shark	Scyliorhinidae	*Apristurus ampliceps* Sasahara, Sato & Nakaya 2008	Roughskin cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus* cf. *australis* Sato, Nakaya & Yorozu 2008	Pinocchio cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus exsanguis* Sato, Nakaya and Stewart 1999	Pale catshark	APR	Non-QMS	LC	NOT	
Shark	Scyliorhinidae	*Apristurus melanoasper* Iglésias, Nakaya & Stehmann 2004	Fleshynose cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus pinguis* Deng, Xiong & Zhan 1983	Cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus sinensis* Chu & Hu 1981	Freckled cat shark	APR	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Apristurus* sp.	Cat shark	APR	Non-QMS		NOT	
Shark	Scyliorhinidae	*Bythaelurus dawsoni* (Springer, 1971)	Dawson's cat shark	DCS	Non-QMS	DD	NOT	
Shark	Scyliorhinidae	*Cephaloscyllium isabellum* (Bonnaterre, 1788)	Carpet shark	CAR	Non-QMS	LC	NOT	
Shark	Scyliorhinidae	*Cephaloscyllium* sp.	Swellshark		Non-QMS		DD	
Shark	Scyliorhinidae	*Parmaturus bigus* Seret & Last, 2007	Shorttail cat shark		Non-QMS	DD		
Shark	Scyliorhinidae	*Parmaturus macmillani* Hardy, 1985	McMillan's cat shark	PCS	Non-QMS	DD	DD	SO
Shark	Scyliorhinidae	*Parmaturus* sp.	Rough-backed cat shark		Non-QMS		DD	
Shark	Scyliorhinidae	*Parmaturus* sp.			Non-QMS			

Appendix 9.1(continued)

Group	Family	Species	Common name	Code	Manage-ment class	IUCN redlist class	DoC threat class	DoC qualifier
Shark	Pseudotriakidae	*Gollum attenuatus* (Garrick, 1954)	Slender smooth hound	SSH	Non-QMS	LC	NOT	SO
Shark	Pseudotriakidae	*Pseudotriakis microdon* Capello, 1868	False cat shark	PMI	Non-QMS	DD	DD	SO
Shark	Triakidae	*Galeorhinus galeus* (Linnaeus, 1758)	School shark	SCH	QMS	VU	NOT	CD,TO
Shark	Triakidae	*Mustelus lenticulatus* Phillipps, 1932	Rig	SPO	QMS	LC	NOT	CD
Shark	Triakidae	*Mustelus* sp.	Kermadec Rig		Non-QMS		RR	SO
Shark	Carcharhinidae	*Carcharhinus brachyurus* (Günther, 1870)	Bronze whaler	BWH	Non-QMS	NT	NOT	SO
Shark	Carcharhinidae	*Carcharhinus galapagensis* (Snodgrass & Heller, 1905)	Galapagos shark	CGA	Non-QMS	NT	RR	SO
Shark	Carcharhinidae	*Carcharhinus longimanus* (Poey, 1861)	Oceanic whitetip shark	OWS	Protected	VU	MI	SO
Shark	Carcharhinidae	*Carcharhinus obscurus* (Le Sueur, 1818)	Dusky shark	DSH	Non-QMS	VU	MI	SO
Shark	Carcharhinidae	*Galeocerdo cuvier* (Peron & Le Sueur, 1822)	Tiger shark	TIS	Non-QMS	NT	MI	SO
Shark	Carcharhinidae	*Prionace glauca* (Linnaeus, 1758)	Blue shark	BWS	QMS	NT	NOT	SO
Shark	Sphyrnidae	*Sphyrna zygaena* (Linnaeus, 1758)	Hammerhead shark, smooth hammerhead	HHS	Non-target	VU	NOT	SO
Batoid	Narkidae	*Typhlonarke aysoni* (Hamilton, 1902)	Blind electric ray	TAY	Non-QMS	DD	NOT	DP
Batoid	Narkidae	*Typhlonarke tarakea* Phillipps, 1929	Oval electric ray	TTA	Non-QMS	DD	NOT	DP
Batoid	Torpedinidae	*Torpedo fairchildi* Hutton, 1872	Electric ray	ERA	Non-QMS	DD	NOT	
Batoid	Arhynchobatidae	*Arhynchobatis asperrimus* Waite, 1909	Longtail skate	LSK	Non-QMS	DD	NOT	
Batoid	Arhynchobatidae	*Bathyraja* cf. *eatonii*	Antarctic allometric skate	BEA	Non-QMS			
Batoid	Arhynchobatidae	*Bathyraja maccaini* Springer 1971	MacCain's skate	MCS	Non-QMS	NT		
Batoid	Arhynchobatidae	*Bathyraja richardsoni* (Garrick, 1961)	Richardson's skate	RIS	Non-QMS	LC	DD	SO
Batoid	Arhynchobatidae	*Bathyraja shuntovi* Dolganov, 1985	Longnose deepsea skate	PSK	Non-QMS	DD	NOT	
Batoid	Arhynchobatidae	*Bathyraja* sp.	Antarctic dwarf skate	BHY	Non-QMS			
Batoid	Arhynchobatidae	*Bathyraja* sp.	Blonde skate		Non-QMS			
Batoid	Arhynchobatidae	*Brochiraja albilabiata* Last & McEachran, 2006			Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja asperula* (Garrick & Paul, 1974)	Smooth deepsea skate	BTA	Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja leviveneta* Last & McEachran, 2006			Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja microspinifera* Last & McEachran, 2006			Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Brochiraja spinifera* (Garrick & Paul, 1974)	Prickly deepsea skate	BTS	Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Notoraja sapphira* Seret & Last 2009	Sapphire skate	BTH	Non-QMS	DD	DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus C] sp. A [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus C] sp. B [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus C] sp. C [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Arhynchobatidae	*Notoraja* [subgenus D] sp. A [Last & McEachran]		BTH	Non-QMS		DD	
Batoid	Rajidae	*Amblyraja georgiana* (Norman 1938)	Antarctic starry skate	SRR	Non-QMS	DD		
Batoid	Rajidae	*Amblyraja* cf. *hyperborea* (Collette, 1879)	Arctic skate	DSK	Non-QMS		NOT	
Batoid	Rajidae	*Dipturus innominatus* (Garrick & Paul, 1974)	Smooth skate	SSK	QMS	NT	NOT	CD
Batoid	Rajidae	*Zearaja nasuta* (Banks in Müller & Henle, 1841)	Rough skate	RSK	QMS	LC	NOT	
Batoid	Dasyatidae	*Dasyatis brevicaudata* (Hutton, 1875)	Shorttail stingray	BRA	Non-QMS	LC	NOT	SO
Batoid	Dasyatidae	*Dasyatis thetidis* Ogilby in Waite, 1899	Longtail stingray	WRA	Non-QMS	DD	NOT	SO
Batoid	Dasyatidae	*Pteroplatytrygon violacea* (Bonaparte, 1832)	Pelagic stingray	DAS	Non-QMS	LC	NOT	SO
Batoid	Myliobatidae	*Myliobatis tenuicaudatus* Hector, 1877	Eagle ray	EGR	Non-QMS	LC	NOT	SO
Batoid	Mobulidae	*Manta birostris* (Donndorff, 1798)	Manta ray	RMB	Protected	VU	MI	SO
Batoid	Mobulidae	*Mobula japanica* (Müller & Henle, 1841)	Spinetail devilray	MJA	Protected	NT	NOT	SO

Appendix 9.2: Indicative information on status of stocks for the eleven shark species subject to the QMS.

	November 2014 STOCK STATUS (as at the stated 'last assessment date')						
Species name	**Plenary stock**	**Last assessment date**	**At or above target levels?**	**Below the soft limit?**	**Below the hard limit?**	**Overfishing?**	**Corrective management action**
Blue shark*	BWS1	2014					-
Elephant fish	ELE2	-					-
Elephant fish	ELE3	2014	●	●●	●●●	●●	-
Elephant fish	ELE5	2014		●●	●●	●●	-
Elephant fish	ELE7	2014		●●	●●●	●●	-
Ghost shark - dark	GSH1, GSH2, GSH7, GSH8, GSH9	-					-
Ghost shark - dark	GSH3	-				●●	-
Ghost shark - dark	GSH4, GSH5, GSH6	-					-
Ghost shark - pale	GSP1, GSP5	2011		●●	●●●		-
Ghost shark - pale	GSP7	-					-
Mako shark*	MAK1	2008					TAC reduced in 2012
Porbeagle shark*	POS1	2014					TAC reduced in 2012
Rig	SPO1	2013					-
Rig	SPO2	2013			●●		-
Rig	SPO3, SPO8	2013					-
Rig	SPO7	2013	■■	■	●●		TACC reduced in 2006
School shark	SCH1, SCH2, SCH3, SCH4, SCH5, SCH7, SCH8	2014			●●		-
Skate - rough	RSK1, RSK3, RSK7, RSK8	2007					-
Skate - smooth	SSK1, SSK3, SSK7, SSK8	2007					-
Spiny dogfish	SPD1, SPD8	-					-
Spiny dogfish	SPD3, SDP7	2009			●●		-
Spiny dogfish	SPD4	2009			●●		-
Spiny dogfish	SPD5	-					-

* denotes highly migratory species, for which stock status cannot be determined for the portion of the stock found within New Zealand waters.

NOTES

At or above target levels? The "at or above target levels" indicator describes the present status of the stock relative to its target (usually B_{MSY}, the average biomass associated with a maximum sustainable yield (MSY) strategy, or F_{MSY}, the associated fishing mortality, or appropriate surrogates or proxies for these metrics, or alternative reference points that will result in higher average biomass – see Maximum Sustainable Yield Harvest Strategies for definitions and explanations of these terms).

Below the soft limit? Below the hard limit? Overfishing? In 2014, for the sixth consecutive year, three additional indicators of stock and fishery status have been analysed. The three new indicators are defined in the Harvest Strategy Standard for New Zealand Fisheries approved by the Minister of Fisheries on 24 October 2008.

In April 2009, the Ministry's Stock Assessment Methods Working Group adopted a probabilistic scale for categorising the "At or above target levels", "below the soft limit", "below the hard limit" and "overfishing" indicators (based on the scale developed by the Intergovernmental

Panel on Climate Change (IPCC) in 2007). While these probability categories are best applied in situations where models give appropriate quantitative outputs, they can also be used subjectively, based on expert opinion, when such model outputs are not available, or are highly uncertain.

The stock status table uses the IPCC criteria, coded according to the following key:

At or above target levels?	Probability	Description	Below the soft limit? Below the hard limit? Overfishing?
●●●●	> 99 %	Virtually Certain	■■■■
●●●	> 90 %	Very Likely	■■■
●●	> 60 %	Likely	■■
●	40 - 60 %	About as Likely as Not	■
■■	< 40 %	Unlikely	●●
■■■	< 10 %	Very Unlikely	●●●
■■■■	< 1 %	Exceptionally Unlikely	●●●●

Note that green circles indicate a favourable status, while orange squares indicate an unfavourable status, with the number of circles or squares indicating the degree to which the status is favourable or unfavourable.

Whether or not a stock is likely to be at or above the target level, or to be below the soft or hard limits, or subject to overfishing, is based on the most recent stock assessment summarised in the Ministry's Fishery Assessment Plenary Reports. The current (2015) stock status may be better or worse than that indicated by the most recent stock assessment. Where several alternative assessment runs are reported (as is frequently the case), or if the assessment results are contentions, the result reported represents the best judgement on the part of the Chair of the appropriate Fisheries Assessment Working Group, and the Ministry's Principal Advisor Fisheries Science.

Corrective management action: This column describes corrective management action underway for those stocks believed to be below the target level, or the soft or hard limits, or subject to overfishing.

Grey shading indicates that stock status is unknown, because an appropriate quantitative analysis to ascertain stock status relative to a target or limit has not been undertaken, or because such an analysis was not definitive, generally because of insufficient or inadequate data.

Source: based on the Status of the Stocks 2014 data published by the Ministry for Primary Industries on its website (http://fs.fish.govt.nz/Page.aspx?pk=16&tk=478)

Appendix 9.3. QMS chondrichthyan risk assessment results from Ford et al. (2015).

QMS SPECIES RISK

COMPONENTS OF RISK		RISK	CONFIDENCE	
Intensity	Consequence		Data	Consensus
6	3.5	21 - Rough skate	✓✓	✓✓
5	4	20 - Smooth skate	✓✓	✓✓
6	3	18 - Dark ghost shark	✓✓	✓✓
6	3	18 - Elephantfish	✓✓✓	✓✓
6	3	18 - Rig	✓✓✓	✓✓
6	3	18 - School shark	✓✓✓	✓✓
6	3	18 - Spiny dogfish	✓✓✓	✓✓
5	3	15 - Mako shark	✓✓✓	✓
5	3	15 - Pale Ghost Shark	✓✓	✗
5	3	15 - Porbeagle shark	✓✓✓	✓
4	3	12 - Blue shark	✓✓✓	✓✓

Figure 6: QMS Species Risk scores. For the COMPONENTS OF RISK higher numbers indicate greater intensity or consequence of impact (for more details see Table 2 and Table 3). For RISK longer bars and larger numbers indicate higher risk, and for CONFIDENCE more ticks indicate higher confidence in the data, or greater consensus and a cross indicates a lack of consensus (Two ticks in the consensus column indicate full consensus). Where species scored identical risk scores they are presented so that higher consequences are reported first and then in alphabetical order.

Appendix 9.3 (continued). Non-QMS chondrichthyan risk assessment results from Ford et al. (2015).

NON-QMS SPECIES RISK

COMPONENTS OF RISK		RISK	CONFIDENCE	
Intensity	Consequence		Data	Consensus
6	3.5	21 - Carpet Shark	✓✓	✓✓
5	4	20 - Baxters dogfish	✓✓	✓✓
5	4	20 - Seal shark	✓✓	✓
4.5	4	18 - Leafscale gulper shark	✓✓	✓✓
4	4.5	18 - Longnose velvet dogfish	✓✓	✓
4	4.5	18 - Plunkets shark	✓✓	✓
5	3.5	17.5 - Electric ray	✓	✓
5	3.5	17.5 - Shovelnose dogfish	✓✓	✓✓
4	4	16 - Blind electric ray	✓✓	✓
4	4	16 - Oval electric ray	✓✓	✓
4	4	16 - Owstons dogfish	✓✓	✓
3.5	4.5	15.75 - Dawsons catshark	✓✓	✓
4.5	3.5	15.75 Longnose spookfish	✓✓	✗
3.5	4	14 - Bronze whaler	✓✓	✗
4	3.5	14 - Longtail stingray	✓	✓✓
4	3.5	14 - Northern spiny dogfish	✓✓	✓
3.5	4	14 - Prickly dogfish	✓✓	✓
4	3.5	14 - Shorttail stingray	✓	✓✓
3.5	3.5	12.25 - Prickly deepsea skate	✓✓	✓
3.5	3.5	12.25 - Smooth deepsea skate	✓✓	✓
4	3	12 - Broadnose sevengill shark	✓✓	✓
3	4	12 - *Brochiraja* complex	✓	✓
3	4	12 - Brown chimaera	✓	✓✓
3	4	12 - Catsharks	✓	✓
3	4	12 - Deepwater spiny skate	✓	✓
4	3	12 - Hammerhead shark	✓✓	✓
3	4	12 - Longnose deepsea skate	✓	✓
3	4	12 - Longtail skate	✓	✓
3	4	12 - Lucifer dogfish	✓✓	✓
3	4	12 - Pacific spookfish	✓	✓✓
3	4	12 - Pelagic stingray	✓	✓
3	4	12 – Portugese dogfish	✓✓	✓

Figure 7: Non-QMS Species Risk scores. For the COMPONENTS OF RISK higher numbers indicate greater intensity or consequence of impact (for more details see Table 2 and Table 3). For RISK longer bars and larger numbers indicate higher risk, and for CONFIDENCE more ticks indicate higher confidence in the data, or greater consensus and a cross indicates a lack of consensus (Two ticks in the consensus column indicate full consensus). Where taxa scored identical risk scores they are presented so that higher consequences are reported first and then in alphabetical order.

Appendix 9.3 (continued). Non-QMS chondrichthyan risk assessment results from Ford et al. (2015).

NON-QMS SPECIES RISK CONTINUED

COMPONENTS OF RISK		RISK	CONFIDENCE	
Intensity	Consequence		Data	Consensus
3	4	12 - Slender smooth hound	✓✓	✓
3.5	3	10.5 - Thresher shark	✓✓	✓
4	2.5	10 - Eagle ray	✓✓	✓
3	3	9 - Sharpnose sevengill shark	✓✓	✓
2	4	8 - Frill shark	✓✓	✓
2	4	8 - Longsnout dogfish	✓	✓✓
2	4	8 - Pointynose blue ghost shark	✓	✓
2	4	8 - Purple chimaera	✓	✓
2	4	8 - Southern mandarin dogfish	✓	✓
2	4	8 - Southern sleeper shark	✓	✓✓
3	2	6 - Sixgill shark	✓✓	✓
2	2	4 - Bigeye thresher	✓✓✓	✓
2	2	4 - Little sleeper shark	✓	✓
2	2	4 - Prickly shark	✓	✓✓
2	2	4 - Velvet dogfish	✓	✓
2	1	2 - Black ghost shark	✓	✓✓
1	2	2 - Galapagos shark	✓✓✓	✓
2	1	2 - Tiger shark	✓✓✓	✓✓
1	1	1 - Bramble shark	✓	✓✓
1	1	1 - Cookie cutter shark	✓✓	✓✓
1	1	1 - Crocodile shark	✓	✓✓
1	1	1 - Dusky shark	✓✓	✓✓
1	1	1 - False cat shark	✓	✓✓
1	1	1 - Goblin shark	✓	✓✓
1	1	1 - Harrisson's dogfish	✓	✓✓
1	1	1 - Kermadec spiny dogfish	✓	✓✓
1	1	1 - Leopard chimaera	✓	✓✓
1	1	1 - McMillan's cat shark	✓	✓
1	1	1 - Port Jackson shark	✓	✓✓
1	1	1 - Richardson's skate	✓	✓✓
1	1	1 - Sapphire skate	✓	✓✓
1	1	1 - Sherwood's dogfish	✓	✓✓
1	1	1 - Smallspine spookfish	✓✓	✓✓
1	1	1 - Whitetail dogfish	✓	✓

Figure 7 (continued): Non-QMS taxa risk scores (see the previous page for full legend details).

Appendix 9.3 (continued). Protected chondrichthyan risk assessment results from Ford et al. (2015).

PROTECTED SPECIES RISK

COMPONENTS OF RISK		RISK	CONFIDENCE	
Intensity	Consequence		Data	Consensus
3	4.5	13.5 - Basking shark	✓✓	✓
3	4.5	13.5 - Spinetail devil ray	✓	✓
3	4	12 - Great white shark	✓✓	✓
2	4	8 - Smalltoothed sandtiger	✓	✓
1	1	1 - Whale shark	✓✓✓	✓✓
1	1	1 - Oceanic whitetip shark	✓✓✓	✓✓
1	1	1 - Manta ray	✓✓	✓✓

Figure 8: Protected Species Risk scores. For the COMPONENTS OF RISK higher numbers indicate greater intensity or consequence of impact (for more details see Table 2 and Table 3). For RISK longer bars and larger numbers indicate higher risk, and for CONFIDENCE more ticks indicate higher confidence in the data, or greater consensus and a cross indicates a lack of consensus (Two ticks in the consensus column indicate full consensus). Where species scored identical risk scores they are presented so that higher consequences are reported first and then in alphabetical order.

THEME 3: BENTHIC IMPACTS

10 BENTHIC (SEABED) IMPACTS

Scope of chapter	This chapter outlines the main effects of mobile bottom (or demersal) fishing gear on seabed habitats and communities All trawl gears contacting the seabed and shellfish dredges are included. Danish seines and more or less static methods like bottom longline and potting are excluded in this version, as are fisheries outside the EEZ.
Area	All of the New Zealand Territorial Sea (TS) and Exclusive Economic Zone (EEZ). There will be some relevance for out-of-zone bottom trawl fisheries.
Focal localities	Areas that are fished more frequently and habitats that are more sensitive to disturbance are likely to be most affected; areas that are closed to bottom impacting methods will not be directly affected. Bottom trawling offshore is most intense on the western flanks and to the southwest of the Chatham Rise, the edge of the Stewart-Snares shelf, south of the Auckland Islands, and off the northwest coast of the South Island. In coastal waters shallower than 250 m, trawling is most intense along the east coast of North Island, south of East Cape, and in Tasman and Golden Bays. Shellfish dredges probably have the greatest effect but their footprint is much smaller than that of bottom trawl fisheries and in generally shallow waters.
Key issues	Habitat modification, potential loss of biodiversity, potential loss of benthic productivity, potential modification of important breeding or juvenile fish habitat leading to reduced fish recruitment.
Emerging issues	Potential for effects on habitats of particular significance to fisheries management (HPSFM). The need for (and opportunities presented by) better spatial information on inshore fisheries from finer scale reporting of fishing locations (including logbooks). Cumulative effects and interactions with other stressors (including existing effects, especially in the coastal zone, and climate change.
MPI Research (current)	BEN2007/01, *Assessing the effects of fishing on soft sediment habitat, fauna, and processes;* DAE2010/04, *Monitoring the trawl footprint for deepwater fisheries;* DAE2010/01, *Taxonomic identification of benthic samples*; ZBD201203, *Chatham Rise Benthos – Ocean Survey 20/20*.
NZ Government Research (current)	MBIE programmes: C01X0907, *Coastal Conservation Management;* C01X0906, *Impacts of resource use on vulnerable deep-sea communities*. Previous OBI programmes *Coasts & Oceans* C01X0501 and *Marine Biodiversity & Biosecurity* C01X0502, and MBIE programme C01X0808, *Deepsea mining of the Kermadec Ridge* are now part of NIWA core funding. DOC14302, Overlap of trawl footprint with protected coral distributions
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture
Related chapters/issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring, marine mining/sand extraction, land-based effects.

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

10.1 CONTEXT

For the purpose of this document, the term "mobile bottom fishing methods" includes all types of trawl gear that are used in contact with the seabed as well as shellfish dredges of various designs and Danish seines. Relative to the information about trawls and dredges there is little information available about the distribution and effects of Danish seining, so Danish seining is not considered in detail. The benthic effects of other methods of catching fish on or near the seabed that do not involve deliberately towing or dragging fishing gear across the seabed are thought to be considerably less than those of the mobile methods (although they are not always negligible) and these methods are not considered in this document.

Trawls and dredges are used to catch a relatively high proportion of commercial landings in New Zealand and such methods can represent the only effective and economic way of catching some species. However, the resulting disturbance to seabed habitats and communities may have consequences for biodiversity and ecosystem services, including fisheries and other secondary production. The guiding sections of the Fisheries Act 1996 for managing the effects of fishing, including benthic

effects, are s.8(2)(b) which specifies that "ensuring sustainability" (s.8(1)) includes "avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment" and s.9 which specifies a principle that "biological diversity of the aquatic environment should be maintained". Also potentially relevant is the principle in s.9 that "habitat of particular significance for fisheries management should be protected" (see the chapter on Habitats of Particular Significance for Fisheries Management for more details).

One approach to managing the effects of mobile bottom fishing methods is through the use of spatial controls. A wide variety of such controls apply in New Zealand waters (Figure 10.1). 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 10.2 for areas where trawling is prohibited, Figure 10.3 for areas where gear and seasonal restrictions apply, and Figure 10.4 for areas related to marine reserves and marine farms). Marine reserves provide marine protection in a range of habitats within the Territorial Sea. Although marine reserves provide a higher level of protection by prohibiting all extractive activities, most tend to be small. New Zealand's 34 marine reserves protect about 7.6% of New Zealand's Territorial Sea; however, 99% of this is in two marine reserves in the territorial seas around offshore island groups in the far north and far south of New Zealand's EEZ (Helson et al 2010). Until 2000, most closures that had the effect of protecting areas of seabed from disturbance by trawling and dredging were in the Territorial Sea.

In the Exclusive Economic Zone, 18 seamount closures were established in 2000 to protect representative underwater topographic features from bottom trawling and dredging (Brodie & Clark 2003, see Figure 10.1). These areas include 25 features, including 12 large seamounts more than 1000 m high, covering 2% (81 000 km2) of the EEZ. The seamount areas are closed to all types of trawling and dredging. In 2006, members of the fishing industry proposed the closure of about 31% of the EEZ to bottom trawling and dredging in Benthic Protection Areas (BPAs), including the existing seamount closures. The design criteria for the BPAs were they should be large, relatively unfished, have simple boundaries, and be broadly representative of the marine environment. After a consultation process, a substantially revised package of BPAs (including three additional areas totalling 13 887 km2, 10 additional active hydrothermal vents, and 35 topographic features) that complemented the existing seamount closures was implemented by regulation in 2007 (Helson et al 2010, Figure 10.1). BPAs cover about 1.1 million km2 (30%) of New Zealand's EEZ and are closed to trawling on or close to the bottom. Midwater trawling well off the bottom is permitted in the BPAs if two observers are on board and an approved net monitoring system is used. Much of the seabed within BPAs is below trawlable depth (maximum trawlable depth is about 1600 m) and all are outside the Territorial Sea. In combination, the seamount closures and the BPAs include: 28% of underwater topographic features (a term that includes underwater hills, knolls, and seamounts); 52% of seamounts over 1000 m high; and 88% of known active hydrothermal vents.

10.2 GLOBAL UNDERSTANDING

Concerns about the use of towed fishing gear on benthic habitats were first raised by fishermen in the fourteenth century in the UK (Lokkeborg 2005). They were worried about the capture of juvenile fish and the detrimental effects on food sources for harvestable fish. Despite this long history of concern, it is really only in the last 20 years that research efforts have focused strongly on the effects of mobile bottom fishing methods on benthic (seabed) communities, biodiversity, and production. This activity, combined with controversy around fishing effects, has spawned numerous reviews in the past 10 years that seek to summarise or synthesise the information (Jones 1992, Dayton et al 1995; Jennings & Kaiser 1998; Watling & Norse 1998; Lindeboom & deGroot 1998, Auster & Langton 1999; Hall 1999; ICES 2000a and b, Kaiser & de Groot 2000; NMFS 2002, NRC 2002, Dayton et al 2002; Thrush & Dayton 2002; Lokkeborg 2005, Barnes & Thomas 2005, Clark & Koslow 2007).

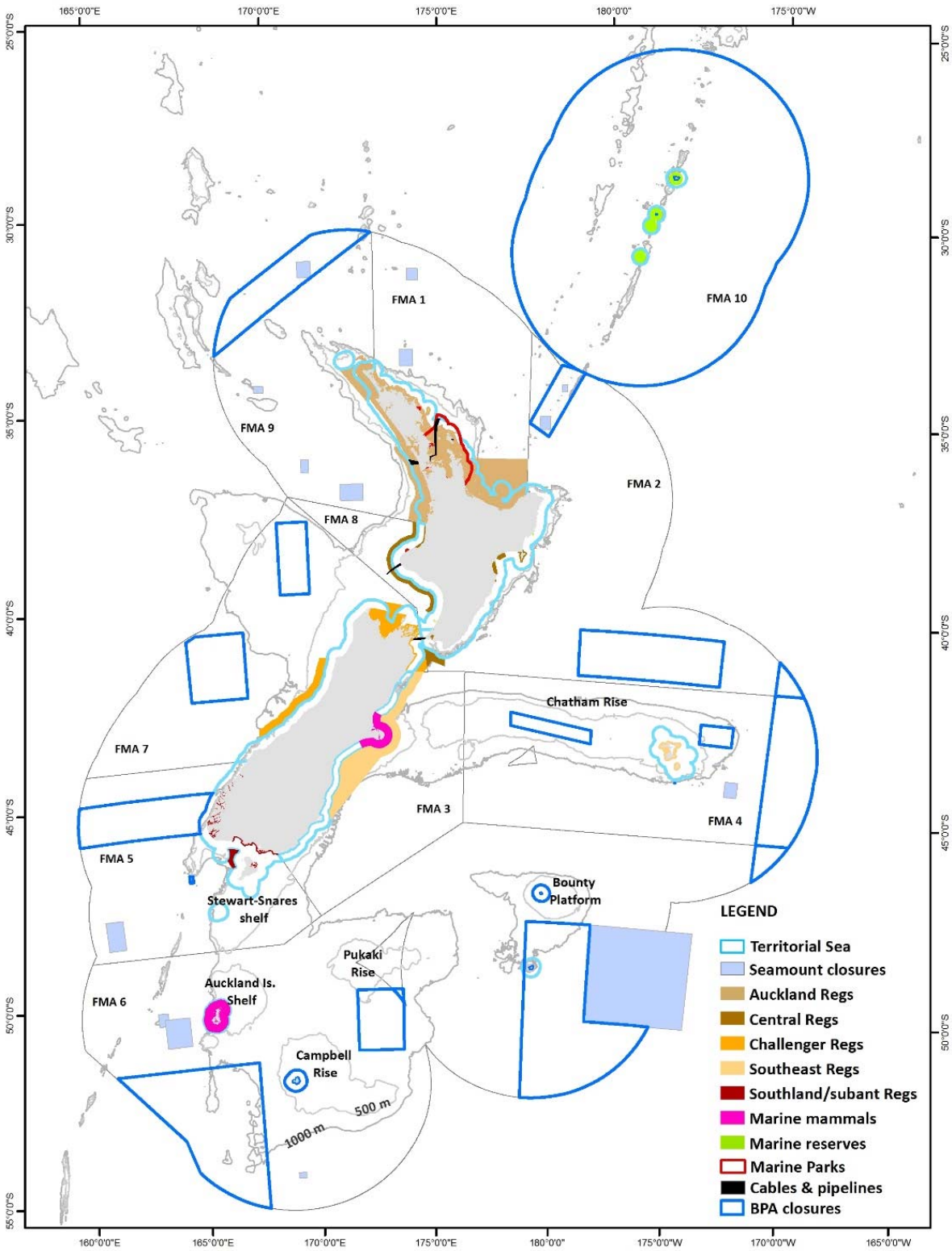


Figure 10.1: Map, adapted from Baird & Wood 2010, of the major spatial restrictions to trawling and the Ministry for Primary Industries Fishery Management Areas (FMAs) within the outer boundary of the New Zealand EEZ. Vessels longer than 28 m may not trawl within the TS and additional restrictions are specified in the Fisheries (Auckland Kermadecs Commercial Fishing) Regulations 1986, the Fisheries (Central Area Commercial Fishing) Regulations 1986, the Fisheries (Challenger Area Commercial Fishing) Regulations 1986 the Fisheries (South East Area Commercial Fishing) Regulations 1986, and the Fisheries (Southland and Sub-Antarctic Areas Commercial Fishing) Regulations 1991. For more details of BPAs see Helson et al 2010.

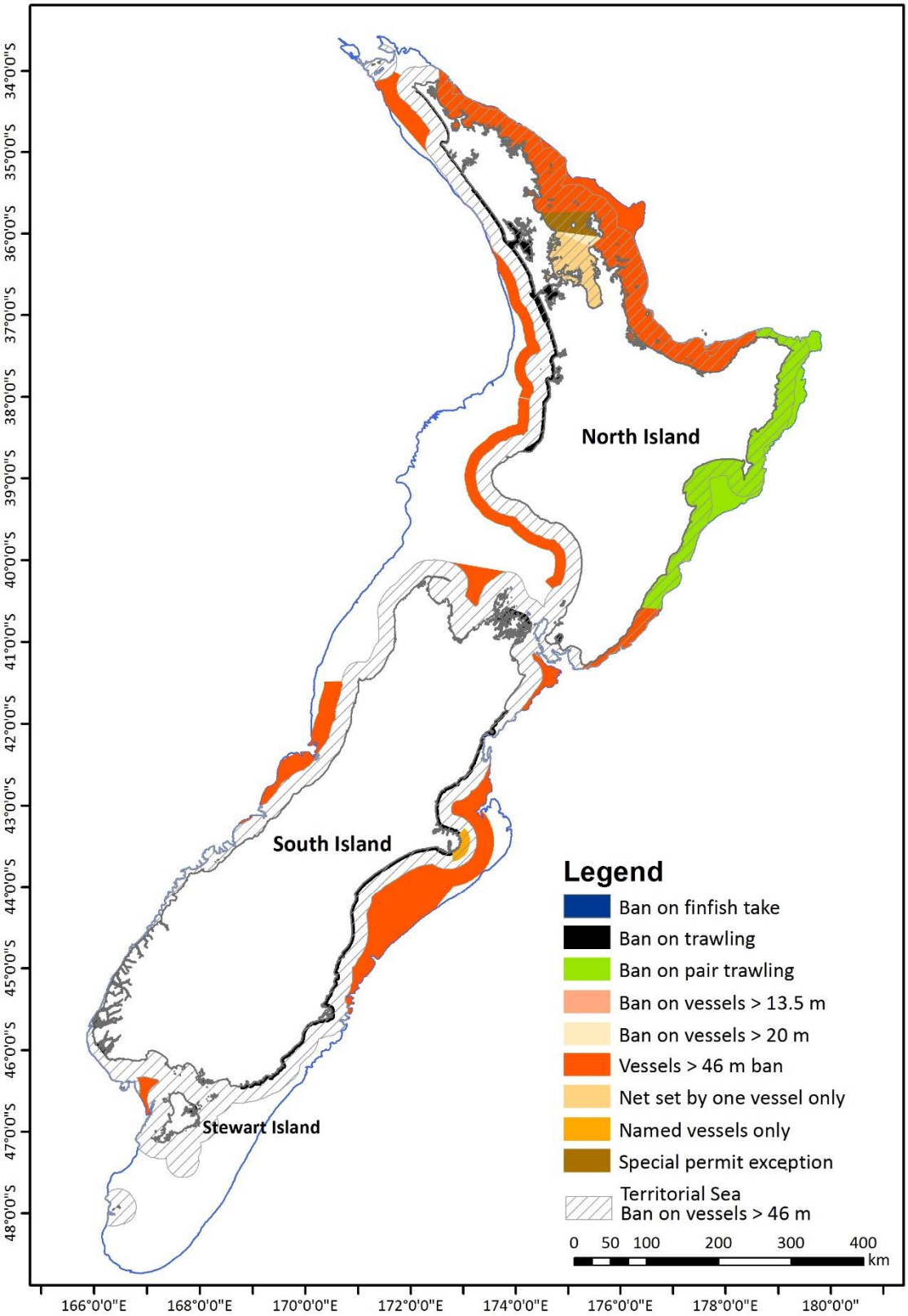


Figure 10.2: Areas showing where trawling is prohibited and other relevant restrictions apply in waters shallower than 250 m depth. Note the area shown as "Ban on pair trawling" also is closed to vessels over 46 m (Baird et al 2014).

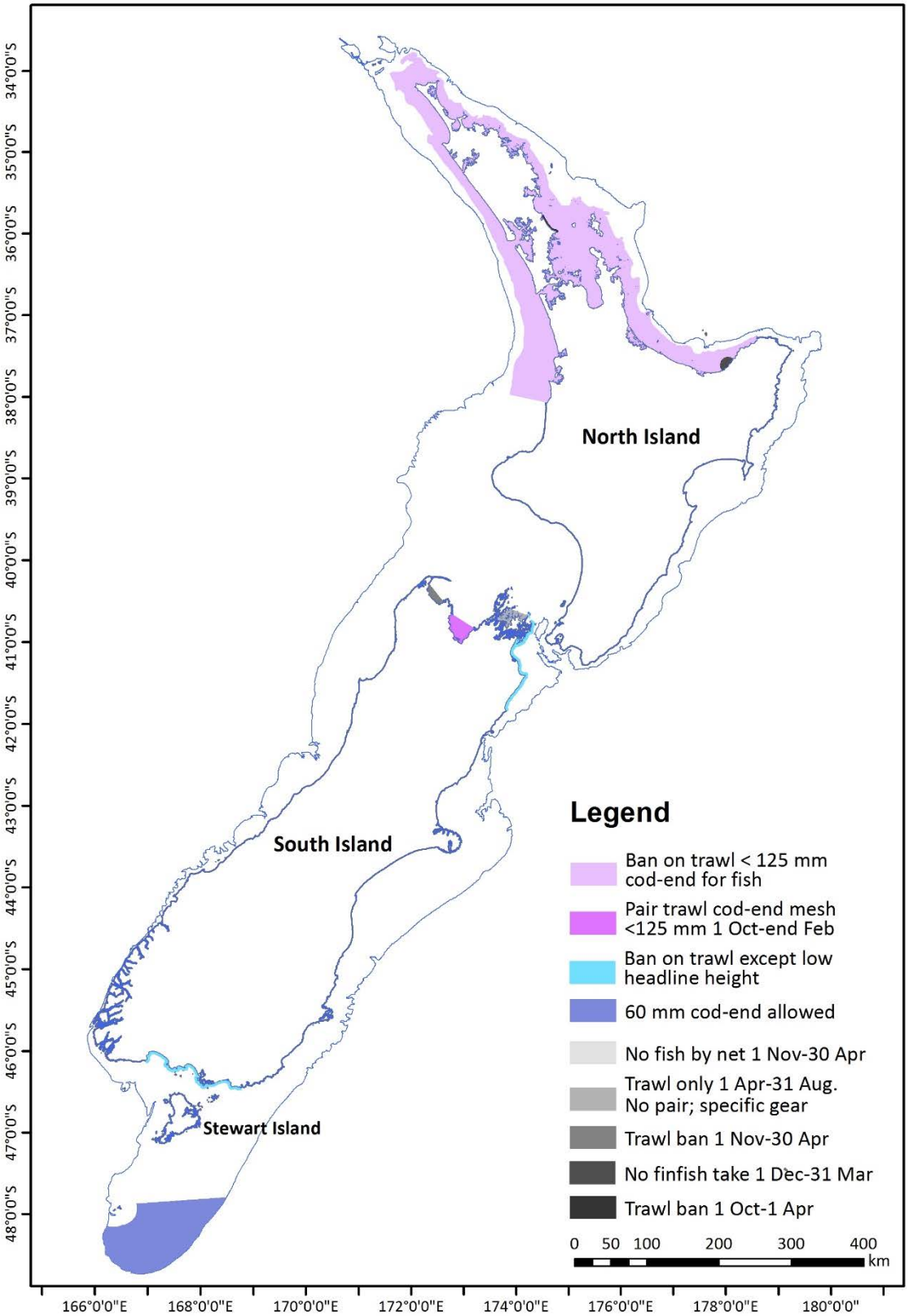


Figure 10.3: Areas where gear and seasonal restrictions apply to the use of trawl gear, in waters shallower than 250 m depth (Baird et al 2014).

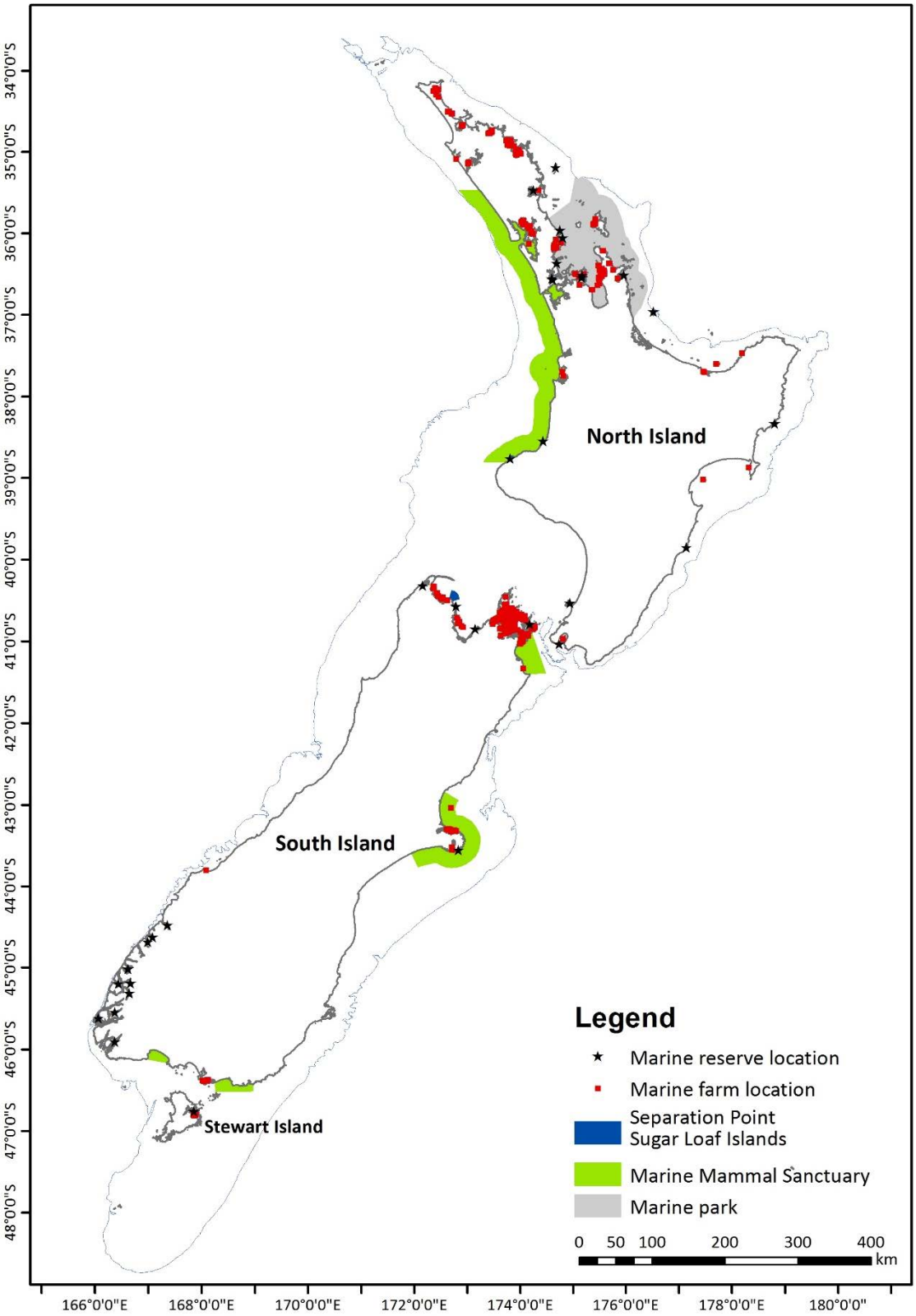


Figure 10.4: Points indicative of locations of marine reserves and marine farms, Separation Point and Sugar Loaf Islands closed areas, marine mammal sanctuaries, and marine parks, in waters shallower than 250 m depth (Baird et al 2014).

Benthic habitats provide shelter and refuge for juvenile fish and the associated fauna can be the prey of demersal fish species. Towed fishing gears (particularly trawl doors), affect benthic habitats and organisms but the level of effect will depend on the type of trawl doors and ground gear used, and the physical and biological characteristics of the seabed habitats in the fishing grounds. The effects are difficult to assess because of the complexity of benthic communities and their temporal and spatial variability, and interpretation can also be complicated by environmental gradients or change. For reasons of accessibility, cost, and tractability, most research on seabed disturbance caused by human activities worldwide has been carried out in coastal systems, and our understanding of the effects of physical disturbance in the sparse but highly diverse communities of the deep sea has developed only recently. The reviews above broadly indicate that numerical abundance of many invertebrates declines (sometimes substantially) after mining, trawling, or other major disturbance. Trawling and dredging can re-suspend sediment and can, depending on sediment and local currents, alter sediment characteristics. Physical effects include furrows and berms from trawl doors, furrows from the bobbins and rock hoppers, and sediment resorting, but the magnitude of these effects depends on sediment type, currents, and wave action (if any). Bottom trawling can also alter natural sediment fluxes and reduce organic carbon turnover (Pusceddu et al 2014), the depth of the oxic layer in sediments (Churchill 1989, Warnken et al 2003, Bradshaw et al 2012), and the shape of the upper continental slope (Puig et al 2012), reducing morphological complexity and benthic habitat heterogeneity. The mixing of sediments and overlying water can alter the chemical makeup of the sediment and have considerable effects in deep, stable waters (Rumohr 1998). Chemical release from the sediment can also be changed, as shown for phosphate in the North Sea (ICES 1992, noting lower fluxes were observed after trawling events). Trawling can alter benthic communities, reduce total biomass of benthic species, and increase predation by scavengers. Sites subject to greater natural disturbance are generally thought to be less susceptible to change from bottom contact fishing (but see Schratzberger et al 2009 who concluded that common anthropogenic disturbances differ fundamentally from natural disturbance). There has been less work on the effects of other methods of catching demersal fish or crustaceans that do not involve deliberately towing or dragging fishing gear across the seabed, but some of these methods can have non-negligible effects (e.g., Sharp et al 2009, Williams et al 2011).

Studies of recovery dynamics are rarer still, but a return to pre-disturbance levels after bottom-contact fishing can take up to several years, even in some sites subject to considerable natural disturbance (see Kaiser et al 2006 for a summary). In shallow regions with mobile sediments, the effects are generally difficult to detect and recovery can be rapid (e.g., Jennings et al 2005). Examining epifauna, Lambert et al (2014) estimated recovery from scallop dredging to take from less than 1 year to over 10 years, depending on functional group, with faster recovery in areas with faster tidal currents, and large bodied species recovering faster when conspecifics were abundant locally. Hard-bottom fauna is predicted to recover most slowly and Williams et al (2010) concluded that hard-bottom fauna on Australasian seamounts did not show signs of recovery within 5–10 years. Recovery rate is typically correlated with the spatial extent of a disturbance event (e.g., Hall 1994, Kaiser et al 2003, see also Figure 10.5) and the effects of some "catastrophic" natural disturbance events, such as large-scale marine mudslides, can be detected for hundreds of years, even for taxa thought to be robust to physical disturbance such as nematodes (Hinz et al 2008).

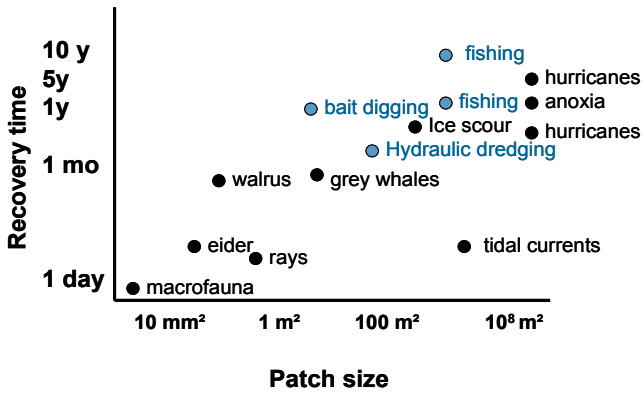


Figure 10.5: General relation between the spatial extent of disturbance events and the time taken to recover from such events in marine systems (after Kaiser et al 2003). Blue dots signal human impacts, including fishing in habitats of different abilities to recover, and black dots signal natural disturbance.

Rice (2006) summarised the findings of five major reviews of the effects of mobile bottom-contacting fishing gears on benthic species, communities, and habitats (available at: http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf). In this "review of reviews" Rice (2006) summarised the findings of the multiple working groups that contributed to the reviews as follows:

Rice's (2006) conclusions about the effects on habitats of mobile bottom fishing gears were that they:

- can damage or reduce structural biota (All reviews, strong evidence or support).
- can damage or reduce habitat complexity (All reviews, variable evidence or support).
- can reduce or remove major habitat features such as boulders (Some reviews, strong evidence or support).
- can alter seafloor structure (Some reviews, conflicting evidence for benefits or harm).

Other emergent conclusions on habitat effects included:

- There is a gradient of effects, with greatest effects on hard, complex bottoms and least effect on sandy bottoms (All reviews, strong support, with qualifications).
- There is a gradient of effects, with greatest effects on low energy environments and least (often negligible) effect on high-energy environments (All reviews, strong support).
- Trawls and mobile dredges are the most damaging of the gears considered (Three of the reviews considered other gears; all drew this conclusion, often with qualifications).

Mobile bottom gears affect benthic species and communities in that they:

- can change the relative abundance of species (All reviews, strong evidence or support).
- can decrease the abundance of long-lived species with low turnover rates (All reviews, moderate to strong evidence or support).
- can increase the abundance of short-lived species with high turnover rates (All reviews, moderate to occasionally strong evidence or support).
- affect populations of surface-living species more often and to greater extents than populations of burrowing species (All reviews, weak to occasionally strong evidence or support).
- have lesser effects in high-energy or frequent natural disturbance environments than in low energy environments where natural disturbances are uncommon (Four reviews (the other did not address the factor), strong evidence or support).
- affect populations of structurally fragile species more often and to greater extents than populations of "robust" species (All reviews, variable evidence and support).
- Abundance of scavengers increases temporarily in areas where bottom trawls have been used (Three reviews, variable support or evidence, all argue for the effects being transient).
- Rates of nutrient cycling or sedimentation are increased in areas where bottom trawls have been used (Two reviews, mixed views on magnitude of effects and conditions under which they occur).

Considerations in the application or adoption of mitigation measures:

- The effect of mobile fishing gears on benthic habitats and communities is not uniform. It depends on:
  - The features of the seafloor habitats, including the natural disturbance regime (All reviews, strong evidence or support);
  - the species present (All reviews, strong evidence or support, though not mentioned by NMFS panel);
  - the type of gear used and methods of deployment (All reviews, moderate to strong evidence support);
  - the history of human activities, particularly past fishing, in the area of concern (All reviews, strong evidence or support).
- Recovery time from trawl-induced disturbance can take from days to centuries, and depends on the same factors as listed above. (All reviews, strong evidence or support).
- Given the above considerations, the effect of mobile bottom gears has a monotonic relationship with fishing effort, and the greatest effects are caused by the first few fishing events (All reviews, moderate to strong evidence or support).
- Application of mitigation measures requires case specific analyses and planning; there are no universally appropriate fixes (Three reviews, moderate to strong evidence or support. The issue of implementing mitigation was not addressed in the FAO review. It was also stressed in the US National Academy of Sciences review and discussed in the ICES review that extensive local data are not necessary for such case-specific planning. The effects of mobile bottom gears on seafloor habitats and communities are consistent enough with well-established ecological theory,

and across studies, that cautious extrapolation of information across sites is legitimate).

Rice (2006) concluded *"These overall conclusions on impacts and mitigation measures, and recommendations for management action form a coherent and consistent whole. They are relevant to the general circumstances likely to be encountered in temperate, sub-boreal, and boreal seas on coastal shelves and slopes, and probably areas … beyond the continental shelves. They allow use of all relevant information that can be made available on a case by case basis, but also guide approaches to management in areas where there is little site-specific information."*

Since Rice's (2006) paper, Kaiser et al (2006) published a meta-analysis of 101 separate manipulative experiments that confirms many of Rice's findings. Shellfish dredges have the greatest effect of the various mobile bottom fishing gears, biogenic habitats are the most sensitive to such disturbance (especially for attached fauna on hard substrates) and unconsolidated, coarse sediments (e.g., sands) are the least sensitive. Kaiser et al (2006) concluded that recovery from disturbance events can take months to years, depending on the combination of fishing method and benthic habitat type. This meta-analysis of manipulative experiments was an important development, reinforcing the inferences drawn from multiple mensurative observations at much larger scale ("fisheries scale") in New Zealand (e.g., Thrush et al 1998, Cryer et al 2002) and overseas (e.g., Craeymeersch et al 2000, McConnaughey et al 2000, Bradshaw et al 2002, Blyth et al 2004, Tillin et al 2006, Hiddink et al 2006). This is a powerful combination that implies substantial generality of the findings.

The international literature is, therefore, clear that bottom (demersal) trawling and shellfish dredging are likely to have largely predictable and sometimes substantial effects on benthic community structure and function. However, the positive or negative consequences for ecosystem processes such as production had not been addressed until more recently (e.g., Jennings et al 2001, Reiss et al 2009, Hiddink et al 2011). It has been mooted that frequent disturbance should lead to the dominance of smaller species with faster life histories and that, because smaller species are more productive than larger ones, system productivity and production should increase under trawling disturbance. However, when this proposition has been tested, it has not been supported by data in real fishing situations (e.g., Hermsen et al 2003, Reiss et al 2009) and where overall productivity has been assessed, it decreases with increasing trawling disturbance.

For example, Veale et al (2000) examined spatial patterns in the scallop fishing grounds in the Irish Sea and found that total abundance, biomass, and secondary production (including that of most individual taxa examined) decreased significantly with increasing fishing effort. Echinoids, cnidarians, prosobranch molluscs, and crustaceans contributed most to the differences. Jennings et al (2001) showed that, in the North Sea, trawling led to significant decreases in infaunal biomass and production in some areas even though production per unit biomass rose with increased trawling disturbance. The expected increase in relative production did not compensate for the loss of total production that resulted from the depletion of large-bodied species and individuals. Hermsen et al (2003) found that mobile fishing gear disturbance had a conspicuous effect on benthic megafaunal production on Georges Bank, and cessation of such fishing led to a marked increase in benthic megafaunal production, dominated by scallops and urchins. Hiddink et al (2006) estimated that more than half of the southern North Sea was trawled sufficiently frequently to depress benthic biomass by 10% or more, and that 27% was in a state where benthic production was depressed by 10% or more. They estimated that recovery from this situation would take 2.5–6 years or more once fishing effort had been eliminated. They further estimated that fishing reduced benthic biomass and production by 56% and 21%, respectively, compared with an unfished situation. Reiss et al (2009) found that, although sediment composition was the most important driver of benthic community structure in their North Sea study area, the intensity of fishing effort was also important and reductions in the secondary production of the infaunal community could be detected even within this heavily fished region.

The types of models developed by Hiddink et al 2006, 2011 (but see also Ellis & Pantus 2001 and Dichmont et al 2008) can be used to assess the likely performance of different management approaches or levels of fishing intensity. Such management-strategy-evaluation (MSE) methods involve specifying management objectives, performance measures, a suite of alternative management strategies, and evaluating these alternatives using simulation (Sainsbury et al 2000). For instance, the early

study by Ellis & Pantus (2001) assessed the effect of trawling on marine benthic communities by combining an implementation of the spatial and temporal behaviour of the local fishing fleet with realistic ranges for the removal and recovery of benthic organisms. The model was used to compare the outcomes of two radically different management approaches, spatial closures and reductions in fishing effort. From a New Zealand perspective, Mormede & Dunn (2013) developed a simple spatially explicit population model as a tool to assist Ecological Risk Assessments, and Lundquist et al (2010, 2013) used a more sophisticated spatially explicit landscape mosaic model with variable connectivity between patches to assess the implications of different spatial and temporal patterns of disturbance in the model landscape. They found that the scale of the disturbance regime (which could be trawling or any other physical disturbance) and the dispersal processes interact, and that the scales of these processes greatly influenced changes in the structure and diversity of the model community, and that recovery across the mosaic depended strongly on dispersal. System stability also decreased as dispersal distance decreased. Patterns of abundance of different species groups observed across gradients of fishing pressure were in general agreement with model predictions.

10.3 STATE OF KNOWLEDGE IN NEW ZEALAND

To understand the effects of mobile bottom fishing methods on benthic habitats, it is necessary to have knowledge of:

- the distribution of such habitats,
- the extent to which mobile bottom fishing methods are used in each habitat (the overlap),
- the consequences of any such disturbance (potentially in conjunction with other disturbances or stressors), and
- the nature and speed of recovery from the disturbance.

These components will be dealt with in turn.

10.3.1 DISTRIBUTION OF HABITATS

Mapping of benthic habitats at the large scales inherent in fisheries management is expensive and time-consuming so the New Zealand government commissioned an environmental classification to provide a spatial framework that subdivided the TS and EEZ into areas having similar environmental and biological character. This Marine Environment Classification (MEC) was launched in 2005 (Snelder et al 2004, 2005, 2006) using available physical and chemical predictors, because environmental pattern was thought a reasonable surrogate for biological pattern. The authors suggested that the MEC provided managers with a useful spatial framework for broad scale management, but cautioned that the full utility and limitations would become clear only as the MEC was applied to real issues. They described the MEC as a tool to organise data, analyses and ideas, and as only one component of the information that would be employed in any analysis. The 20-class version (Figure 10.6, Table 10.1) has been the most widely cited, although additional classification levels provide more detail that is significantly correlated with biological layers. The 2005 MEC was not optimised for any specific ecosystem component but was "tuned" against data for demersal fish, phytoplankton, and benthic invertebrates. It performed least well as a classification of benthic invertebrates and, at the 20-class level, grouped most of the Chatham Rise and Challenger Plateau into a single class. Although separation of these two areas was evident as the MEC was driven to larger numbers of classes, their inclusion within a single class in the 20-class classification was considered counter-intuitive because their productivity and fisheries are known to be very different.

This disquiet with the predictions of the original MEC for benthic habitat classes led to the development of alternatives that might perform better for benthic systems. First of these was a classification optimised for demersal fish (Leathwick et al 2006). Several variants of this classification out-performed the original MEC for demersal fish, particularly at lower levels of classification detail and it was adopted by the Ministry for the Environment for their indicators related to bottom trawling and their 2010 Environmental Snapshot where the trawl footprint is compared with putative habitats (Ministry for the Environment 2010, see also: https://www.mfe.govt.nz/environmental-reporting/marine/fishing-activity-indicator/fishing-activity-seabed-trawling.html).

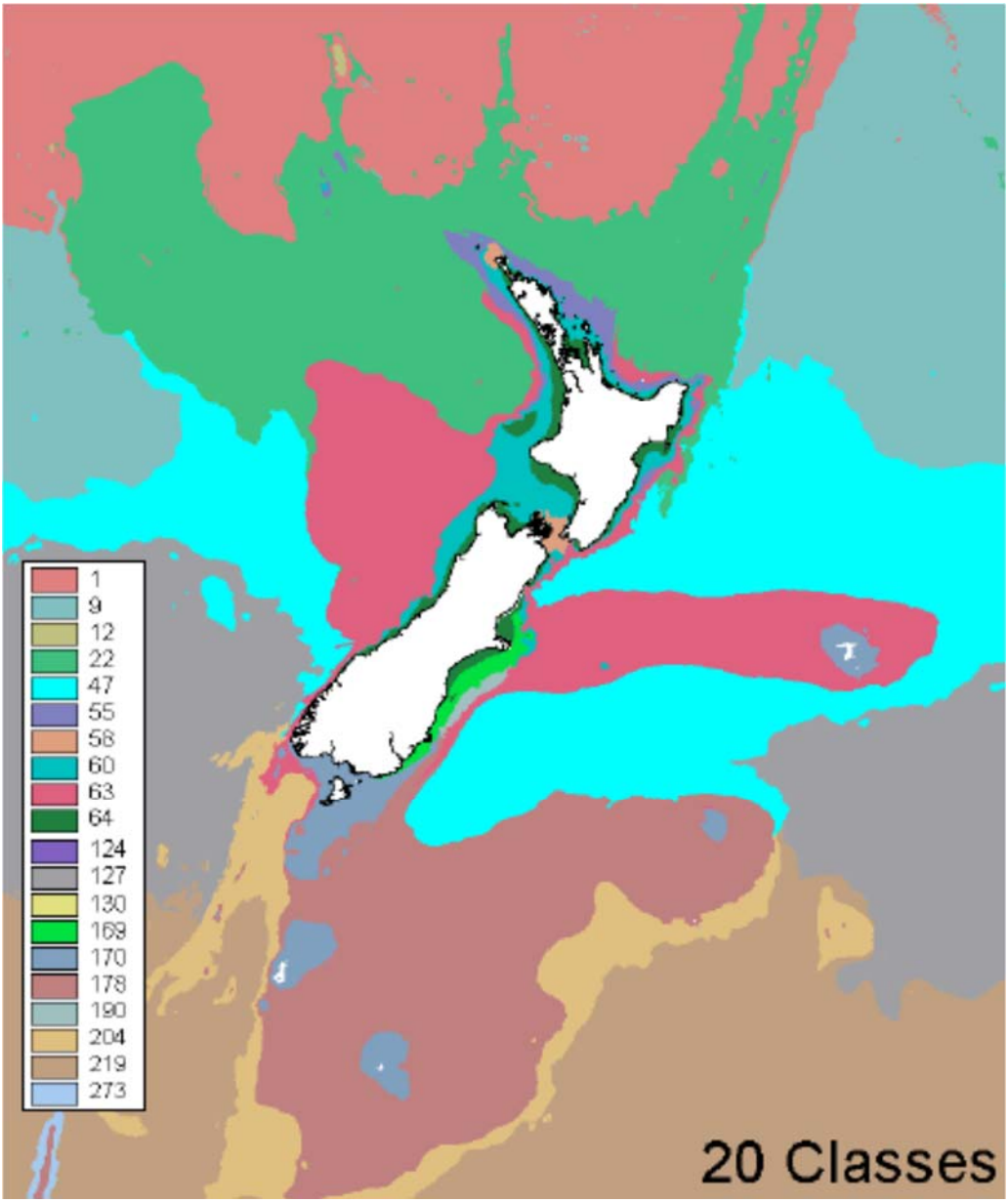


Figure 10.6: The 20-class version of the 2005 general purpose Marine Environment Classification (MEC, from Snelder et al 2005). The class numbers are nominal; for attributes of each class at this level, see Table 10.1.

Based partly on this experience, the Ministry of Fisheries commissioned a Benthic-Optimised Marine Environment Classification, BOMEC. Many more physical, chemical, and biological data layers were available for the development and tuning of this classification than for the 2005 MEC. Especially relevant for benthic invertebrates was the inclusion of a layer for sediment grain size (notably absent from the MEC). Generalised Dissimilarity Modelling (GDM, Ferrier et al 2002, 2007, Leathwick et al 2011) was used to define the classification because this approach is well suited to the sparse and unevenly distributed biological data available. The BOMEC classes (15-class level version shown in Figure 10.7) were strongly driven by depth, temperature, and salinity into five major groups: inshore and shelf; upper slope; northern mid-depths; southern mid-depths; and deeper waters (generally beyond the fishing footprint, down to 3000 m, the limit of the analysis). Waters deeper than 3000 m could be considered an additional class. The 15-class BOMEC levels were used in conjunction with a broad sediment type classification and broad depth bands to identify 112 benthic habitats shallower than 250 m (Figure 10.8)(Baird et al 2014).

Recent testing (Bowden et al 2011) has indicated that the BOMEC out-performs the original MEC at predicting benthic habitat classes on and around the Chatham Rise,

but that none of the available classifications is very good at predicting the abundance and composition of benthic invertebrates at the fine scale of the sampling undertaken (tens of metres to kilometres). This, in conjunction with the findings of Leathwick et al (2006), reinforces the role of environmental classifications as broad-scale predictors of general patterns at broad scale (tens to hundreds of kilometres) when more specific biological information is not available.

Where broad scale classification methods are not applicable, other approaches have been taken. The trawl fisheries for orange roughy, oreos, and cardinalfish take place to a large extent on seamounts or other features (Clark & O'Driscoll 2003, O'Driscoll & Clark 2005). These features are often geographically small and, in common with other, localised habitats like vents, seeps, and sponge beds, do not appear on broad-scale habitat maps (e.g., at EEZ scale) and cannot realistically be predicted by broad-scale environmental classifications. Many features have been extensively mapped in recent years (e.g., Rowden et al 2008), and seamount classifications based on biologically-referenced physical and environmental "proxies" have also been developed, in New Zealand waters by Rowden et al (2005), and globally by Clark et al (2010a&b). Davies & Guinotte (2011) developed a method of predicting the framework-forming (i.e, physically structuring) coldwater corals that are a focus for benthic biodiversity in deepwater systems. Work continues worldwide, including in New Zealand, on the development of sampling, analytical, and modelling techniques to provide cost-effective assessments of the distribution of marine habitats at a range of scales. Bowden et al (2014) provide a desk top assessment of future options for monitoring deepwater benthic communities, and conclude that photographic approaches sampling mega-epifauna are likely to be the most cost effective and relevant for detecting ecological effects at the scale of deep sea fisheries. Such sampling could be added to existing surveys, but would require dedicated time. Opportunistic sampling from trawl surveys or observer data cannot be relied upon to provide representative samples of the benthic community. NIWA has a MBIE-funded project "Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region" in collaboration with Victoria University of Wellington and the Marine Conservation Institute (USA). The research will develop a model to predict the locations of VMEs to inform New Zealand and South Pacific Regional Fisheries Management Organisation (SPRFMO) initiatives on spatial management in the South Pacific region. There may be applications within the New Zealand EEZ.

Table 10.1: 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

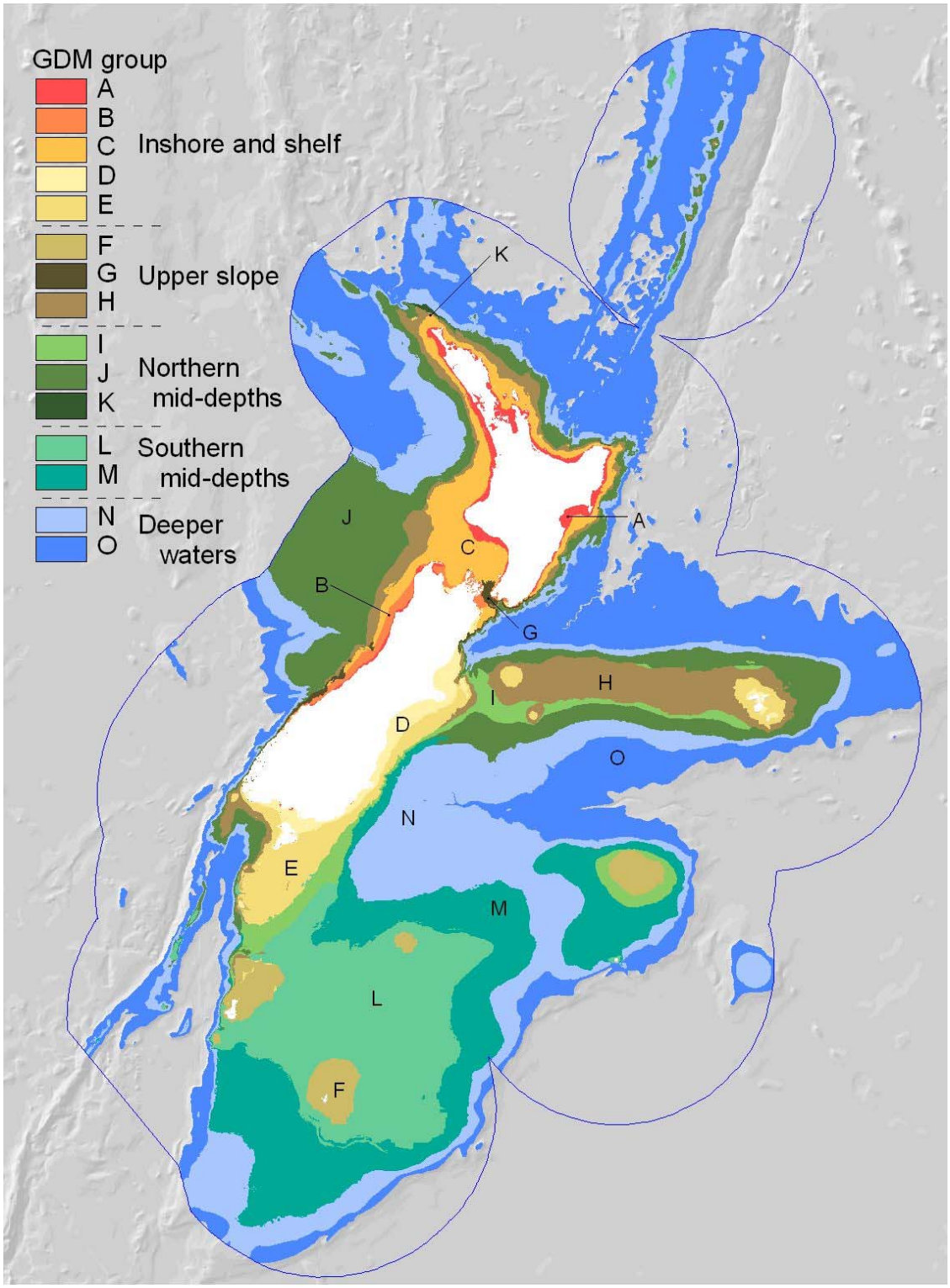


Figure 10.7: Map of the distribution of Benthic Optimised Marine Environment Classification (BOMEC) classes defined by multivariate classification of environmental data transformed using results from GDM analyses of relationships between environment and species turnover averaged across eight taxonomic groups of benthic species. From Leathwick et al 2010.

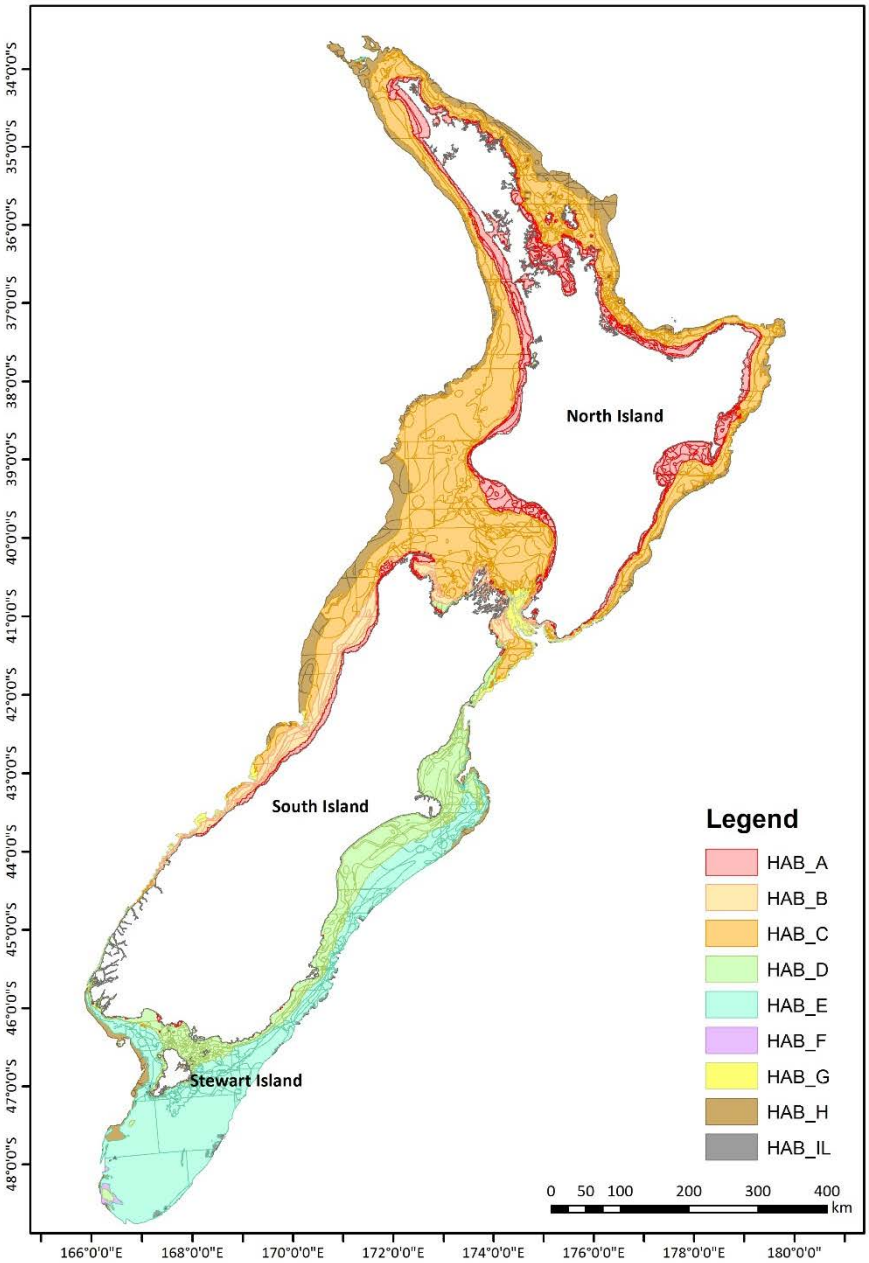


Figure 10.8: The broad habitat definitions based on the BOMEC classes, with divisions indicating areas of different sediment, depth zone, and statistical area in waters shallower than 250 m depth. From Baird et al (2014).

10.3.2 DISTRIBUTION OF FISHING

Since 1989–90, mobile bottom fishing has been reported on one of three standardised reporting forms (Table 10.2). Trawl Catch Effort and Processing Returns (TCEPRs) contain detailed spatial and other information for each trawl tow, whereas Catch Effort and Landing Returns (CELRs) include only summarised information for each day's fishing, with very limited spatial resolution. Since 2007–08, Trawl Catch and Effort Returns (TCERs) have been available for smaller, predominantly inshore trawlers. These include spatial and other information for each trawl tow but in less detail than on TCEPRs. Between 1989–90 and 2004–05, only about 25% of all mobile bottom fishing events were reported on TCEPRs. Another 25% were bottom trawls reported on CELRs, and the remaining 50% were dredge tows for shellfish reported on CELRs. The distribution of trawling reported on CELRs is not the same as that reported on TCEPRs; the smaller trawlers using CELRs are much more likely than the larger boats to fish close to the coast and target inshore species such as flatfish, red cod, tarakihi, and red gurnard (collectively 73% of all trawl tows reported on CELRs).

Table 10.2: Attributes, usage, and resolution of spatial reporting required on Trawl Catch Effort and Processing Returns (TCEPRs) Trawl Catch and Effort Returns (TCERs) and Catch Effort and Landing Returns (CELRs).

	Trawl catch and effort reporting forms		
	TCEPR	TCER	CELR
Year of introduction	1988–89	2007–08	1988–89
Vessels using	All trawlers >28 m Other vessels as directed Other vessels optional	All trawlers 6–28 m unless exempted	Trawlers not using TCER or TCEPR Shellfish dredgers
Trawl tow reporting	Tow by tow, start and finish locations, speed, depth, gear	Tow by tow, start location, speed, depth, gear	Daily summary, number of tows, effort, gear
Spatial resolution	1 minute (lat/long)	1 minute (lat/long)	Statistical reporting area (optionally lat/long)

Baird et al (2002) and Baird et al (2011) described the distribution and frequency of reported fishing by mobile bottom fishing gear (dredge, Danish seine, bottom trawl, bottom pair trawl, and mid-water trawl in contact with the bottom) in New Zealand's TS and EEZ during the 1990s and up to 2004–05, respectively, and this work has recently been updated to 2009–10 by Black et al (2013) for data reported on TCEPR. They showed that fishing was highly heterogeneous (spatially), but had considerable consistency among years; sites that were fished heavily in one year were likely to be fished heavily in other years and vice versa. A similar but more detailed analysis was conducted for the Chatham Rise and Sub-Antarctic areas by Baird et al (2006). Tows reported on TCEPRs were included in the main spatial analysis but some additional analysis was possible using tows reported on CELRs. Until 2006–07, many inshore vessels used CELRs and these comprised a substantial proportion of reported trawling, even for some "deepwater" species. For instance, Cryer & Hartill (2002) estimated that, in the Bay of Plenty in the 1990s, 78%, 75%, and 39% of trawl tows targetting tarakihi, gemfish, and hoki, respectively, were reported on CELR forms. Since 2007–08, almost all trawling effort has been reported on TCEPR or TCER forms.

Black et al (2013) updated the three annual measures of fishing effort: the number of tows, the aggregate swept area (using assumed door spreads, see Figure 10.9), and the coverage ("footprint") of the total trawl contact. Trawls were represented spatially as tracklines between the reported start and finish positions buffered by the assumed door spread to generate trawl polygons. The aggregate swept area for a year is the sum of the areas of the polygons and the "footprint" is the estimated area of the seabed that is covered by the polygons overlaid. The estimated swept areas and footprint do not account for any modification that might occur alongside the trawl path as represented by the swept area polygon (e.g., by suspended sediments transported by currents away from the trawl track). Black et al (2013) produced maps of the aggregate swept area by year for each of the 11 main target species or species groups, and various tables and figures describing trends. The annual number of trawls peaked in 1997–98 at 74 504 tows (swept area about 201 575 km^2). In 2009–10, 34 060 tows were reported on TCEPRs (about 79 600 km^2)

Baird et al (2011) used reported tows on small topographic features that are a focus for orange roughy and cardinalfish fisheries by defining polygons for these tows as radii around the reported start position with the area swept estimated from the reported duration and speed of the tow. These short tows do not appear to contribute substantially to broad-scale plots like Figure 10.9, yet can represent intense fishing effort on particular, small seamount features (e.g. Rowden et al 2005, O'Driscoll & Clark 2005).

Previous trawl footprint analyses (Baird et al 2011; Black et al 2013) have recognised that they underestimated trawl effort in inshore areas through exclusion of data recorded on CELR forms. Baird et al (2014) analysed a combined data set of TCEPR and TCER data for the area shallower than 250 m for 2007–08 to 2011–12 (Figure 10.9, Figure 10.10).

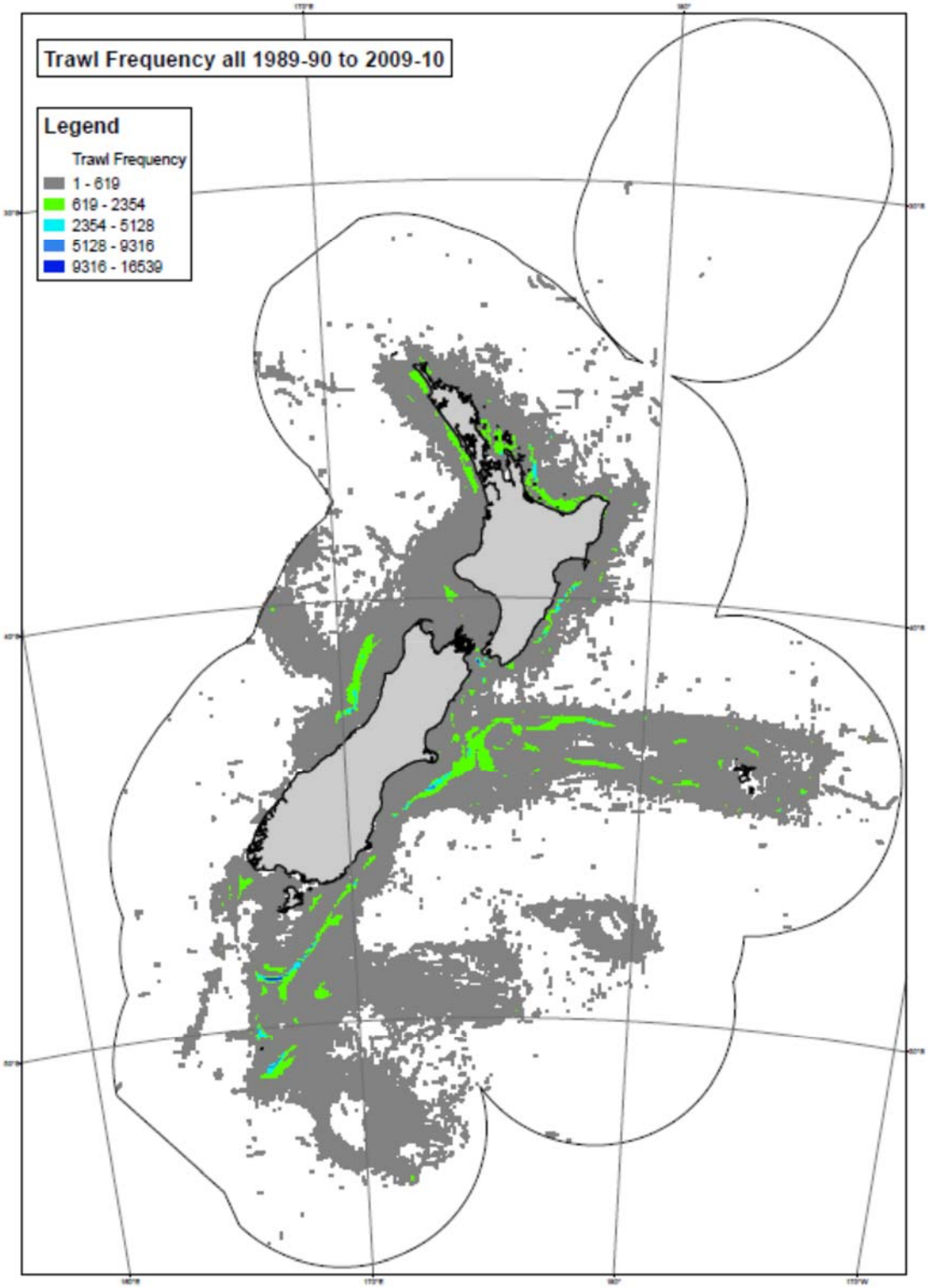


Figure 10.9: Map from Black et al 2013 showing the frequency of bottom-contacting trawling effort reported on TCEPR forms 1989–90 to 2009–10. The colour scale indicates the frequency of bottom trawling estimated by Black et al for each 5 × 5 km cell, all target species combined (e.g., the most frequently fished 25 km2 cells had over 16 000 tows recorded over 21 years).

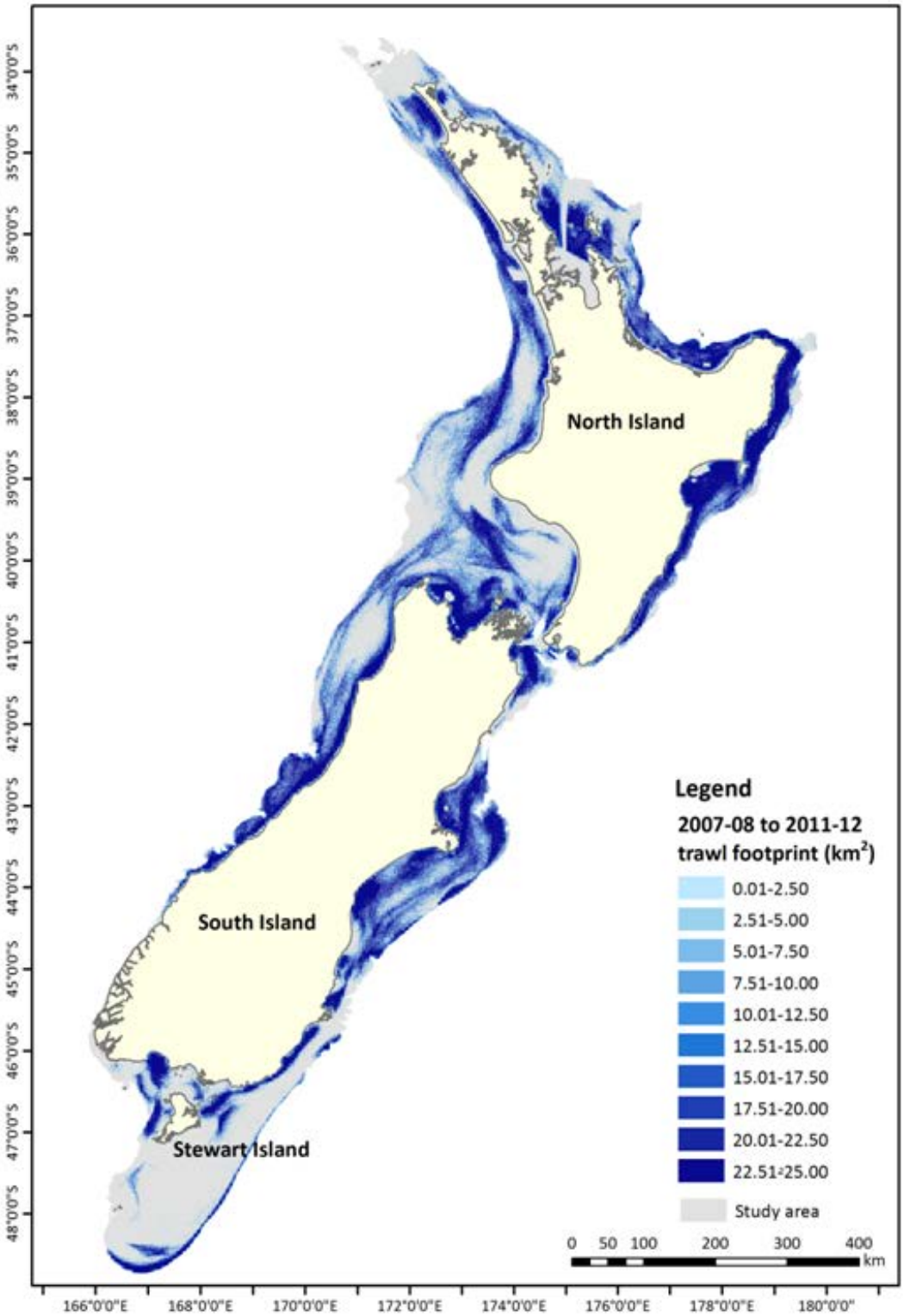


Figure 10.10: Total trawl cell based for footprint for the area shallower than 250 m for 2007–08 to 2011–12 combined (Baird et al 2014).

After the peak of over 140 000 reported trawl tows in 1996–97 and 1997–98 (Figure 10.11) when slightly over half of all tows were reported on TCEPRs, overall trawling effort declined to less than 80 000 tows per year by 2013–14, only about 40% of which is reported on TCEPRs (virtually all other tows are reported on TCERs).

Dredging for shellfish (oysters and scallops) is conducted in a number of specific areas that have separate, smaller statistical reporting areas (Figure 10.12). Over the 16-year dataset, there were almost 1.5 million scallop dredge tows in the four main scallop fisheries and over 0.6 million oyster dredge tows in the two dredge oyster fisheries. These data are collected on CELRs, usually at the spatial scale of a scallop or oyster fishery area and the data have been summarised as the number of dredge tows. No estimates of the area swept by these dredges have been made, but the number of reported tows has declined markedly since the early 1990s (Figure 10.13).

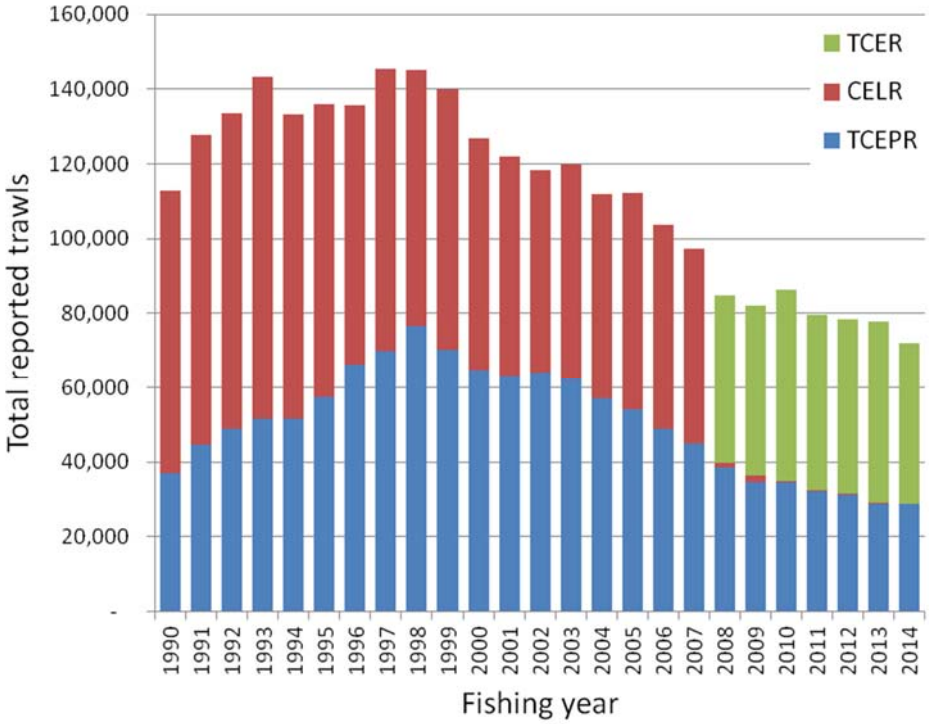


Figure 10.11: The number of trawl tows reported on Trawl Catch Effort and Processing Returns (TCEPR), Catch Effort and Landing Returns (CELR) and Trawl Catch and Effort Return (TCER) between the 1989–90 (1990) and 2013–14 (2014) fishing years. Data for the 2013–14 year may be incomplete.

Our knowledge of the distribution of mobile bottom fishing effort within our TS and EEZ is, by international standards, very good; since 2007–08 we have had tow-by-tow reporting of almost all trawling with a spatial precision of about 1 nautical mile. The distribution of dredge tows for shellfish is not reported with such high precision, but records kept by fishers in industry logbooks are often much more detailed than the Ministry for Primary Industries standard returns, and have sometimes been used to support spatial analyses that would not have been possible using the standard returns (e.g., Tuck et al 2006 for project ZBD2005/15 on the Coromandel scallop fishery and Michael et al 2006 for project ZBD2005/04 on the Foveaux Strait oyster fishery). These studies indicate the value of records with higher spatial precision.

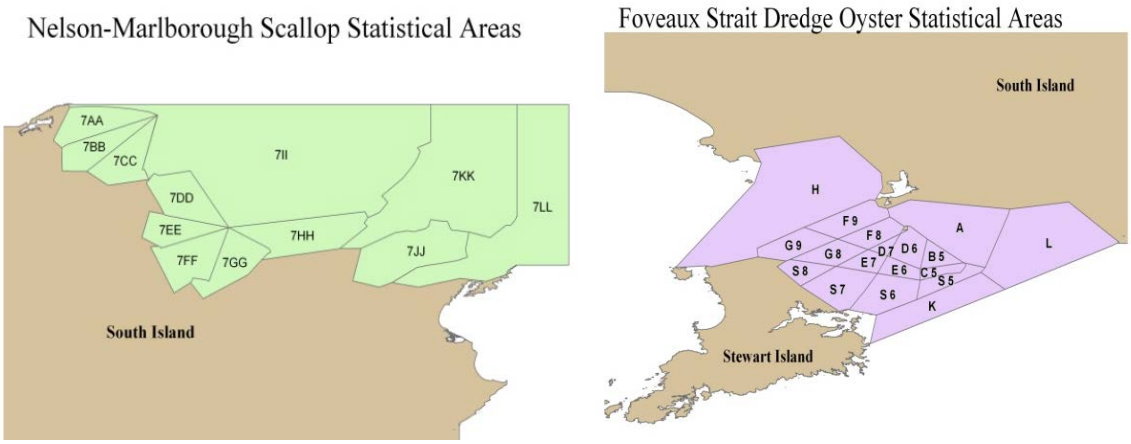


Figure 10.12: Maps taken from Baird et al 2011 of statistical reporting areas for the main oyster and scallop dredge fisheries (scales differ). Note that these reporting areas are generally much smaller than the standard statistical reporting areas used for most finfish reporting. [Continued on next page]

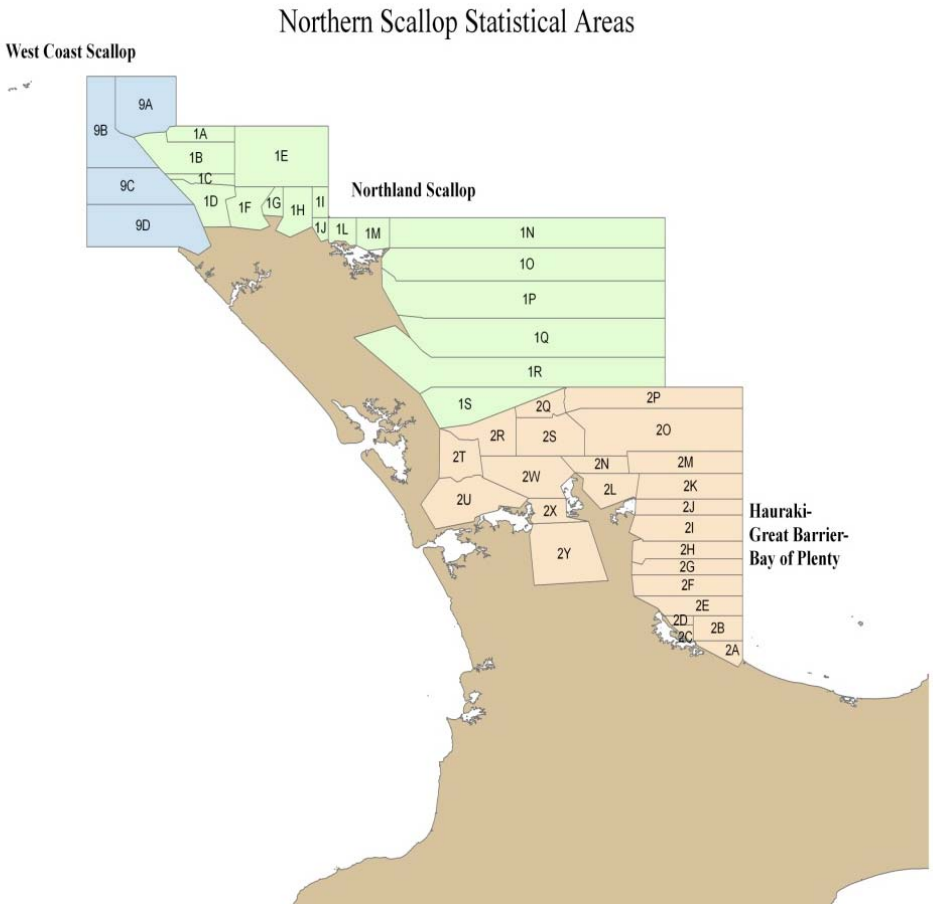


Figure 10.12 [Continued]: Maps taken from Baird et al 2011 of statistical reporting areas for the main oyster and scallop dredge fisheries (scales differ). Note that these reporting areas are generally much smaller than the standard statistical reporting areas used for most finfish reporting.

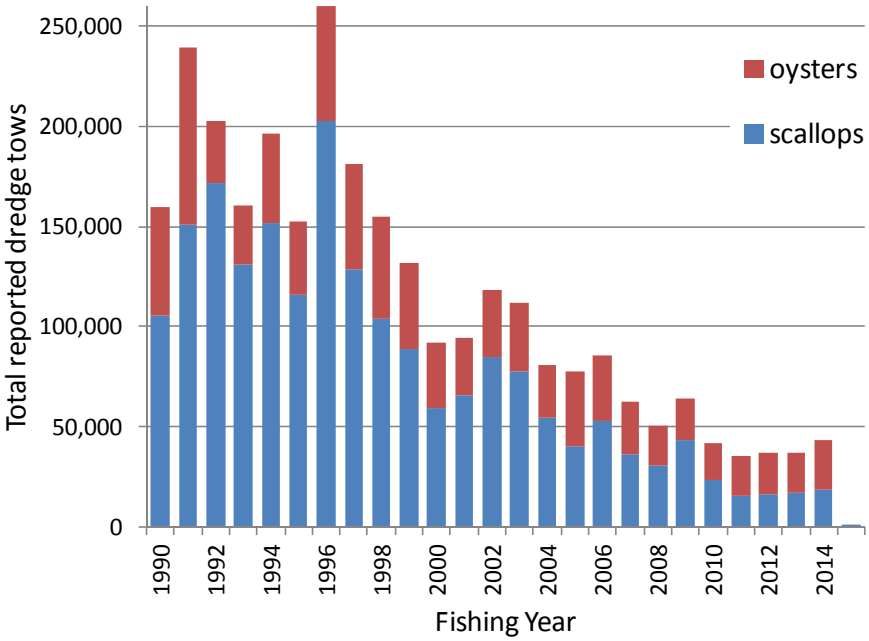


Figure 10.13: The number of dredge tows for scallop or oysters reported on Catch Effort and Landing Returns (CELR) between the 1989–90 (1990) and 2014–15 (2015) fishing years (data from Baird et al 2011 and MPI databases). Data for the 2014–15 year may be incomplete.

10.3.3 OVERLAP OF FISHING AND PREDICTED HABITAT CLASSES

Tuck et al (2014) reviewed a wide range of ecosystem indicators for deepwater fisheries, and concluded that in relation to benthic impact of fishing, indices of fishing footprint and fishing intensity by habitat and gear or fishery were likely to be the most useful. Black et al (2013) overlaid the 1989–90 to 2009–10 fishing year trawl footprint on the 15-class BOMEC to estimate the proportion of each class that had been trawled (and reported on TCEPRs) (Figure 10.14). They found that the size of the footprint and the proportion of each class trawled varied substantially between habitat classes (Figure 10.15, Table 10.3). Class O is the largest BOMEC class but has almost no reported fishing effort. Conversely, class I is one of the smaller classes but has a larger trawl footprint that overlaps 73% of the total class area. Two contrasting classes, together with their trawl footprints, are shown in Figure 10.16, based on analysis up to 2004–05. The trawl footprint from Black et al's analysis overlaps about 15% of the 2.6 million km2 of seafloor covered by the BOMEC, or about 9% of the 4.1 million km2 of seafloor within the New Zealand EEZ boundary (i.e., including the Territorial Sea). However, this overlap and that for some individual BOMEC classes (particularly coastal classes A–E) will be underestimated because of the omission of CELR data from these analyses.

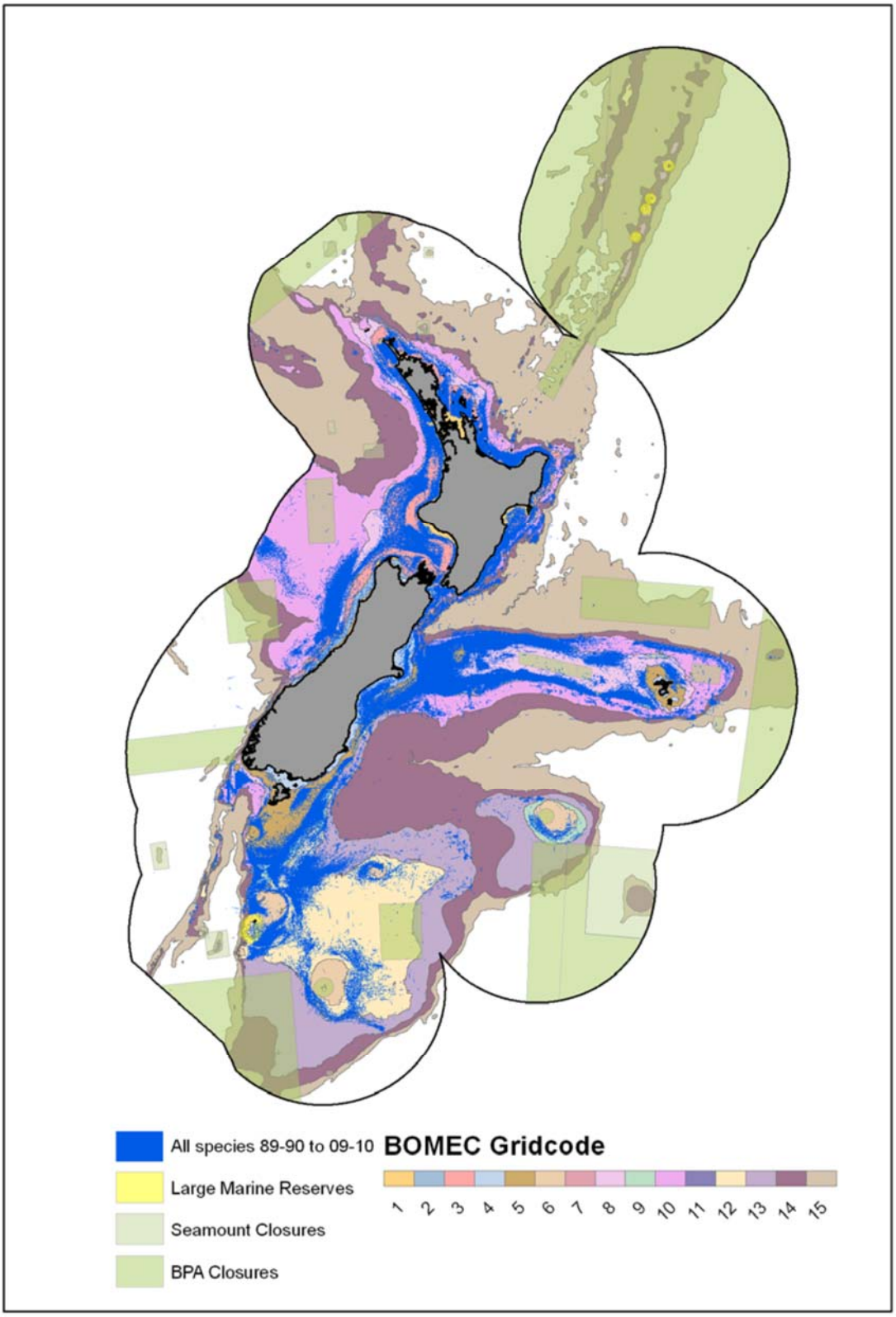


Figure 10.14: Plots from Black et al (2013) of the TCEPR trawl footprint (1989–90 to 2009–10) overlaid onto the 15-class level BOMEC.

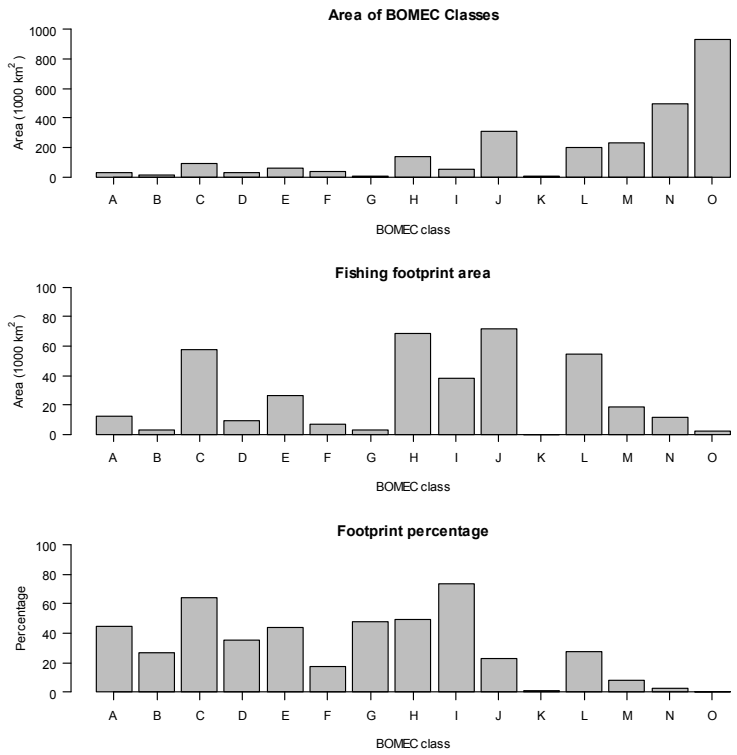


Figure 10.15: Plots from data provided by Black et al (2013) of the areas of each BOMEC Class (top), the fishing footprint up to 2009–10 shown in Figure 10.8 (centre), and percentage of each BOMEC Class area covered by the fishing footprint (bottom).

Table 10.3: Estimated area of each BOMEC class (within the outer boundary of the EEZ), and cumulative footprint from TCEPR over the fishing years 1989–90 to 2009–10 (Black et al 2013).

BOMEC class	Area (km^2)	Footprint area (km^2)	Footprint area (%)
A*	27 557	12 400	45%
B*	12 420	3 324	27%
C*	89 710	57 840	64%
D*	27 268	9 592	35%
E*	60 990	23 612	44%
F	38 608	6 691	17%
G	6 342	3 043	48%
H	138 550	68 389	49%
I	52 224	38 238	73%
J	311 361	71 594	23%
K	1 290	14	1.1%
L	198 577	54 337	27%
M	233 825	18 503	8%
N	493 034	11 369	2%
O	935 315	2 431	0.3%
Total	2 627 073	384 376	15%

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

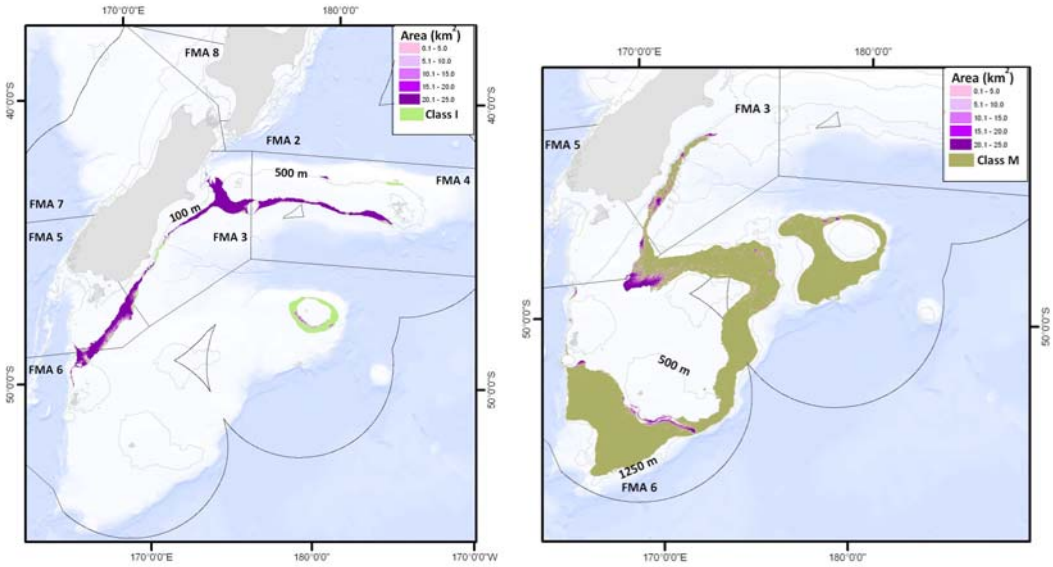


Figure 10.16: Maps from Baird & Wood (2010) showing BOMEC classes I (left) and M (right) overlaid with the footprint of trawls on or near the seafloor reported on TCEPR forms to 2004–05 for each 25-km2 cell.

Baird et al (2014) overlaid the combined TCER and TCEPR 2007–08 to 2011–12 fishing years trawl footprint on a classification for benthic habitats shallower than 250 m (presented in Figure 10.8). As with the offshore data, the size of the footprint and proportion of each class trawled varied between habitat classes (Table 10.4), and ranged from 21% (class F) to 76% (class B). Over the 2007–08 to 2011–12 period, the trawl footprint overlays 48% of the area shallower than 250m.

Table 10.4: Areas* of the separate habitat classes and areas† of the 5-y trawl footprint in each habitat class, for the BOMEC classes, depth zones, and sediment types, and the percentage of the 5-y trawl footprint in each class (see Baird et al. 2014 for more details).

Habitat class descriptors	Habitat class area (km²)	Total footprint (km²)	% area with trawl contact
BOMEC class			
A	27 375.2	14 047.1	52.1
B	12 318.8	9 322.3	75.7
C	89 560.4	47 120.0	52.6
D	25 513.1	16 344.7	64.4
E	47 186.8	13 890.6	29.6
F	381.7	73.2	21.1
G	3 898.4	1 902.9	50.8
H	25 204.4	9 228.1	36.8
I	473.2	340.8	72.0
J	133.9	31.3	30.0
L	188.9	121.5	67.6
Depth zone			
< 50 m	50 781.3	29 529.4	58.8
50–100 m	63 493.9	37 375.2	59.1
100–250 m	117 959.8	45 517.9	38.7
Sediment type			
Sand	104 830.2	54 851.9	52.4
Mud	72 518.1	41 001.8	57.0
Gravel	18 530.0	9 339.3	50.6
Sandy mud	203.4	203.4	99.98
Calcareous sand	6 763.7	2 080.7	31.3
Calcareous gravel	29 389.5	4 945.4	17.0
All	232 235.0	112 422.5	48.4

* The area measures for the habitat classes include any seafloor closed to trawling.

† The area measures for the 5-y footprint represent 98.8% of the total footprint.

10.3.4 STUDIES OF THE EFFECTS OF MOBILE BOTTOM FISHING METHODS IN NEW ZEALAND

The widespread nature of bottom trawling suggests that fishing is the main anthropogenic disturbance agent to the seabed throughout most of New Zealand's EEZ. Wind waves are certainly very widespread, but both field studies and modelling (Green et al 1995) suggest that erosion of the seabed deeper than 50 m by waves occurs only very rarely in the New Zealand EEZ. Despite their widespread distribution at the surface, therefore, wind-waves are not a dominant feature of the long-term disturbance regime throughout most of the EEZ. In some places, especially in the coastal zone and in areas close to headlands, straits, or islands, currents and tides may dominate the natural disturbance regime and a community adapted to this type of disturbance will have developed. However, over most of the EEZ between about 100 and 1000 m depth, especially in areas where there are few strong currents, fishing is probably the major broad-scale disturbance agent.

Several studies have been conducted since 1995 in New Zealand, focussing on the effects of various dredge and trawl fishing methods on a variety of different habitats in several geographical locations (Table 10.5). Despite the diversity of these studies, and their different depths, locations, and habitat types, the results are consistent with the global literature on the effects of mobile bottom fishing gear on benthic communities. Generally, there are decreases in the density and diversity of benthic communities and, especially, the density of large, structure-forming epifauna, and long-lived organisms along gradients of increasing fishing intensity. Large, emergent epifauna like sponges and framework-forming corals that provide structured habitat for other fauna are particularly noted as being susceptible to disturbance by mobile bottom fishing methods (Cranfield et al 1999, 2001, 2003, Cryer et al 2000), especially on hard (non sedimentary) seabeds (Clark & Rowden 2009, Clark et al 2010a&b, Williams et al 2011). Even though large emergent fauna seem most susceptible, effects have also been shown in the sandy or silty sedimentary systems usually considered to be most resistant to disturbance (Thrush et al 1995, 1998, Cryer et al 2002). Also reflecting the international literature is a substantial variation in the extent to which individual New Zealand studies have shown clear effects. For instance, in Foveaux Strait, Cranfield et al (1999, 2001, 2003) inferred substantial changes in the benthic system caused by over 130 years of oyster dredging, but Michael et al (2006) did not support such conclusions in the same system. Subsequent review of these studies found much common ground but no overall consensus on the long-term effects of dredging on the benthic community of the strait.

These studies have focussed predominantly on changes in patterns in biodiversity associated with trawling and/or dredging and less work has been done to assess changes in ecological process or to estimate the rate of recovery from fishing. Projects that have started on recovery rates are focussed on relatively few habitats and primarily those that are known to be sensitive to physical disturbance, including by trawling or dredging (e.g., seamounts, project ENV2005/16, and areas of high current and natural biogenic structure, projects ENV9805, ENV2005/23 and BEN2009/02). Thus, the understanding of the consequences of fishing (or of ceasing to fish) for sustainability, biodiversity, ecological integrity and resilience, and fish stock productivity in the wide variety of New Zealand's benthic habitats remains incomplete. Reducing this uncertainty would allow the testing of the utility and likely long-term productivity of a variety of management strategies, and enable a move towards a regime that maximises value to the nation consistent with Fisheries 2030.

Table 10.5: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters [Continued on next page].

Location	Approach	Key findings	References
Mercury Islands sandy sediments. Scallop dredge	Experimental	Density of common macrofauna at both sites decreased as a result of dredging at two contrasting sites; some populations were still significantly different from reference plots after 3 months.	Thrush et al 1995
Hauraki Gulf various soft sediments. Bottom trawl and scallop dredge.	Observational, gradient analysis	Decreases in the density of echinoderms, longlived taxa, epifauna, especially large species, the total number of species and individuals, and the Shannon-Weiner diversity index with increasing fishing pressure (including trawl and scallop dredge). Increases in the density of deposit feeders, small opportunists, and the ratio of small to large heart urchins.	Thrush et al 1998

Table 10.5 [Continued]: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters.

Bay of Plenty continental slope. Scampi and other bottom trawls.	Observational, multiple gradient analyses	Depth and historical fishing activity (especially for scampi) at a site were the key drivers of community structure for large epifauna. The Shannon-Weiner diversity index generally decreased with increasing fishing activity and increased with depth. Many species were negatively correlated with fishing activity; fewer were positively correlated (including the target species, scampi).	Cryer et al 1999 Cryer et al 2002
Foveaux Strait, sedimentary and biogenic reef. Oyster dredge.	Observational, various	Interpretations of the authors differ. Cranfield et al's papers concluded that dredging biogenic reefs for their oysters damages their structure, removes epifauna, and exposes associated sediments to resuspension such that, by 1998, none of the original bryozoan reefs remained. Michael et al concluded that there are no experimental estimates of the effect of dredging in the strait or on the cumulative effects of fishing or regeneration, that environmental drivers should be included in any assessment, and that the previous conclusions cannot be supported. The authors agree that biogenic bycatch in the fishery has declined over time in regularly-fished areas, that there may have been a reduction in biogenic reefs in the strait since the 1970s, and that simple biogenic reefs appear able to regenerate in areas that are no longer fished (dominated by byssally attached mussels or reef-building bryozoans). There is no consensus that reefs in Foveaux Strait were (or were not) extensive or dominated by the bryozoan *Cinctopora*.	Cranfield et al 1999, 2001, 2003 Michael et al 2006
Spirits Bay, sedimentary and biogenic areas. Scallop dredge.	Observational, gradient analysis	In 1999, depth was found to be the most important explanatory variable for benthic community composition but a coarse index of dredge fishing intensity was more important than substrate type for many taxonomic groups. Sponges seemed most affected by scallop dredging, and samples taken in an area once rich in sponges had few species in 1999. This area had probably been intensively dredged for scallops. Analysis of historical samples of scallop survey bycatch showed a marked decline in sponge species richness between 1996 and 1998. In 2006, significant differences were identified between areas within which fishing was or was not allowed. Species contributing to these differences included those identified as being most vulnerable to the effects of fishing. These differences could not be attributed specifically to fishing because of interactions with environmental gradients and uncertainty over the history of fishing. No significant change between 1999 and 2006 was identified. In 2010, analysis of both epifaunal and infaunal community data identified change since 2006, and significant depth, habitat and fishing effects. The combined fishing effects accounted for 15 – 30% of the total variance (about half of the explained variance). Individual species responses to fishing were examined, and those identified as most sensitive to fishing in this analysis had previously been categorised as sensitive on the basis of life history characteristics within the 2006 study.	Cryer et al 2000 Tuck et al 2010 Tuck & Hewitt 2013
Tasman and Golden Bays. Bottom trawl, scallop and oyster dredge	Observational, gradient analysis	A gradient analysis was adopted to investigate the importance of the different factors affecting epifaunal and infaunal communities in Tasman and Golden Bays. Fishing was consistently identified as an important factor in explaining variance in community structure, with recent trawl and scallop effort being more important than other fishing terms. Important environmental variables included maximum current speed, maximum wave height, depth, % mud, and salinity. Fishing accounted for 31–50% of the explained variance in epifaunal and infaunal community composition, species richness, and Shannon-Weiner diversity. Overall, models explained 30–54% of variance, and additional spatial patterns identified in the analysis explained a further 5–16% of variance.	Tuck et al 2011

Table 10.5 [Continued]: Summary of studies of the effects of bottom trawling and dredging in New Zealand waters.

Graveyard complex "seamounts", northern Chatham Rise. Orange roughy bottom trawl.	Observational, multiple analyses	From surveys in 2001 and 2006, substrate diversity and the amount of intact coral matrix were lower on fished seamounts. Conversely, the proportions of bedrock and coral rubble were higher. No change in the megafaunal assemblage consistent with recovery over 5–10 years on seamounts where trawling had ceased. Some taxa had significantly higher abundance in later surveys. This may be because of their resistance to the direct effects of trawling, their protection in natural refuges, or because these taxa represent the earliest stages of seamount recolonisation.	Clark et al 2010a&b Williams et al 2011

An expert based assessment of 65 threats to 62 marine habitats from saltmarsh to the abyss (MacDiarmid et al 2012) concluded that only 7 of the 20 most important threats to New Zealand marine habitats were directly related to human activities within the marine environment. The most important of these was bottom trawling (ranked third equal most important), but invasive species, coastal engineering, and aquaculture were also ranked highly. However, the two top threats, five of the top six threats, and over half of the 26 top threats stemmed largely or completely from human activities external to the marine environment (the most important being ocean acidification, rising sea temperatures, and sedimentation resulting from changes in land-use). The assessment suggested that the number and severity of threats to marine habitats declines with depth, particularly deeper than about 50 m. Shallow coastal habitats face up to 52 non-trivial threats whereas most deep water habitats are threatened by fewer than five. Coastal and estuarine reef, sand, and mud habitats were considered to be the most threatened habitats whereas slope and deep water habitats were among the least threatened.

10.3.5 CURRENT RESEARCH

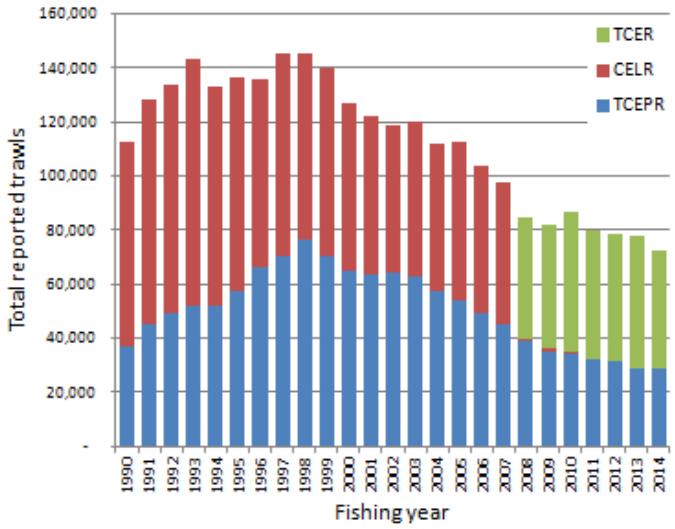
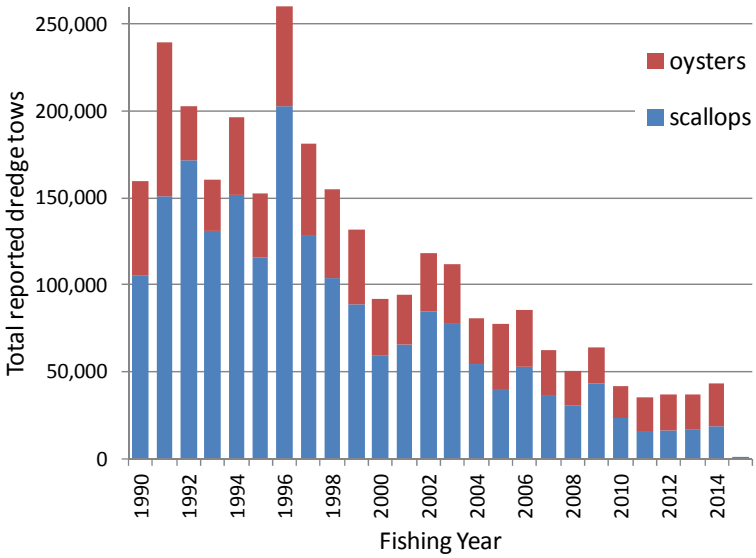
Project BEN2007/01 is a 5-year project to assess the effects of fishing on soft sediment habitat, fauna, and processes across the range of habitat types in the TS and EEZ. Sampling and analytical strategies for such broad-scale assessments have been developed and the project has moved into a phase of data collection, collation, and analysis. Two field-based "case studies" in different habitat types will be assessed, and a variety of existing information will be drawn together and analysed to provide a TS and EEZ-wide perspective. The focus of this study is on the relative sensitivities of different habitats in the TS and EEZ to disturbance by mobile bottom fishing methods.

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

Project ZBD2012/03 will use data collected from recent Oceans Survey 20/20 sampling on the Chatham Rise to determine whether there are quantifiable effects of variations in seabed trawling intensity on benthic communities, and also conduct seabed mapping and photographic surveys in previously un-sampled areas on the central crest of the rise.

Several MBIE-funded projects also have strong linkages with MPI research on benthic impacts. These include "Vulnerable Deep-Sea Communities" (CO1X0906) which is analysing the time series of data from the "Graveyard seamounts" (surveys in 2001, 2006, 2009, all carried out with support from MFish or the cross-departmental Oceans Survey 20/20 programme), as well as evaluating the relative vulnerability of benthic communities in several deep-sea habitats (e.g., seamounts, canyons, continental slope, hydrothermal vents, seeps) and their risk from bottom trawling.

10.4 INDICATORS AND TRENDS

Annual number of tows	2010–11 fishing year: 86 024 trawl tows 35 150 shellfish dredge tows
Trend in number of tows	Trawl and dredge effort stable or decreasing in recent years:  

Cumulative overlap of TCEPR trawl footprint with BOMEC habitat classes for 1989–90 to 2009–10

BOMEC class	Area (km²)	Footprint area (km²)	Footprint area (%)
A*	27 557	12 400	45%
B*	12 420	3 324	27%
C*	89 710	57 840	64%
D*	27 268	9 592	35%
E*	60 990	23 612	44%
F	38 608	6 691	17%
G	6 342	3 043	48%
H	138 550	68 389	49%
I	52 224	38 238	73%
J	311 361	71 594	23%
K	1 290	14	1.1%
L	198 577	54 337	27%
M	233 825	18 503	8%
N	493 034	11 369	2%
O	935 315	2 431	0.3%
Total	2 627 073	384 376	15%

Cumulative overlap of trawl footprint shallower than 250 m with BOMEC habitat classes, depth zones and sediment types for 2007–08 to 2011–12

Habitat class descriptors	Habitat class area (km²)	Total footprint (km²)	% area with trawl contact
BOMEC class			
A	27 375.2	14 047.1	52.1
B	12 318.8	9 322.3	75.7
C	89 560.4	47 120.0	52.6
D	25 513.1	16 344.7	64.4
E	47 186.8	13 890.6	29.6
F	381.7	73.2	21.1
G	3 898.4	1 902.9	50.8
H	25 204.4	9 228.1	36.8
I	473.2	340.8	72.0
J	133.9	31.3	30.0
L	188.9	121.5	67.6
Depth zone			
< 50 m	50 781.3	29 529.4	58.8
50–100 m	63 493.9	37 375.2	59.1
100–250 m	117 959.8	45 517.9	38.7
Sediment type			
Sand	104 830.2	54 851.9	52.4
Mud	72 518.1	41 001.8	57.0
Gravel	18 530.0	9 339.3	50.6
Sandy mud	203.4	203.4	99.98
Calcareous sand	6 763.7	2 080.7	31.3
Calcareous gravel	29 389.5	4 945.4	17.0
All	232 235.0	112 422.5	48.4

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

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THEME 4: ECOSYSTEM EFFECTS

11 NEW ZEALAND'S CLIMATE AND OCEANIC SETTING

Scope of chapter	This chapter provides context within which to consider interactions between the environment and the sea food sector. It provides an overview of primary productivity, oceanography, bentho-pelagic coupling, ocean acidification and oceanic climate trends in the SW Pacific region.
Area	New Zealand regional setting
Focal localities	All New Zealand waters
Key issues	• Climate and oceanographic variability and long-term changes are of relevance to fisheries and the broader marine environment. • Allows for improved understanding of the links between observed patterns and drivers of biological processes. • Allows for testing of likely future scenarios • New Zealand trends of increasing air and sea temperatures and ocean acidification are consistent with global trends.
Emerging issues	• New Zealand's oceanic climate is changing. • Causal mechanisms that link the dynamics of a variable marine environment to variation in biological productivity, particularly of fisheries and biodiversity, are not well understood in New Zealand or internationally, but are the subject of multiple studies. • The cumulative effects of ocean climate change and other anthropogenic stressors on aquatic ecosystems (productivity, structure and function) are likely to be high, and seen in the next 20–30 years. • Some long-term trends in the marine environment available at a national scale are to be incorporated in the new Environmental Reporting system being developed by MfE and Statistics New Zealand. • There is a growing recognition that stressors will act both individually and interactively, confounding predictions of the net effects of climate change. • Improved scenario setting and the need for risk evaluation • The first regime shift in IPO since most fisheries monitoring began occurred in 2000 which is likely to result in fewer El Niño events for a 20–30 year period, which is likely to impact fish productivity.
MPI Research (current)	ZBD2013-02 VME connectivity ZBD2014-01 Live DW coral experiment phase 2 ZBD2013-08 NZ-Ross sea connectivity Humpback whales ZBD2014-10 BPA biodiversity ZBD2014-03 Sublethal effects of environment change on fish populations ZBD2014-04 Isoscapes for trophic studies ZBD2014-05 Ocean acidification ZBD2014-06 Macroalgae mapping and potential as national scale indicators ZBD2014-07 Southern coralline algae shellfish habitat ZBD2014-09 Climate change risks and opportunities ZBD2013-03 Continuous plankton recorder (16849) ZBD2013-06 Shell generation ZBD2012-03 CRise benthos (16589)
Government and other research	NIWA Coast & Oceans Centre, Climate and Atmosphere Centre; University of Otago-NIWA shelf carbonate geochemistry & bryozoans; Munida time-series transect; Physical Oceanography research Geomarine Services-foraminiferal record of human impact; Regional Council monitoring programmes; Statistics New Zealand Environmental Domain review; Department of Conservation the impacts of climate change on marine protected species.

	Relevant global climate programmes: Argo; Southern Ocean Observing System Dragonfly science: Fast-forward fish: resilience of exploited marine populations to a changing ocean
Links to 2030 objectives	Environmental Outcome Objective 1; environmental principles of Fisheries 2030; MPI's "Our Strategy 2030": key stated focuses are to maximise export opportunities and improve sector productivity; increase sustainable resource use, and protect from biological risk. Note that Fisheries 2030 is undergoing a substantial refresh.
Related chapters/issues	This chapter provides background environmental information that is relevant to all chapters, but is of particular relevance to the following chapters: Biodiversity Trophic and ecosystem-level effects

Note: This chapter has been fully updated for the AEBAR 2015.

11.1 CONTEXT

This chapter summarises information on ocean acidification, and oceanography around New Zealand, and climate trends in the Southwest Pacific region. This information provides context to understand the interaction between the environment and seafood productivity in the region. Climate and oceanographic conditions play an important role in driving the productivity of our oceans and the abundance and distribution of our fishstocks and fisheries. The most recent analysis of trends in climate and oceanographic variables relevant to fisheries management in New Zealand is given in Hurst et al (2012).

New Zealand is essentially part of a large submerged continent (Figure 11.1). The territorial sea (TS extending from mean low water shore line to 12 nautical miles), 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 11.1). New Zealand waters straddle more than 25 degrees of latitude from 30°S in warm subtropical waters to 56°S in cooler, subantarctic waters, and 30 degrees of longitude from 161°E in the Tasman Sea to 171°W in the west Pacific Ocean. New Zealand's coastline, with its numerous embayments, is also long, with estimates ranging from 15 000 to 18 000 km, depending on the method used for measurement (Gordon et al 2010).

New Zealand lies across an active subduction zone in the western Pacific plate; tectonic activity and volcanism have resulted in a diverse and varied seascape within the EEZ. The undersea topography comprises a relatively narrow band of continental shelf down to 200 m water depth, extensive continental slope areas from 200 to 1000 m, extensive abyssal plains, submarine canyons and deep sea trenches, ridge systems and numerous seamounts and other underwater topographic features such as hills and knolls. There are three significant submarine plateaus, the Challenger Plateau, the Campbell Plateau, and the Chatham Rise.

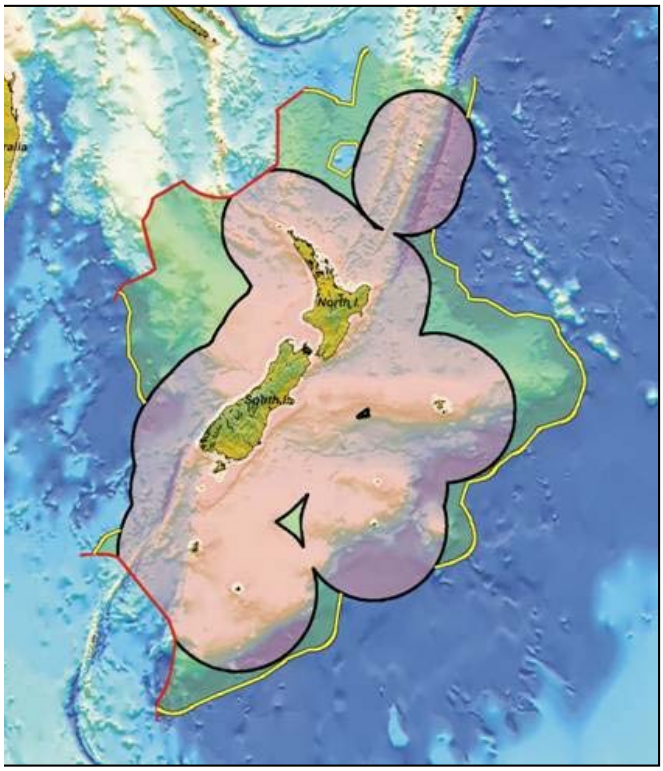

Figure 11.1: New Zealand land mass area 250 000 km^2; EEZ and territorial sea area (pink) 4 200 000 km^2; extended continental shelf extension area (light green) 1 700 000 km^2; Total area of marine jurisdiction 5 900 000 km^2. The black line shows the boundary of the New Zealand EEZ, the yellow line indicates the extension to New Zealand's legal continental shelf, and the red line the agreed Australia/New Zealand boundary under UNCLOS Article 76. Image courtesy of GNS.

The physical oceanography of the deep seas around New Zealand has recently been reviewed by Chiswell et al (2015). Multiple platforms including satellites, drifting and profiling floats, moorings and oceanographic cruises have provided a wealth of new observations over the last 30 years and analysis of these observations has substantially improved our understanding of the oceanography over the basic description of the circulation around New Zealand that was known in 1985. Chiswell et al summarises and integrates earlier research through a series of schematics of the ocean currents around New Zealand. The surface currents are shown in Figure 11.2.

The Tasman Sea, to the west of New Zealand, is separated from the South Pacific Gyre by the New Zealand landmass. The South Pacific Western Boundary Current, the East Australian Current (EAC) flows down the east coast of Australia, before separating from the Australian land mass at about 31°S to 32°S (Ridgway & Dunn 2003). Part of the separated flow crosses the Tasman Sea as the Tasman Front (Stanton 1981; Ridgway & Dunn 2003; Sutton & Bowen 2014) while the remaining flow continues south in the EAC extension. Sutton & Bowen (2014), found that the Tasman Front is a weaker connection than previously thought between the EAC and East Auckland Current (EAUC). They found that the Tasman Front was shallower than both the EAC and EAUC and transported less water than the other currents.

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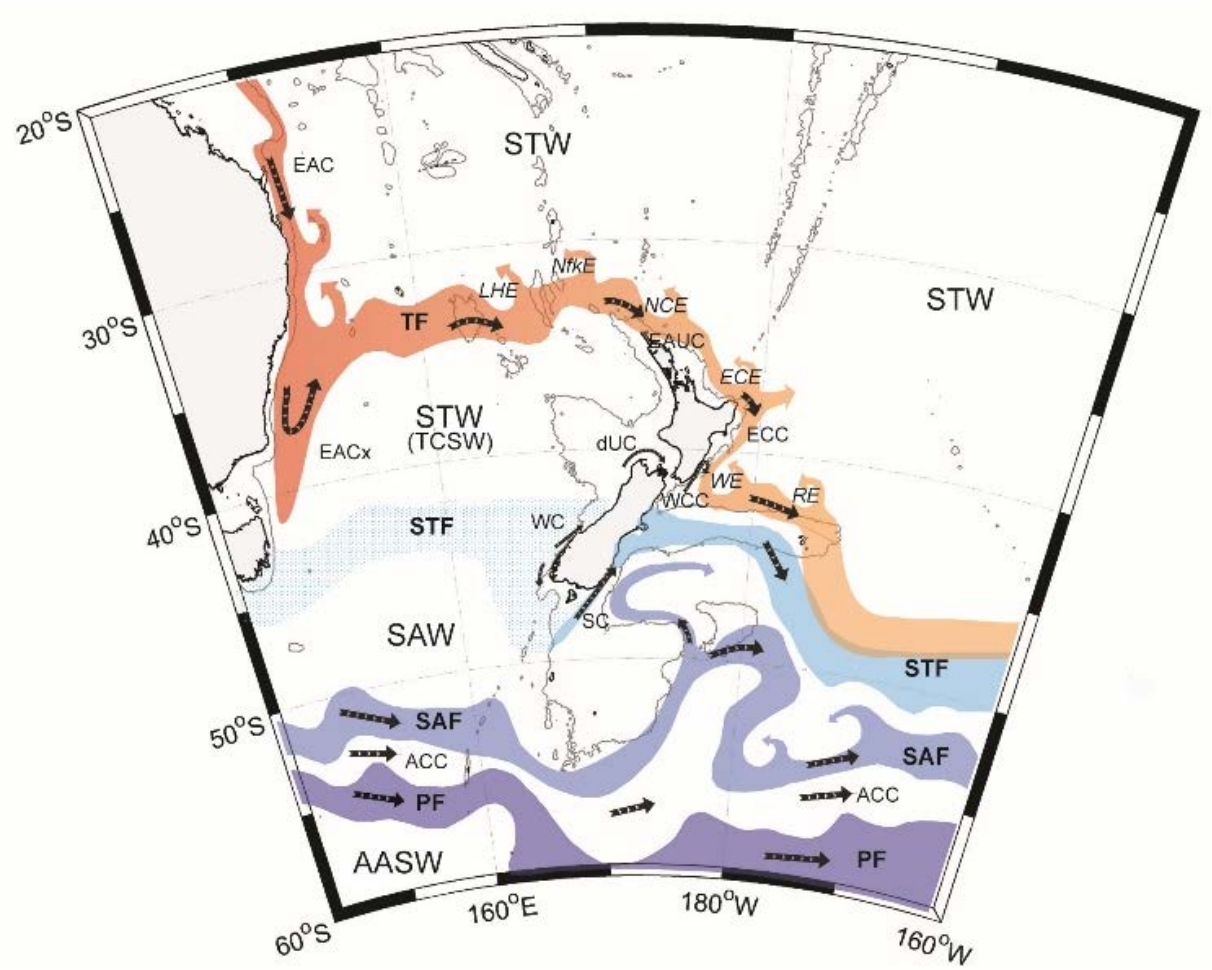

Figure 11.2: Schematic surface circulation around New Zealand based on drifter and hydrographic data. Regions of flow are shown as coloured streams. Colours reflect the temperature of the flows with red being warmest, and dark blue being coldest. The STF in the Tasman Sea is density compensated with little flow, as indicated by the shading. Water Masses are Subtropical Water (STW), Tasman Sea Central Water (TSCW), Subantarctic Water (SAW) and Antarctic Surface Water (AASW). Ocean fronts are Tasman Front (TF), Subtropical Front (STF), Subantarctic Front (SAF) and Polar Front (PF). Ocean currents are East Australia Current (EAC), East Australia Current extension (EACx), East Auckland Current (EAUC), East Cape Current (ECC), d'Urville Current (dUC), Wairarapa Coastal Current (WCC), Westland Current (WC), Southland Current (SC) and Antarctic Circumpolar Current (ACC). Eddies are Lord Howe Eddy (LHE), Norfolk Eddy (NfkE), North Cape Eddy (NCE), East Cape Eddy (ECE), Wairarapa Eddy (WE) and Rekohu Eddy (RE). (With permission from Chiswell et al 2015).

At 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 & Ridgway 1988; Hamilton 2006). Around 165°E it diverts south across Macquarie Ridge where the front has two clear branches (Smith et al 2013) which continue onto the Campbell Plateau where they merge as the Southland Front along the Otago Coast (Chiswell 1996; Sutton 2003).

The circulation in the central Tasman Sea, east of the influence of the EAC, and between the Tasman Front and Subtropical Front is thought to be relatively slow. Ridgway & Dunn (2003) showed eastward surface flow across the interior of the Tasman Sea sourced from the southernmost limit of the EAC, with the flow separating around Challenger Plateau and, ultimately, New Zealand. Reid's (1986) analysis indicates that a small anticlockwise 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 islands, and Cook Strait, which are highly energetic. Along the northeast coast of North Island there are two near permanent eddies that vary in size and strength, the North Cape and East Cape Eddies. These both sit within the EAUC, which flows down the east coast of the North Island to East Cape. From here most of the water continues south in the East Cape Current, while the remainder is split between the East Cape Eddy and the Pacific Ocean. There are several eddies in the East Cape Current region, with the largest known as the Wairarapa Eddy. It sits between the North Island and the northern flanks of the Chatham Rise (Chiswell et al 2015).

Along the southeastern coast of the South Island the Subtropical Front flows north (while locally known as the Southland Front) to approximately the latitude of Banks Peninsula. It then turns east along the Chatham Rise before flowing south of the Chatham Islands into the Pacific Ocean.

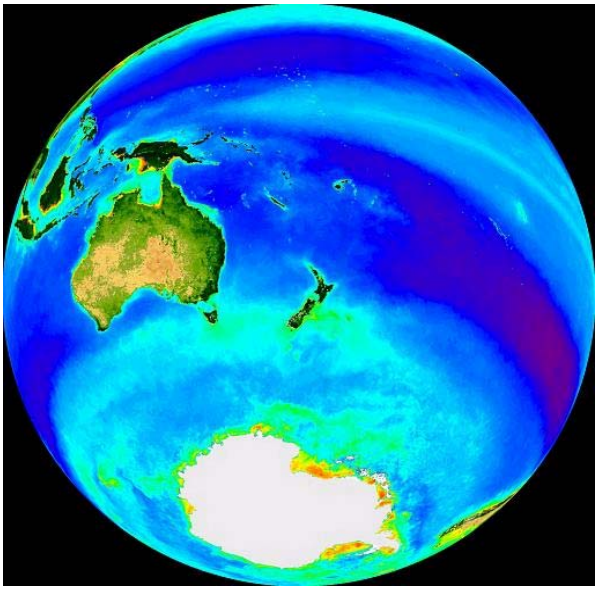

Figure 11.3: SeaWIFS image showing elevated chlorophyll a (green) near New Zealand. Image courtesy of NOAA.

Forcén-Vázquez (2015) showed that water from the Subtropical Front is found over a large fraction of the Campbell Plateau and can vary significantly from year to year. They also found water from the Southern Ocean is mixed onto the plateau, giving it a distinct oceanography from the surrounding seas. These waters are well mixed and are also known to be iron limited (Boyd et al 1999). It has been suggested that there are high transfer efficiencies between low and high trophic levels (Bradford-Grieve et al 2003).

Steering of current flow along and around plateaus and ridges gives rise to higher ocean productivity than might be expected in the generally oligotrophic western Pacific Ocean (Figure 11.3). New Zealand net primary productivity levels are high compared with most of Australasia, but lower than most coastal upwelling systems around the world (Field et al 1998).

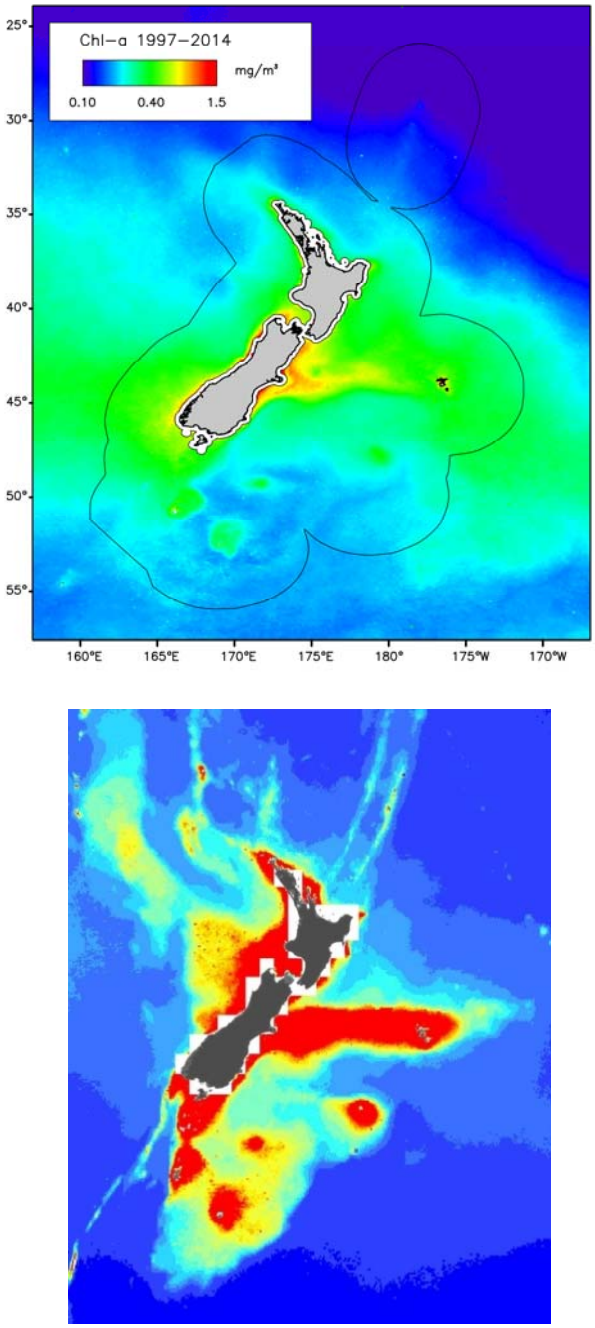

Figure 11.4: Top panel: Mean annual concentration of chlorophyll-a (the ubiquitous phytoplankton pigment) from satellite ocean colour observations. The image is based on the merged dataset of SeaWiFS and MODIS-Aqua which covers the period 1997 - 2014. The boundary of the New Zealand EEZ is also shown. Data in the territorial sea (12 n.mile from the coast) is excluded because of possible contamination by suspended sediment and river run-off. Bottom panel: The relative concentrations of particulate organic carbon (POC) that reach the seafloor. Red shows the highest levels, which are likely to be associated with areas of enhanced benthic productivity (based on the model of Lutz et al (2007)). Images courtesy of NIWA.

It is clear that the Chatham Rise has the highest productivity levels in the region, and this is associated with the Subtropical Front and mixing across the front. Macronutrient limited subtropical water (Bradford-Grieve et al 1997) mix with high nutrient low-chlorophyll (NHLC) iron-limited subantarctic waters (Boyd et al 1999) effectively removing both the iron and macronutrient restraints within the mixed waters of the Subtropical Front. The increased productivity resulting from the mixing can be seen in the high chlorophyll a detected with ocean colour remote sensing (Figure 11.3 and Figure 11.4 top panel).

Around the coast turbulence and upwelling play a key role in driving primary productivity (Figure 11.3; Pinkerton et al 2005). However, care is needed in interpreting remotely sensed ocean colour as algorithms cannot readily distinguish between primary productivity (from phytoplankton) and sediments in freshwater runoff. Thus interpretation of the relative productivity levels inshore has to be made in conjunction with knowledge of river flow.

The high productivity in coastal waters and on ocean plateaus support a range of commercial shellfish and finfish fisheries from the shoreline to depths of about 1500 m. Seamounts, seamount chains and ridge structures in suitable depths can also provide additional localized areas of upwelling and increased productivity sometimes associated with commercial fisheries.

Patterns in surface waters of primary productivity are mirrored to an extent in the amount of “energy” that sinks to the seafloor (Figure 11.4 bottom panel). This POC flux is based on a model which accounts for sinking rates of dead organisms and predation in the water column (Lutz et al 2007). This is a potential surrogate for benthic production, and indicates where bentho-pelagic coupling may be strong. Highest levels of POC flux match with surface productivity to a large extent, with coastal waters (including around the offshore islands) and the Chatham Rise having the highest estimated production (Figure 11.4 bottom panel).

11.2 INDICATORS AND TRENDS

11.2.1 SEA TEMPERATURE

Sea surface temperature (SST), sea surface height (SSH), air temperature and ocean temperature to 1000 m depth, all exhibit some correlation with each other over seasonal and inter-annual time scales (Hurst et al 2012). New Zealand air temperatures have increased by about 1°C since 1900 (Figure 11.5).

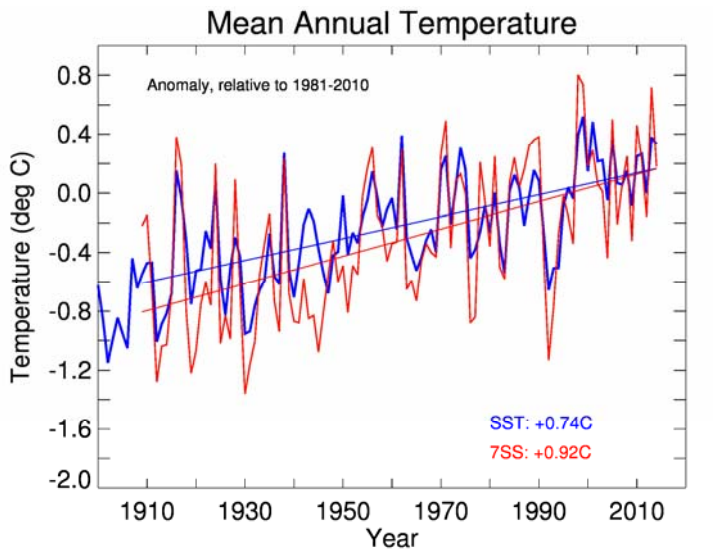

Figure 11.5: Annual time series in New Zealand. NOAA annual mean sea surface temperatures averaged over the box outlined in Figure 11.6 (blue line) and NIWA's seven-station annual mean air temperature composite series (red line), expressed as anomalies relative to the 1981-2010 climatological average. SST data from http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html Linear trends over the period 1909-2014, in °C/century, are noted under the graph. (Image Source: updated from Mullan et al 2010).

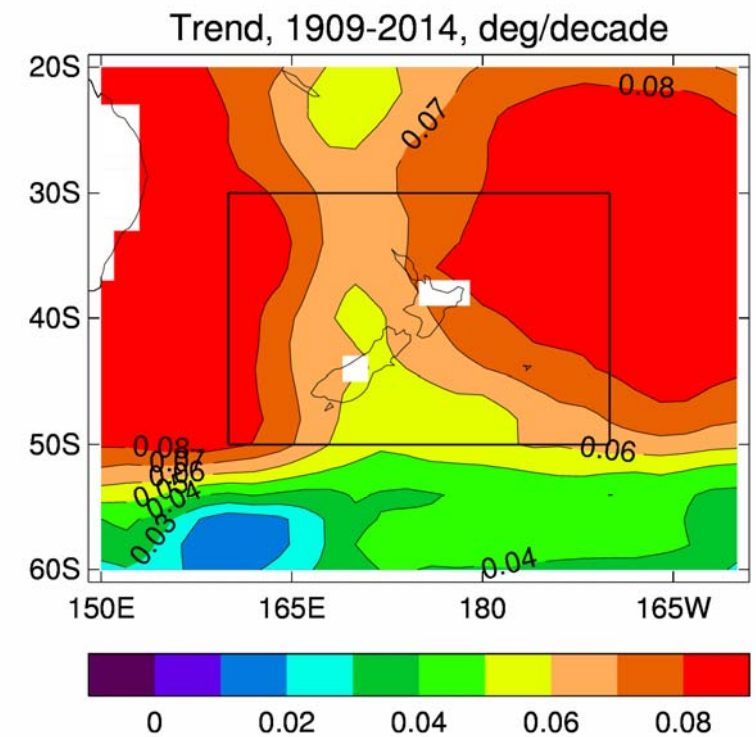

Figure 11.6: Trends in sea surface temperature, in °C/decade over the period 1909–2014, calculated from the NOAA_ERSST_v3 data-set (provided by NOAA's ESRL Physical Sciences Division, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/). The data values are on a 2° latitude-longitude grid. (Image Source: updated from Mullan et al 2010.

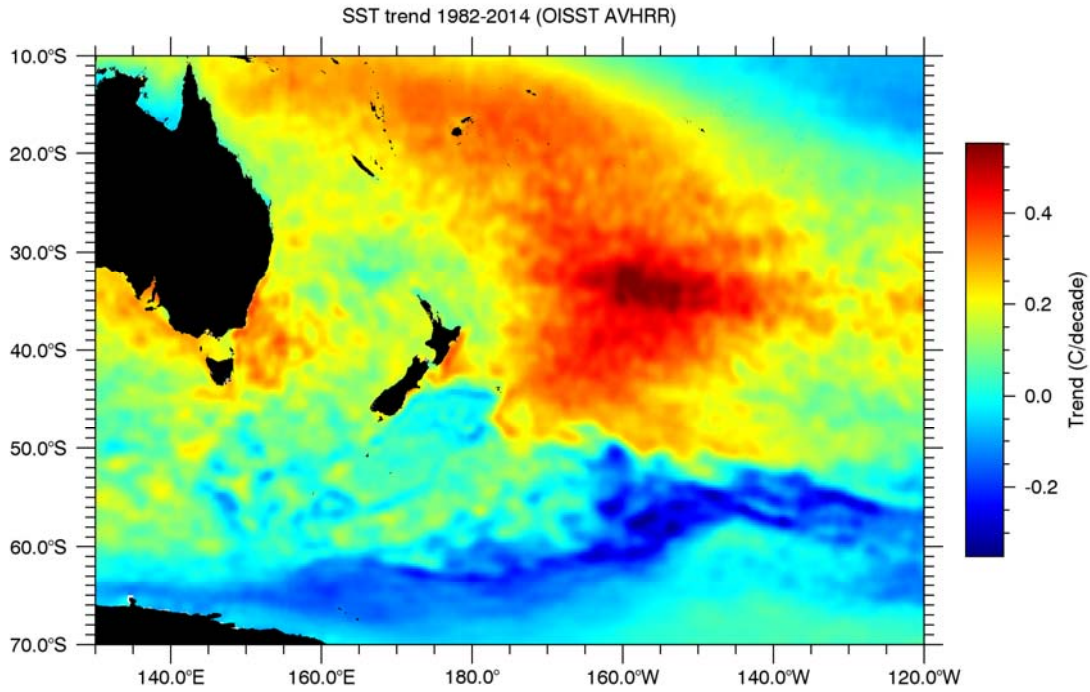

Figure 11.7: Trends in sea surface temperature, in °C/decade over the period 1982–2014. The data are from NOAA based on daily interpolated satellite measurements over a 0.25° grid. See http://www.ncdc.noaa.gov/oa/climate/research/sst/oi-daily.php. (after Reynolds et al (2007)).

Although a linear trend has been fitted to the seven-station temperatures in Figure 11.5, the variations in temperature over time are not completely uniform. For example, a markedly large warming occurred through the periods 1940–1960 and 1995–2014. Higher frequency variations can be related to fluctuations in the prevailing north-south airflow across New Zealand (Mullan et al 2010). Temperatures are higher in years with stronger northerly flow, and are lower in years with stronger southerly flow. One would expect this, since southerly flow transports cool air from the Southern Oceans up over New Zealand.

The unusually steep warming in the 1940–1960 period is paralleled by an unusually large increase in northerly flow during this same period (Mullan et al 2010). On a longer timeframe, there has been a trend towards less northerly flow (more southerly) since about 1960 (Mullan et al 2010). However, New Zealand temperatures have continued to increase over this time, albeit at a reduced rate compared with earlier in the twentieth century. This is consistent with a warming of the whole region of the southwest Pacific within which New Zealand is situated (Mullan et al 2010).

Trends in sea surface temperature (SST) in the New Zealand region tend to be slightly smaller than trends in air temperature over land (Figure 11.5). 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 along the East Australian coast and to the east of the North Island, and much lower rates of warming south and east of the South Island (Figure 11.6).

Figure 11.7 shows the satellite sea surface temperature trends since 1982. These are at a higher spatial resolution than Figure 11.6 providing more detail but over a shorter period. It is apparent that sea temperatures are increasing north of about 45°S; they are increasing more slowly, and actually decreasing in recent decades, off the Otago coast and south of New Zealand. This regional pattern of cooling (or only slow warming) to the south, and strong warming in the Tasman and western Pacific can be related to increasing westerly winds and their effect on ocean circulation (Mullan et al 2010). Thompson & Solomon (2002) discuss the increase in Southern Hemisphere westerlies and the relationship to global warming; Roemmich et al (2007) describe recent ocean circulation changes; Thompson et al

(2009) discuss the consequent effect on sea surface temperatures in the Tasman Sea.

Coastal SST data, particularly the longer time series from Leigh and Portobello, have been used to link changes in the near shore environment with larger scale climate signals. SST anomalies at Leigh, and at Portobello after 1968 suggest a strong relationship between SST anomalies and SOI (Figure 11.8)

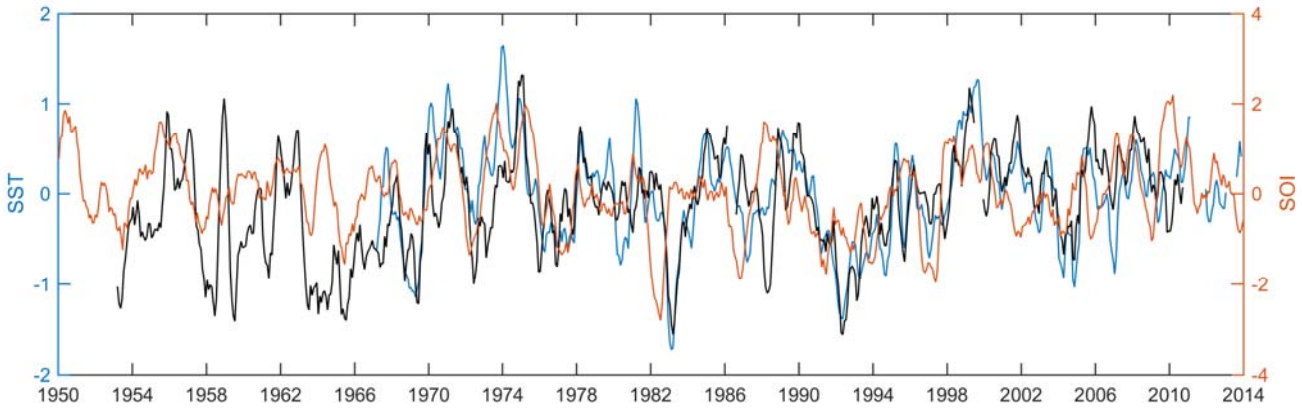

Figure 11.8: Sea surface temperature (SST) anomalies from a 40-year climatology from 1971–2010 of observations at Leigh; blue line), Portobello (black line) and the Southern Oscillation Index (SOI; red). (Image updated from Hurst et al 2012).

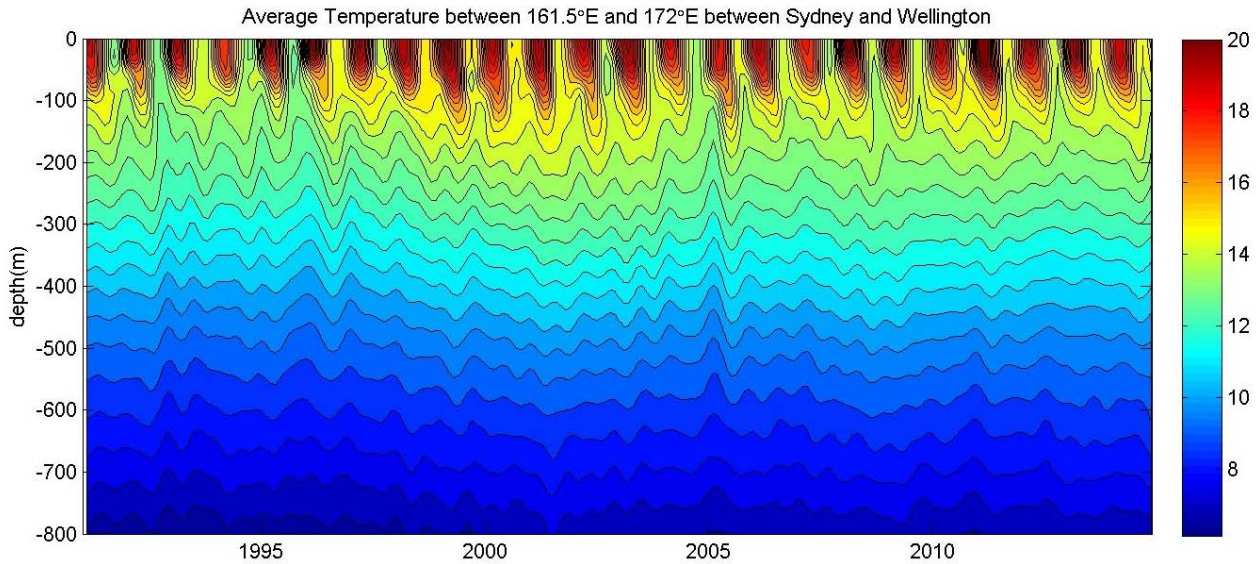

Figure 11.9: Eastern Tasman ocean temperature: Wellington to Sydney 1991–2008. Coloured scale to the right is temperature °C. (Image updated from Sutton et al 2005).

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 late 2014. Variation is also seen in temperature data on the Campbell Plateau (Forcén-Vázquez 2015).

The ocean temperature between Sydney and Wellington has been sampled about four times per year since 1991. The measurements are made in collaboration with the Scripps Institution of Oceanography and CSIRO. Analyses of the subsurface temperature field using these data include Sutton & Roemmich (2001) and Sutton et al (2005). The temperature as a function of depth and time for the eastern portion (between 161.5°E and 172°E) of this section is shown in Figure 11.9. This eastern Tasman section is close to New Zealand, and has low oceanographic variability meaning that subtle interannual changes can be seen. The portion of the transect shown is along a fairly constant latitude and is therefore unaffected by latitudinal temperature and seasonal cycle variation. The upper panel shows the temperature averaged along the transect between the surface and 800 m and from 1991 to the most recent sampling.

The seasonal cycle is clearly visible in the upper 100–150 m. There is a more subtle warming signal that occurred through the late 1990s, which is made apparent by the isotherms increasing in depth through that time period. This warming was significant in that it extended through the full 800 m of the measurements (effectively the full depth of the eastern Tasman Sea). It also began during an El Niño period when conditions would be expected to be relatively cool. Finally, it was thought to be linked to a large-scale warming event centred on 40°S that had hemispheric and perhaps global implications. This warming has been discussed by Sutton et al (2005) who examined the local signals, Bowen et al (2006) who studied the propagation of the signal into the New Zealand area, and Roemmich et al (2007), who examined the broad-scale signal over the entire South Pacific Ocean. Roemmich et al (2007) hypothesized that the ultimate forcing was due to an increase in high latitude westerly winds effectively speeding up the entire South Pacific gyre.

Other phenomena have led to periods of warming that are not as yet fully understood. Both stochastic environmental variability and predictable cycles of change influence the productivity and distribution of marine biota in our region.

On the Campbell Plateau, temperature data has been collected each December as part of annual trawl surveys between 2002 and 2009 and biannually since then. Forcén-Vázquez (2015) has analysed the first 8 years (Figure 11.10) and found two types of variability. In the Subtropical Front near the South Island coast there was year to year variability in the temperature. On the plateau there was not only temperature variability but changes in flow patterns which were attributed to variability in the position of the Subtropical Front and influences from the Subantarctic Front

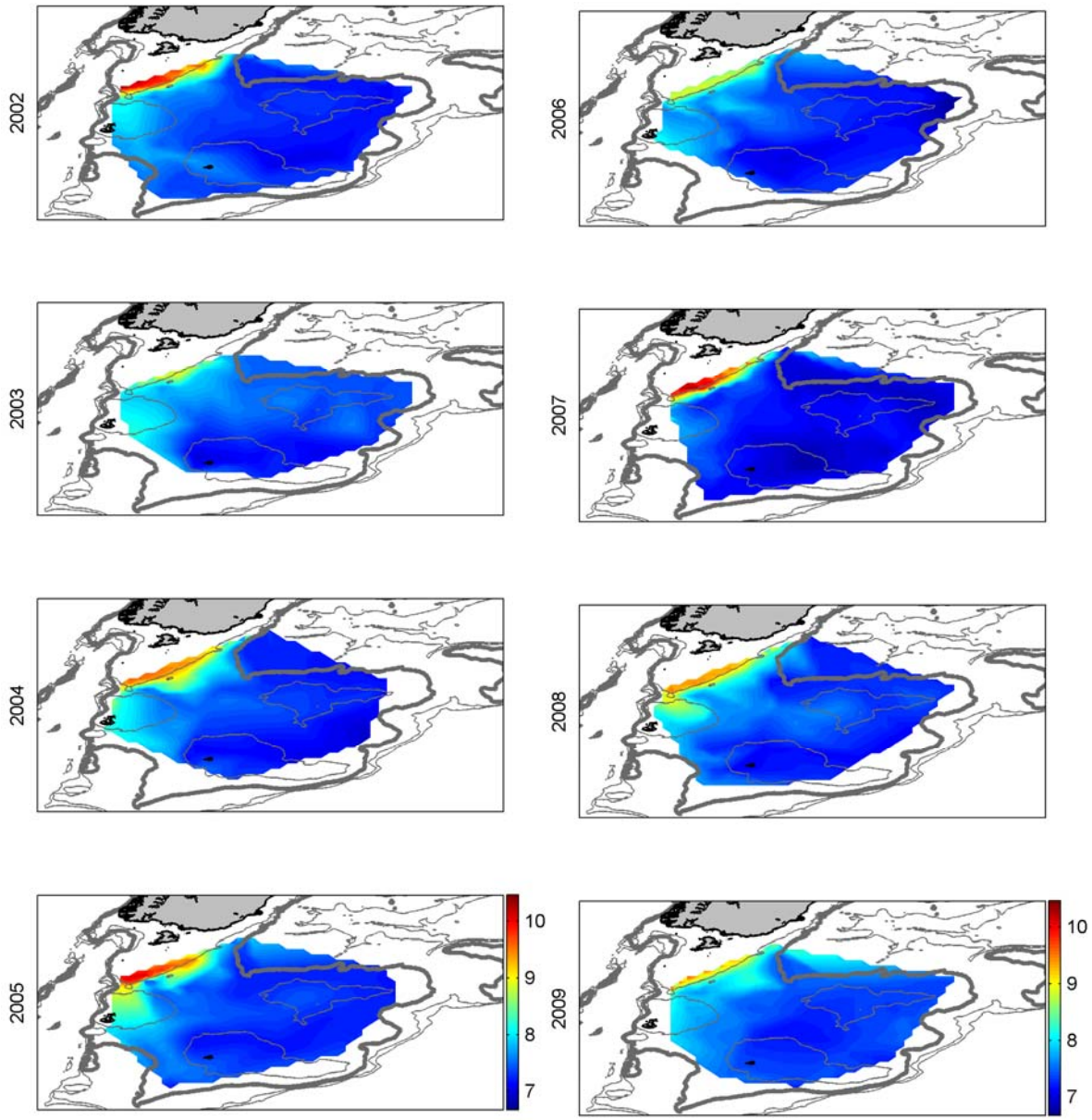

Figure 11.10. Temperature at 250 m on the Campbell Plateau interpolated from trawl mounted CTD data (Reproduced with permission from Forcén-Vázquez , 2015)

11.2.2 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 15–30 year time scales. In the past 100 years, regime shifts occurred in 1925, 1947, 1977 and about 2000 (Figure 11.11). The latest shift should result in New Zealand experiencing periods of reduced westerlies, with associated warmer air and sea temperatures and reduced upwelling on western coasts (Hurst et al 2012).

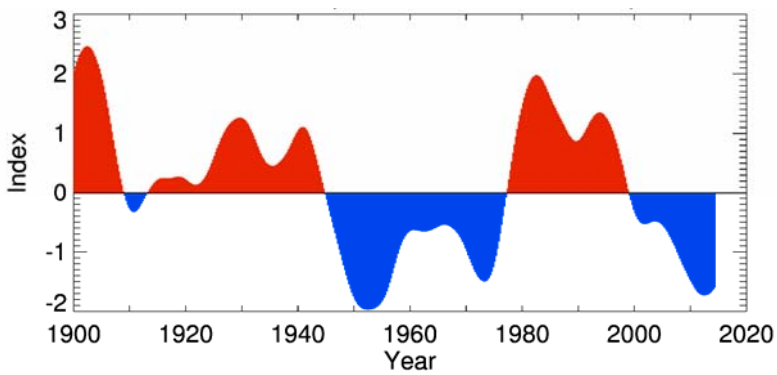

Figure 11.11: Smoothed index of the Interdecadal Pacific Oscillation (IPO) since 1900. (Image source NIWA based on data from the United Kingdom Meteorological Office, UKMO).

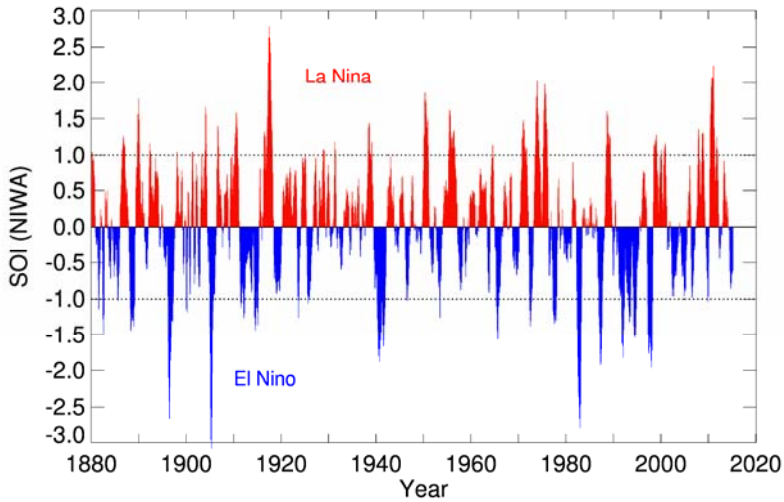

Figure 11.12: Southern Oscillation Index (SOI) 5-month running mean 1880–mid 2015. Red indicates warmer temperatures, blue indicates cooler conditions for New Zealand (and the opposite in the equatorial Pacific). (Image courtesy of NIWA.)

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 (persisting above +1, Figure 11.12), a La Niña event is taking place and New Zealand tends to experience more north easterlies, reduced westerly winds, and milder, more settled, warmer anticyclonic weather and warmer sea temperatures (Hurst et al 2012). When the SOI is strongly negative (persisting below -1), an El Niño event is taking place and New Zealand tends to experience increased westerly and south-westerly winds and cooler, less settled weather and enhanced along shelf upwelling off the west coast South Island and north east North Island (Shirtcliffe et al 1990, Zeldis 2004, Chang & Mullan 2003). The SOI is available monthly from 1876 onwards (Mullan 1995) (Figure 11.12).

11.2.3 WATER CHEMISTRY: OCEAN ACIDIFICATION

An increase in atmospheric carbon dioxide (CO_2) since the industrial revolution has been paralleled by an increase in CO_2 concentrations in the upper ocean (Sabine et al 2004), with global ocean uptake on the order of about 2 gigatonnes (Gt) per annum (about 30% of total global anthropogenic emissions, Rhein et al (2013)). The anthropogenic CO_2 signal is apparent to an average depth of about 1000 m.

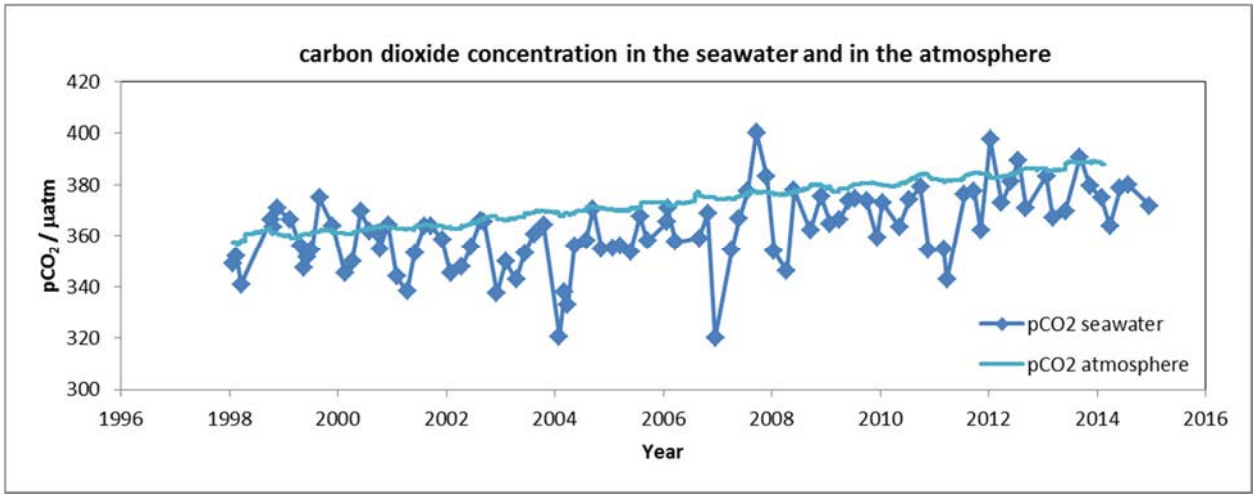

Figure 11.13: pCO_2 (partial pressure of CO_2) in subantarctic surface seawater and the overlying atmosphere from the Munida Time Series Transect, 1998–2014. (Image courtesy of K. Currie, NIWA).

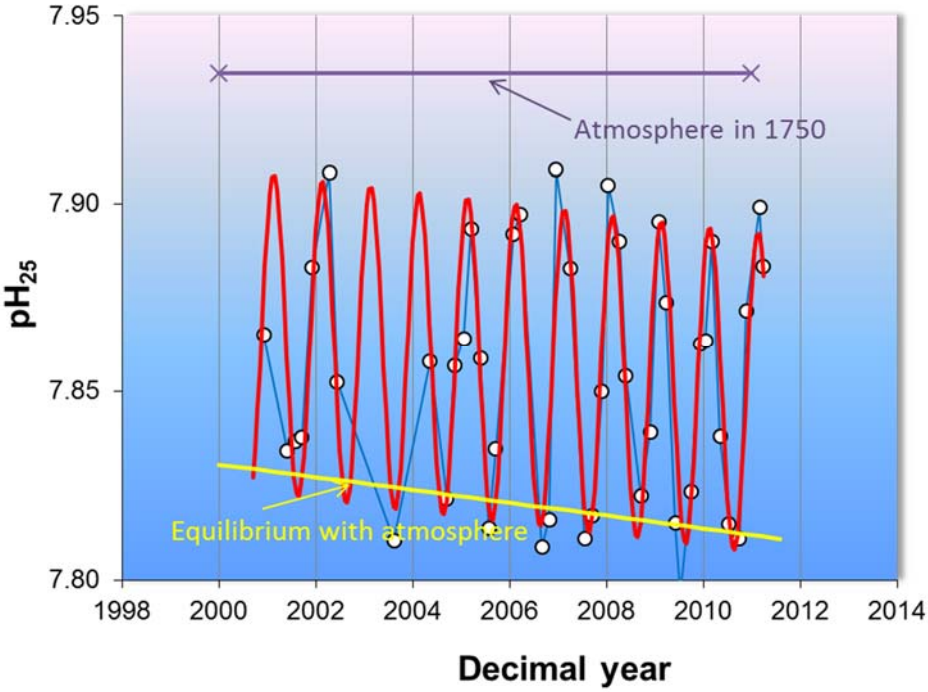

Figure 11.14: pH in subantarctic surface seawater on the Munida Time Series transect, 1998–2011. The blue points and joining lines are the actual measurements, and the red line a best fit to the points using a sine wave function (to represent seasonal change). The black line represents pH assuming equilibrium with the atmosphere concentration in the Year 1750. The yellow line is the pH assuming equilibrium with actual CO_2 concentrations measured at the NIWA Baring Head Atmospheric Station. pH25 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.)

Carbon dioxide absorbed by seawater reacts with the water and carbonate ions to form bicarbonate ions and in the process, hydrogen ions are released. This reaction raises the acidity and lowers the pH of seawater, in addition to decreasing the amount of carbonate in the seawater. Since the beginning of the industrial era, average surface ocean pH has decreased by 0.1 units, with a further decrease of up to 0.4 units expected by the end of the century (Rhein et al 2013). The pH scale is logarithmic, so a 0.4 pH decrease corresponds to a 150% increase in hydrogen ion

concentration. Both the predicted pH in 2100 and the rate of change in pH are outside the range experienced by the oceans for at least half a million years. In the absence of any decrease in CO_2 emissions this trend is likely to continue (Orr et al 2005).

In New Zealand, the projected change in surface water pH between 1990 and 2070 is a decrease of 0.15–0.18 pH units (Hobday et al 2006). The only time series of dissolved CO_2 in NZ waters is along a transect from the coast across subtropical and subantarctic waters off the Otago shelf – the Munida Time Series (Currie et al 2011). Measurements have been made bimonthly by NIWA / University of Otago since 1998. Dissolved pCO_2 shows a statistically significant increase of 1.3 μatm yr^{-1} for 1998–2012 (Bates et al 2014) and is consistent with long term changes observed at other global time series sites (Figure 11.13). Seasonal variability in subantarctic waters at the time series site is due to biological uptake of dissolved inorganic carbon and seasonal temperature changes (Brix et al 2013).

The Munida Time Series pH data shows a decline in sub-antarctic surface waters since 1998 (Figure 11.14) consistent with that expected from equilibrium with atmospheric CO_2, as recorded at the NIWA Baring Head atmospheric station (K. Hunter (University of Otago), pers. comm.).

Surface pH in the open ocean has been determined at seven long term time series stations, six of which are in the northern hemisphere, plus the southern hemisphere Munida Time Series site (Bates et al 2014; Figure 11.15). All time series records show long term trends of increasing pCO_2 (partial pressure of CO_2) and decreasing pH. 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 events, diel biological activity in the seawater and sediment and other coastal processes. A New Zealand coastal ocean acidification observing network (NZOA-ON) has been set up to establish baseline conditions against which to measure future change. Biological implications of ocean acidification result from increasing hydrogen ion concentration (decreasing pH) and decreasing carbonate availability, increasing dissolved pCO_2. The concern about ocean acidification is that the resulting reduction in carbonate availability may potentially impact organisms that produce shells or body structures of calcium carbonate, resulting in a weakening of shell integrity, redistribution of an organism's metabolic activity and increased physiological stress. Organisms most likely to be affected are those at the base of the food chain (bacteria, protozoa, plankton), coralline algae, rhodoliths, shallow and deepwater corals, echinoderms, molluscs, and possibly cephalopods (e.g., squids) and high-activity pelagic fish (e.g., tunas) (see Feely et al 2004 and references therein; Orr et al 2005, Langer et al 2006). This is particularly of concern for deep-sea habitats such as seamounts, which can support structural reef-like habitat composed of stony corals (Tracey et al 2011). A shoaling carbonate saturation horizon could push such biogenic structures to the tops of seamounts, or cause widespread die-back (e.g., Thresher et al 2012). This has important implications for the structure and function of benthic communities.

Ocean Acidification may also impact commercial fisheries for deepwater species such as orange roughy (Clark 1999). In surface and shallow waters some phytoplankton and sea-grasses may benefit from the increase in dissolved pCO_2 due to increased photosynthesis. Early life stages are particularly vulnerable across many phyla (e.g., Byrne et al 2013, Mu et al 2015, Bylenga et al 2015.).

Direct effects of acidification on the physiology and development of fish have also been investigated. Adverse effects on physiology development (e.g. Franke & Clemmesen 2011), and behavior modification (Munday et al 2014) have been documented. Such studies highlight the potential for increasing acidification to impact larval growth and development, with implications for survival and recruitment of both forage fish and fish harvested commercially.

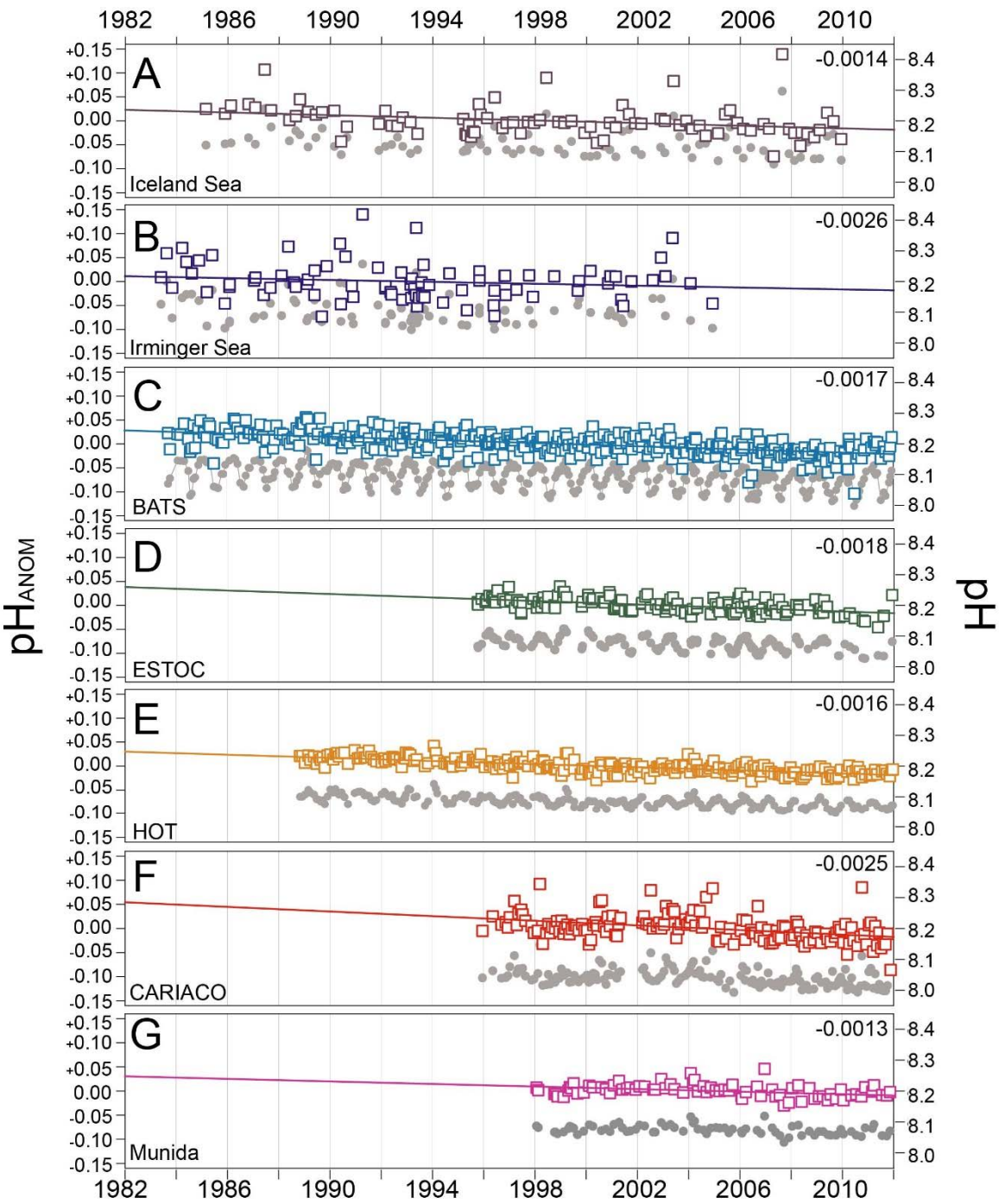

Figure 11.15: Time series of surface ocean pH (grey symbols, right hand axis) and pH anomaly (coloured symbols, left hand axis) at seven time series sites, including the Munida Time Series in New Zealand. Trends (pH change yr^{-1}) are given in the top right of each panel. (A) Iceland Sea, North Atlantic Ocean (purple); (B) Irminger Sea, North Atlantic Ocean (blue); (C) BATS, North Atlantic Ocean (cyan); (D) ESTOC, North Atlantic Ocean (green); (E) HOT, North Pacific Ocean (orange); (F) CARIACO, North Atlantic Ocean (red), and; (G) MUNIDA, South Pacific (pink) (Image directly sourced from Bates et al 2014).

11.3 OCEAN CLIMATE TRENDS AND NEW ZEALAND FISHERIES

This section has been quoted almost directly from the summary in Hurst et al (2012) with updates where relevant from more recent literature. 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 1871; time scale 15–30 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 1970s to 2000, New Zealand experienced periods of enhanced westerlies, with associated cooler air and sea temperatures and enhanced upwelling on western coasts. Opposite patterns are expected under a negative phase. For most New Zealand fisheries, monitoring of changes in populations began in the late 1970s, so there is little information on how New Zealand fishstocks might respond to these longer-term climatic fluctuations. Some of the recent changes in fish populations since the mid 1990s, for example, low western stock hoki recruitment indices (Francis 2009) and increases in some elasmobranch abundance indices (Dunn et al 2009) may be shorter-term fluctuations that might be related in some way to regional warming during the period and only longer-term monitoring will establish whether they might be related to longer-term ecosystem changes.
- The Southern Oscillation Index: available from 1876; best represented as smoothed values over at least 3–5 months. 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 Portobello with SOI indices, Figure 11.8). Upwelling has been found to be related to increased nutrient flux and phytoplankton growth in areas such as the west coast South Island, Pelorus Sound and north-east coast of the North Island (Willis et al 2007, Zeldis et al 2008). El Niño events are likely to occur on 3–7 year time scales and are likely to be less frequent during the negative phase of the IPO which began in about 2000. This is likely to impact positively on species that show stronger recruitment under increased temperature regimes (e.g., snapper, Francis 1993, 1994a, b).
- Surface wind and pressure patterns: available from the 1940s; variation in patterns can be high over monthly and annual time scales and many of the indices are correlated with each other, and with SOI and IPO indices (e.g., more zonal westerly winds, more frequent or regular cycles in southerlies in the positive IPO, 1977–2000). Correlations with biological process in fish stocks may occur over short time scales (e.g., impact on fish catchability) as well as seasonal and annual scales (e.g., impact on recruitment success). Wind and pressure patterns have been found to be correlated with fish abundance indices for southern gemfish (Renwick et al 1998), hake, red cod and red gurnard (Dunn et al 2009), rock lobster (Booth et al 2000), and southern blue whiting (Willis et al 2007, Hanchet & Renwick 1999). The mechanisms implied by the correlations are at best poorly understood, however they motivate hypothesis testing into how wind and pressure patterns are related to fisheries.
- Temperature and sea surface height: available at least monthly over long time scales (air temperatures from 1906) or relatively short time scales (ocean temperatures to 800 m, SST and SSH variously from 1987). Ocean temperatures, SST and SSH are all correlated with each other and smoothed air temperatures correlate well with SST in terms of interannual and seasonal variability; there are also some correlations of SST and SSH with surface wind and pressure patterns (see Dunn et al 2009). SST has been found to be correlated with relative fish abundance indices (derived from fisheries and/or trawl surveys) for elephantfish, southern gemfish, hoki, red cod, red gurnard, school shark, snapper, stargazer and tarakihi (Francis 1994a, b, Renwick et al 1998, Beentjes & Renwick 2001, Gilbert & Taylor 2001, Dunn et al 2009). Air temperatures in New Zealand have increased since 1900; most of the increase occurred since the mid-1940s. Increases from the late 1970s to 2000 may have been moderated by the positive phase of the IPO. Coastal SST records from 1954 at Portobello show a slight increase through the series. Other time series (SSH, ocean

temperature to 800 m) are comparatively short but show cycles of warmer and cooler periods on 1–6 year time scales. All air and ocean temperature series show the significant warming event during the late 1990s which has been followed by some cooling, but not to the levels of the early 1990s.

- Ocean colour and upwelling: these will be important time series because they potentially have a more direct link to biological processes in the ocean and are more easily incorporated into hypothesis testing. The ocean colour series starts in late 1997, so is not able to track changes that may have occurred since before the late 1990s warming cycle. These indices also need to be analysed with respect to SST, SSH and wind patterns, at similar locations or on similar spatial scales. The preliminary series developed exhibit some important spatial differences and trends that may warrant further investigation in relation to fish abundance indices. Of note are the increased chlorophyll indices off the west and south-west coast of the South Island in spring/summer during the last 5–6 years and the relatively low upwelling indices off the west coast South Island during winter in the late-1990s (Hurst et al 2012).
- Currents: there are no general indices of trends or variability at present. Improvements in monitoring technology (e.g., satellite observations of SSH; CTD; ADCP; ARGO floats) have resulted in more information becoming available to enable numerical models of ocean currents to be developed. On the open ocean scale, there is considerable complexity in the New Zealand zone (e.g., frontal systems, eddy systems of the east coast). In the coastal zone, this is further complicated in coastal areas by the effects of tides, winds and freshwater (river) forcing. Nevertheless, the importance of current systems is starting to become more recognised and has been incorporated into analysis and modelling of fisheries processes and trends. Recent examples include the retention of rock lobster phyllosoma (mid-stage larvae) in eddy systems (Chiswell & Booth 2005, 2007), the apparent bounding of orange roughy nursery grounds by the presence of a cold-water front (Dunn et al 2009) and the drift of toothfish eggs and larvae (Hanchet et al 2008).
- Acidification: The increase in atmospheric CO_2 has been paralleled by an increase in CO_2 concentrations in the upper ocean, resulting in a decrease in pH. Maintenance of the one existing New Zealand monitoring programme for pH and pCO_2, and development of new programmes to monitor the impacts of pH on key groups of organisms are critical. Potentially vulnerable groups include organisms that produce shells or body structures of calcium carbonate (corals, molluscs, plankton, coralline algae), and also non-calcifying groups including plankton, squid and high-activity pelagic fishes. Potentially positive impacts of acidification include increased phytoplankton carbon fixation and vertical export and increased productivity of sub-tropical waters due to enhanced nitrogen fixation by cyanobacteria. Secondary effects at the ecosystem level, such as productivity, biomass, community composition and biogeochemical feedbacks, also need to be considered.

Climate change was not specifically addressed as part of the report by Hurst et al (2012), although indices described are an integral part of monitoring the speed and impacts of climate change. As noted in 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.

In conclusion, key ocean climate drivers in the New Zealand region for the last few decades 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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12 . TROPHIC AND ECOSYSTEM-LEVEL EFFECTS

Scope of chapter	This chapter outlines the global and New Zealand understanding of trophic and ecosystem-level effects of fishing, with respect to types of effects, their causes, the types of ecosystems most likely to be affected, the spatial scales of effects, and indicators of trophic and ecosystem-level effects.
Area	All areas and fisheries
Focal localities	Whole EEZ
Key issues	Organisms in an ecosystem are linked by trophic (feeding) connections. Changes to one organism (by whatever means) can affect other organisms and sometimes large parts of the food-web. Changes occurring across many trophic levels (ecosystem-level changes) can have implications for ecosystem resilience.
Emerging issues	Ecosystem approach to fisheries and how fishing interacts with other stressors of marine ecosystems
MPI Research (current)	ZBD200505 (Long term change in New Zealand coastal ecosystems) HMS2014-05 (Stable isotope analysis of highly migratory species to assess trophic linkages and spatial and temporal movement trends of HMS sharks)
NZ Government Research (current)	• NIWA core funding - Coasts & Oceans centre: "Ecosystem structure and function" and "Marine Biological Resources"; Fisheries centre: "Ecosystem effects of fishing" • Climate Change Impacts and Implications (MBIE Contestable, http://ccii.org.nz/) • Marine Futures (MBIE Contestable, http://www.niwa.co.nz/coasts-and-oceans/research-projects/marine-futures)
Links to 2030 objectives	Increase sustainable resource use, and protect from biological risk
Related chapters/issues	Effects of fishing on ecologically dependent species Benthic impacts of fishing (including habitats of particular significance for fisheries management) Climate and oceanographic context of New Zealand fisheries (including effects of climate variability and change) Land-based effects on fisheries Marine biodiversity Marine biosecurity Other work on fishstocks, marine mammals, seabirds, bycatch, etc.

Note: This chapter has not been updated since AEBAR 2014.

12.1 CONTEXT

12.1.1 SCOPE OF CHAPTER

This chapter addresses trophic and ecosystem-level effects which may arise from fishing or from other drivers of change on marine ecosystems in the New Zealand region. "Trophic effects" are changes to the structure and function of ecosystems occurring entirely or largely because of changes in the feeding of organisms within a food-web. "Ecosystem-level effects" are defined as changes occurring across several trophic levels[1]. An ecosystem is defined as a biological community of interacting organisms and their physical environment. The region of interest for the purposes of this chapter is the New Zealand marine exclusive economic zone (EEZ) and territorial waters, including coastal and offshore regions. The focus is on wild-caught fisheries rather than aquaculture.

[1] "Trophic level" is a measure of the position of an organism within a food-web. Primary producers have trophic level 1, herbivores have trophic level 2, and carnivores have trophic levels between about 3 and 5 in aquatic systems (Lindeman 1942).

This chapter focuses on trophic and ecosystem-level effects that are relevant to the sustainability and environmental effects of New Zealand fisheries as set out in the relevant New Zealand legislation, current New Zealand government strategic/operational policies, and international best practice. Relevant legislation, policies and best practices are summarised in Chapter 1 (Sections 1.2 and 1.3). The relevance of these specifically to trophic and ecosystem-level effects include:

- The Fisheries Act 1996 requires that (a) associated or dependent species should be maintained above a level that ensures their long-term viability; (b) biological diversity of the aquatic environment should be maintained.
- Fisheries 2030: environmental principles of Fisheries 2030 include: Ecosystem-based approach; Conserve biodiversity; Environmental bottom lines; Precautionary approach; Responsible international citizen; Inter-generational equity; Best available information; and Respect rights and interests (Ministry of Fisheries 2009). Management of trophic and ecosystem-level effects of fisheries aligns with "Fisheries 2030 Objective 6": Manage impacts of fishing and aquaculture.
- MPI's Strategy "Our Strategy 2030": to increase sustainable resource use, and protect from biological risk.
- FAO best practice requires the application of scientific methods and tools that go beyond the single-species approaches: "Managers and decision-makers must now explicitly consider interactions in the ecosystem" and scientific advice should include ecosystem considerations (FAO 2008).
- Marine Stewardship Council (MSC) Principle 2: "Fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem (including habitat and associated dependent and ecologically related species) on which the fishery depends." (Marine Stewardship Council 2010). This only applies to those fisheries that are MSC certified.

Effects of fishing on target species are considered in the annual New Zealand Fisheries Assessment Plenary (available from the Ministry for Primary Industries website[2]). The Fisheries Assessment Plenary also includes consideration of the effects of fishing on the aquatic environment (under the "environmental and ecosystem considerations" section for each stock). Effects of fishing all stocks on protected species, non-protected bycatch species, and on the benthos are given in other chapters of this AEBAR document. In particular, effects of fishing on seabirds and marine mammals which occur through trophic connections (e.g. fishing affecting the availability of prey for seabirds) are considered in Theme 1 of this report.

12.1.2 WHAT ARE TROPHIC AND ECOSYSTEM-LEVEL EFFECTS?

Trophic and ecosystem-level effects are changes to multiple parts of the foodweb. Such effects can occur in coastal or deepwater ecosystems and can involve a wide range of biological, chemical and physical processes. Because trophic and ecosystem-level effects occur over a range of different organisms and time/space scales, it is often difficult to be sure of the magnitude of the change or its underlying cause. This has led to much speculation and disagreement as to the mechanism or processes involved, and a corresponding high level of disagreement as to what management should have done to prevent it, or should do to respond to the change once it has occurred (Schiermeier 2004; Hilborn 2007; Murawski et al 2007; Schiel 2013). Sometimes controlled experiments are conducted to see if trophic effects can be simulated, but low statistical power is a common problem of this kind of test (Schroeter et al 1993). In general, international research on trophic and ecosystem-level effects is active and one where there are generally more hypotheses than well-accepted empirical demonstrations of the effects. It is probably useful to start with a few examples of some trophic and ecosystem-level effects.

[2] http://www.mpi.govt.nz/document-vault/3888 http://www.mpi.govt.nz/document-vault/3889 http://www.mpi.govt.nz/document-vault/3890 (October 2014)

As part of the widespread pattern of collapses of cod (Gadus morhua) populations in the North Atlantic in the late 1980s and the 1990s, cod biomass off the US East Coast dropped by a factor of five, from more than 150 000 metric tons (MT) to about 30 000 t (Mayo et al 1998). With some slight lag, local stocks of the cod's favoured prey, Atlantic herring (*Clupea harengus*), increased over the same period 20-fold, to nearly two million t (NEFSC 1998). Elsewhere, on the opposite side of the Atlantic, a collapse of the cod resource in the Baltic Sea was followed by an eight fold increase in abundance of European sprat (Sprattus sprattus) – a major prey item for cod in that ecosystem (Köster et al 2003b; Casini et al 2008, 2009). In these cases, a reduction in the abundance of a piscine predator by fishing led to an increase in the prey species – a large scale "predation release" effect (see Section 12.1.3.1).

In New Zealand, observations in a number of northern marine reserves showed an increase in the abundance and size of red rock lobsters and piscine predators of algal grazing invertebrates which coincided with a gradual decrease in urchin density and an increase in algal cover (Babcock et al 1999; Shears & Babcock 2002, 2003; Salomon et al 2008; Babcock et al 2010). These changes, suggestive of a trophic cascade (see Section 12.1.3.2) are consistent with the results of ecosystem models of the role of rock lobsters in New Zealand rocky reef ecosystems, using both qualitative (Beaumont et al 2009) and quantitative frameworks (Pinkerton et al 2008; Eddy et al 2014; Pinkerton 2012). Shears et al (2008) found that the occurrence of this trophic cascade in northern New Zealand was likely to vary at local and regional scales in relation to abiotic factors. From a New Zealand wide perspective, Schiel (2013) concludes that urchin predators play a role in the dynamics of kelp beds only in some northern localities, and that environmental and climatic influences, species' demographics, and catchment-derived sedimentation are generally more important.

12.1.3 TYPES OF TROPHIC AND ECOSYSTEM-LEVEL EFFECTS

12.1.3.1 FIRST ORDER TROPHIC EFFECTS: PREY AVAILABILITY AND PREDATION RELEASE

Changes to the abundance, size structure and functional type[3] of a species can affect both its predators and prey by trophic interactions (Pace et al 1999). Increasing the abundance of a prey species may positively affect its predators (because they have to work less hard to find food) whereas reducing the abundance of a prey item may have a detrimental effect on the predators (by requiring them to hunt more intensively or by forcing a change in their diet); these are "prey availability" or bottom-up effects (Trillmich et al 1991; Jahncke et al 2004). Alternatively, changing the abundance of a predator may affect the abundance of some or all of its prey by changing their natural mortality rates (a top-down effect, Northcote 1988). Decreasing the abundance of a predator (for example by fishing a predatory fish) may cause the abundance of some or all of its prey to increase (a "predation release" effect, Casini et al 2012). These effects act over one trophic link and are hence called "first order" trophic effects.

12.1.3.2 TROPHIC CASCADES

Changes in the abundance of one species may go on to affect other species that are neither its predators nor its prey. This is a second order trophic effect (occurring via an intermediate organism), often called a "trophic cascade". The awareness of trophic cascades arose originally from work in the marine intertidal zone, and lakes (Hrbácek et al 1961; Shapiro et al 1975; Paine 1980), but has since become the focus of considerable theoretical and empirical research in marine ecosystems (Carpenter et al 1985; McQueen & Post 1988a, b; Christoffersen et al 1993; Pace et al 1999; Frank et al 2005; Borer et al 2005; Daskalov et al 2007; Möllmann et al 2008; Casini et al 2009; Schiel 2013). While the term trophic cascade was originally termed for top-down effects of predators, it is now usually defined as the propagation of indirect effects between nonadjacent trophic levels in a food chain or food web, whatever the direction of forcing (Gruner

[3] "Functional type" refers to the collection of life history and ecological characteristics of an organism, including whether it is a herbivore, carnivore or omnivore, its feeding behaviour (including size of prey), location in the water column/benthos, and mobility.

2013). Thus, trophic cascades may also occur when changes in the populations of primary producers force changes at higher tropic levels (Beaugrand & Reid 2003; Bakun 2010). The potential for cascading effects of fishing in marine ecosystems is now thought to be as strong as or stronger than in freshwater ecosystems (Pace et al 1999; ICES 2005; Borer et al 2005).

A well-recognised example of a top-down cascade is the sea otter (Enhydra lutris), urchin (*Strongylocentrotus* spp.), kelp (Macrocystis pyrifera and other kelps) cascade in the north-east Pacific where hunting of sea otters in the eighteenth and nineteenth centuries allowed urchin populations to increase leading to over grazing of kelp beds (Szpak et al 2013). Protection of sea otters and subsequent expansion or reintroduction of populations into its former range reversed this cascade (Estes & Palmisano 1974, Estes 1996, Estes & Duggins 1995). The generality of the sea otter-urchin-kelp cascade has been questioned; for example, based on experimental treatments, Carter et al (2007) concluded that "the sea otter-trophic cascade paradigm is not universally applicable across locations or habitat types."

Where ecosystems are subject to stressors acting on different parts of the system together, changes due to cascading trophic effects can be extensive. For example, using field data collected over a 33-year period, Casini et al (2008, 2009) showed a four level community-wide trophic cascade in the open waters of the Baltic Sea. The dramatic reduction of the cod (*Gadus morhua*) population directly affected its main prey, the zooplanktivorous sprat (Sprattus sprattus) and indirectly the summer biomass of zooplankton and phytoplankton. Changes to the stock size of cod also affected the type of ecosystem control at the level of zooplankton. The cod-dominated configuration was characterized by low sprat abundance and independence between zooplankton and sprat variations (zooplankton abundance was controlled by oceanographic forcing). An alternate sprat-dominated configuration also existed in which cod biomass was low and zooplankton were strongly controlled by sprat predation (Casini et al 2009).

12.1.4 REGIME SHIFT AND INVASIVE SPECIES

An ecosystem can change to an alternative state if perturbations are greater than its resilience can accommodate, - this transition is called a regime-shift (Aebischer et al 1990; Estes & Duggins 1995; Beaugrand et al 2002; Daskalov et al 2007). Regime shifts can occur over large scales, affect many parts of the ecosystem and may be hard or slow to reverse ("hysteresis"). It has been suggested that ecosystem-level restructuring may maintain the system in its new state by means of negative feedbacks (Bakun 2006; Casini et al 2009; Möllman et al 2009; Lindegren et al 2010). Well-documented oceanographic-induced regime shifts in marine ecosystems have historically had substantial, long-lasting and typically (but not always) negative effects on fisheries. For example, during the 1980s, the North Sea experienced a change in hydro-climatic forcing that caused a rapid, temperature-driven ecosystem shift (Beaugrand & Ibanez 2004). In the North Sea the new dynamic regime after the late 1980s favoured jellyfish in the plankton and decapods and detritivores (echinoderms) in the benthos (Kirby et al 2008, 2009). The cod stocks in the North Sea and central Baltic Sea collapsed simultaneously with the ecosystem changes caused by the large-scale oceanographic changes (Reid et al 2003; Beaugrand 2004; Weijerman et al 2005; Casini et al 2008; Möllmann et al 2008; Lindegren et al 2010).

In another type of regime shift, there has been much recent debate as to whether in some regions, more intense, more frequent or more extensive blooms of jellyfish [4] are occurring in response to trophic and ecosystem-level changes in ocean ecosystems (Brodeur et al 1999, 2002; Mills 2001; Lynam et al 2006). In an example reported by Bakun & Weeks (2006), a massive ctenophore ("comb jelly") breakout in the early 1990s led to a nearly total collapse of fisheries in the Black Sea. The Black Sea ecosystems' historically dominant zooplanktivore, European anchovy (*Engraulis encrasicolus*), is a small, filter-feeding pelagic fish. In the late 1980s anchovy landings in the Black Sea increased to levels approaching 900 000 tons per year. At their maximum, in 1988, the catch of anchovy represented more than 60% of the total fishery catches taken from the Black Sea. As a result of heavy fisheries exploitation, anchovy spawning biomass in the following year declined

[4] "Jellyfish" is often taken to include Medusozoa, Ctenophora and Thaliacea (Condon et al 2013) but should strictly be limited to Medusozoa and Ctenophora (Gibbons & Richardson 2013).

by more than 85%. Shiganova (1998) reports that in the year after this drastic reduction in anchovy biomass, zooplankton abundance increased markedly. It was at this point, probably due to the enhanced food source, that the biomass of the ctenophore *Mnemiopsi leidyi* (a gelatinous zooplanktivorous species) in the Black Sea increased to a billion tons.

Condon et al (2013) assembled all available published and unpublished long-term time-series on jellyfish abundance across the oceans (no data from the New Zealand region) and found evidence of an approximately 20 year oscillation in global jellyfish abundance. Although an overall global increase in jellyfish abundance over the whole observational period 1874–2011 could not be detected, there was a weak but significant overall increase in jellyfish abundance since 1970. Gibbons & Richardson (2013) note that it is clear that we currently do not know whether there are really global increases in jellyfish, but that a more relevant question is whether jellyfish abundances are increasing in areas that are particularly important for humans - i.e. the coastal zone and important fishing areas – because costs of jellyfish blooms in these areas can be considerable. Recent increases in jellyfish abundance may be linked to one or more of: (a) warmer seas which enhance production, feeding and growth rates of jellyfish (Purcell 2005); (b) overfishing of competitors of jellyfish (Daskalov et al 2007); (c) increased supply of planktonic food for jellyfish associated with eutrophication of coastal waters (Parsons & Lalli 2002); (d) the spread of hypoxia, to which jellyfish exhibit greater tolerance than most other metazoans (Vaquer-Sunyer & Duarte 2008; Purcell, 2012); and (e) increase of artificial structures in coastal zones which may be habitats for jellyfish polyps (Duarte et al 2012).

12.1.4.1 EFFECTS OF CLIMATE CHANGE

Internationally and domestically, there is increasing recognition of the potential impacts of climate change on fisheries (IPCC 2007a, b; Valdes et al 2009; Rice & Garcia 2011). A changing climate may:

- affect individual physiological and behavioural responses of organisms (or some life stages of organisms, Petitgas et al 2013) which could lead to effects at the population level (Rijnsdorp et al 2009; O'Connor et al 2007; Perry et al 2005);
- change species proportions in fish assemblages (Engelhard et al 2011; Fulton 2011);
- lead to ocean acidification which may affect lower food-web structure and adversely impact calcifying organisms such as shellfish and corals (Fabry et al 2008; Cooley & Doney 2009);
- increase climate variability (Collins 2000) which may increase the risk of regime shift (Mullan et al 2001; Beaugrand 2004);
- change species ranges which might destabilize species relationships that help maintain ecosystem processes (Rice & Garcia 2011);
- lead to phonological (timing patterns) mismatches of grazers and predators (Sydeman & Bograd 2009);
- lead to invasive species becoming a greater threat (ICES 2005).

The global scientific understanding of how a changing climate may affect marine ecosystems is largely hypothetical to date, but it seems likely that impacts of climate change are likely to be largely trophic or ecosystem-level effects in nature (reviews by Lehodey et al 2006; Drinkwater et al 2010; Bakun 2010; Portner & Peck 2010; Ottersen et al 2010; Overland et al 2010; Hollowed et al 2013).

12.1.4.2 POTENTIAL FOR RECOVERY FOLLOWING OVER-DEPLETION

It is possible that trophic and system-level effects of fishing can affect the ability of fisheries to recover (rebuild) following over-exploitation, but this is disputed. Some scientists suggest that after a fisheries collapse the collapsed population often takes much longer to recover than expected based on known biological parameters, the previously observed carrying capacity of the habitat, and the fact that each adult female fish may spawn tens of thousands to millions of eggs (Hutchings 2000; Steele & Schumacher 2000). It is argued that something durable and significant can be done to the ecosystem during over-exploitation and that this inhibits recovery even if fishing mortality is reduced. For example, in the mid-1960s the sardine fishery in the northern Benguela collapsed from a high point of annual catches of about 1.5 million tons (Boyer 1996). Meanwhile, the other major fishery resources of the region, hake (Merlucius paradoxus and M. capensis) and horse mackerel (*Trachurus trachurus*

capensis) also fell to low abundance levels and have not recovered (Bakun & Weeks 2006). The suggestion is that sardines previously occupied the key central position in the ecosystem structure and that these exploitable species have now been largely replaced by a combination of "jelly predators" and pelagic gobies in a stable, alternative ecosystem state (Boyer & Hampton 2001; Lynam et al 2006; Bakun & Weeks 2006).

One hypothesis for how trophic effects can prevent stock recovery is the "cultivation/ depensation" mechanism (Köster & Möllmann 2000; Walters & Kitchell 2001). In this hypothesis, consider a species X whose adults predate a species Y, but whose recruits are predated by species Y. If adults of X are abundant they can create favourable conditions for their own offspring by reducing the abundance of Y and hence reducing mortality of their pre-recruits. If the abundance of adults of X is reduced by fishing, expansion of Y may prevent re-establishment of the former species by increasing predation on the recruits of X (Folke et al 2004). A less theoretical example is that of Casini et al (2008), based on a 33-year time series in the Baltic Sea, that showed the reduction of the cod population by fishing led to increases in abundances of sprat. Sprat, besides being preyed upon by cod, prey heavily on cod eggs and early larvae (Casini et al 2004). Some authors have concluded that this predation, together with the likelihood that zooplanktivorous cod larvae may suffer food competition with the high sprat population, was probably a significant factor preventing the resurgence of that cod population (Jarre-Teichmann et al 2002; Köster et al 2003a,b; Casini et al 2009).

However, the prevalence of trophic or ecosystem-level effects slowing or stopping recovery after fisheries collapses is disputed. Cardinale & Svedang (2011) studied the recent recovery of the eastern Baltic cod stock after more than 20 years of low biomass and productivity and concluded that the recovery was driven by a sudden reduction in fishing mortality and occurred in the absence of any exceptionally large year classes. The recovery of the cod stock during a "cod-hostile" ecological regime is taken by Cardinale & Svedang (2011) as indicative of fisheries (rather than climate or food-web effects) being the main regulator of cod population dynamics in the Baltic Sea. Cardinale & Svedang (2011) concluded that single species regulation still seems to be a well-functioning approach in handling natural resources, provided that it includes both temporal and spatial aspects of stock dynamics and fleet behaviour.

12.1.4.3 EFFECTS ON SCAVENGING SPECIES

Offal and discards from fishing vessels can be important sources of food for some marine species, and this constitutes a trophic perturbation to the ecosystem. In addition to scavenging of discards, fish are known to prey on biota damaged or revealed by recent trawling (Kaiser & Spencer 1994). This may include benthic prey items not normally available to the fish (Dunn et al 2009a). Seabird diets (and ecological success) are also potentially affected by availability of offal and discards near the sea surface. Globally, populations of many scavenging seabirds have grown in recent years (e.g., Lloyd et al 1991) and it is likely that some species have significantly benefited from fishery discards (e.g. Furness & Barrett 1985; ICES 2005). However, population growth in scavenging seabirds can lead to displacement of other species because of limited suitable breeding habitat (Howes & Montevecchi 1993). For example, in Europe, many tern species have been displaced by larger gull species (Theissen 1986; Becker & Erdelen 1986). This has led in many instances to the culling of the large gulls in order to allow terns to return to their original nesting sites (Wanless 1988; Wanless et al 1996).

12.2 WHAT CAUSES TROPHIC AND ECOSYSTEM-LEVEL EFFECTS?

As can be seen in the examples given so far, trophic and ecosystem-level effects in marine systems can be caused by a variety of factors, often acting simultaneously. These factors are often called stressors. Stress in this context refers to physical, chemical and biological constraints on the productivity of species, their interdependencies, and on the structure and function of the ecosystem. Stressors can act over various spatial scales (from local to basin-scale) and various time scales (from days to decadal). Stressors can be natural environmental factors or they may result from the activities of humans. Trophic and ecosystem-level effects can occur because of fishing, because of environmental factors entirely disconnected to fishing (especially related to climate variability/change) or by a combination of fishing and environmental variability/change acting together (Mackinson et al 2009; Frank et al 2007; Schiermeier 2004, Schiel 2013). Trophic and system-level effects can also result from outbreaks of

disease (Cobb & Castro 2006; Freeman & MacDiarmid 2009; Shields 2011), from the arrival of non-indigenous invasive species (Mead et al 2013) and from eutrophication in estuarine ecosystems (Daskalov et al 2007; Oguz & Gilbert 2007; Osterblom et al 2007; Möllman et al 2008). Some of these causes of trophic and ecosystem-level effects are discussed further below.

12.2.1 ENVIRONMENTAL-DRIVEN CHANGE

Marine ecosystem are intimately linked to environmental (climate) forcing (Fasham et al 2001; Schiermeier 2004; Frank et al 2007; Mackinson et al 2009). Variability of climate forcing of the ocean occurs on a wide range of time scales from seasonal periods, to 1–3 year oscillating but erratic periods, to decadal aperiodic variability at 5–50 years, to centennial and longer periods, and can include sudden, large-scale shifts in environmental forcing (Overland et al 2010). Climate trends (such as due to global warming) are defined as changes that are not cyclical or seasonal and exist over a relatively long period (more than decadal).

There are many examples internationally of trophic and ecosystem-level effects occurring as a result of environmental change affecting the bottom of the food-web (Mackinson et al 2009; Frank et al 2007; Schiermeier 2004). For example, during the 1980s, the North Sea experienced a change in hydro-climatic forcing that caused a rapid, temperature-driven ecosystem shift (Beaugrand & Ibanez 2004). This change in sea surface temperature (SST) altered the plankton and negatively affected the recruitment of cod (Beaugrand & Reid 2003; Heath 2005). Changes in the North Sea plankton, following the ecosystem shift, included an increase in microalgae (Kirby et al 2008), a change in the composition and abundance of zooplankton (Beaugrand et al 2002), increases in the frequency of jellyfish (Kirby et al 2009), increases in the abundance of decapod and echinoderm larvae, and a decrease in bivalve larvae (Kirby et al 2008). Another example of bottom-up effects on upper-trophic-level marine predators is the abrupt decline in local primary and secondary production caused by El Nino/Southern Oscillation (ENSO) events in eastern Pacific boundary currents (Barber & Chavez 1983; Pearcy et al 1985; Arcos et al 2001; Hollowed et al 2001). During these ENSO events, the production of small pelagic fishes can be drastically reduced (Barber & Chavez 1983; Rothschild 1994), and predatory fish, seabirds and pinnipeds, which are dependent on these small pelagic fish have been shown to shift their distributions, suffer reduced productivity, and have increased rates of mortality (Trillmich et al 1991; Jahncke et al 2004).

12.2.2 FISHERIES-DRIVEN CHANGE

To some degree, trophic effects will always arise as a consequence of fisheries. As well as reducing the overall abundance of fish, fishing usually reduces the average size of fish in harvested communities and can change the mix of species in a fish community (Pope & Knights 1982; Pope et al 1987; Dayton et al 1995). Fishing also has effects beyond changes to the abundance and population structure of target and bycatch species, including (a) the introduction of discarded bycatch/offal/bait into the ecosystem, (b) the alteration of fish behaviour (and potentially genetic make-up) as a result of fishing, and (c) the modification of the benthos by fishing gear. Fishing will certainly lead to changes (of greater or lesser magnitude) in predation pressure on prey species. Marine ecosystems seem to be remarkably resilient to even quite large trophic changes of this kind, but there are clearly limits to this resilience. Virtually all well-documented regime shifts seem to have been initiated from large-scale climate or oceanographic changes rather than excessive fishing pressure. In some cases however, ecosystem-level changes (regime shifts) have been demonstrated empirically to occur in very highly impacted (highly overfished/collapsed) systems as a result principally of trophic effects (Estes & Duggins 1995; Daskalov et al 2007). For example, the round sardinella (Sardinella aurita) stock off west Africa collapsed in the 1970s following exceptionally high catches made possible by oceanographic changes (Bakun & Weeks 2006). This collapse resulted in a substantial and widespread outbreak of grey triggerfish (Balistes capriscus) which lasted through the 1970s and 1980s until the sardinella population rebuilt. At that point, grey triggerfish essentially disappeared from the ecosystem again. It seems possible that the juvenile triggerfish, being pelagic plankton feeders, took advantage of the collapse of the sardinella population to temporarily replace it as the dominant nektonic zooplanktivore of the ecosystem through one or more trophic effects. For example: (1) the sardinella collapse may have led to increased zooplanktonic food resources and hence accelerated the production rate of triggerfish; (2) the sardinella collapse may have promoted

increased recruitment of triggerfish by reduced predation on their eggs and larvae (Bakun & Weeks 2006).

12.2.3 COMBINED EFFECTS OF FISHING AND ENVIRONMENTAL VARIABILITY/ CHANGE

Although there have been few unequivocal empirical demonstrations of large-scale trophic and system-level effects arising solely from fishing, very many studies have pointed to the potential of fishing to lead to trophic and ecosystem-level effects in concert with other factors, such as environmental variability and change (e.g. Winder & Schindler 2004; Brierley & Kingsford 2009; Kirby et al 2009; Perry et al 2010). The effects of fishing that may lead to reduced ecosystem resilience (see Table 12.1 for definition of "ecosystem resilience") include:

- **Alteration of demographic structure.** Size-selective removal truncates the population's age structure and lowers the buffering capacity of the population (its ability to withstand long periods of environmental conditions that are adverse for recruitment). This leads to the prediction that the relative importance of recruitment variability will be greater in exploited populations as has been observed in a comparison between exploited and unexploited fishes in the California Current Ecosystem (Hsieh et al 2006).
- **Alteration of spatial structure.** The spatial structures of marine fish populations can encompass a wide range of configurations, including patchy populations, networks, and meta-populations (Kritzer & Sale 2004). Removal or curtailment of population spatial structure by fishing is likely to increase the sensitivity of the overall population to climate fluctuations at interannual to multi-decadal scales (e.g. Ottersen et al 2006).
- **Alteration of life-history traits.** Perry et al (2010) suggest that fishing would be likely to accelerate the response of populations to climate forcing by providing selective pressure to decrease growth rates and decrease age-at-maturity (Law 2000; de Roos et al 2006).
- **Alteration of habitat structure.** Changes to benthic habitat by the direct effects of fishing may lead to a reduction in ecosystem resilience (Thrush & Dayton 2002);
- **Alteration of ecosystem trophic structure.** Theoretically, ecosystems under intense exploitation are likely to evolve towards stronger bottom-up control (Figure 12.1). Exploitation leads to a decrease in stock sizes of piscine predators, which may (a) reverse the control structure in top-down ecosystems to bottom-up control, and (b) amplify the control in already bottom-up controlled ecosystems. Multiple weak interactions and generalist predators may stabilize ecosystems by dampening oscillations caused by strongly interacting species (Shin & Cury 2001; Polunin & Pinnegar 2002; Rooney et al 2006; McCann & Rooney 2009, Johnson et al 2014) and by preferentially consuming competitively dominant prey species (Brose et al 2005). Changes to trophic structure by fishing are hence predicted to increase ecosystem variability and reduce resilience (Jackson et al 2001; Perry et al 2010).

Theoretically therefore, fishing is predicted to strengthen the relation between oceanographic forcing and ecosystem variability and hence reduce ecosystem resilience. There are limited real-world, empirical examples of this. For example, the regime shifts of the North Sea and central Baltic Sea are considered to have been driven by the combined and synergistic effects of intense fishing and climate variability (Weijerman et al 2005; Möllmann et al 2009). Using a 47-year time series, Kirby & Beaugrand (2009) showed that the effects of temperature can be magnified by propagation through indirect pathways in the food-web. This "trophic amplification" can intensify the effect of environmental variability, potentially leading to a new stable or unstable ecosystem state (Scheffer & Carpenter 2003; Muradian 2001; Taylor 2002; Hsieh et al 2005). Elsewhere, Ottersen et al (2006) analysed the Arcto-Norwegian cod stock in the Barents Sea over the last 60 years and found evidence of a strengthening of the climate-cod recruitment link during the last decades.

Table 12.1. Ecosystem resilience.

Fishing can affect ecosystem resilience, the capacity of an ecosystem to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks (Pimm 1982; Holling 1973; Cohen et al 1990; Walker et al 2004). Three measures of ecosystem resilience have been identified: • Does the ecosystem retain essentially the same function, structure, identity, and feedbacks after perturbation as before (Walker et al 2004)? • Do perturbations to one part of the ecosystem spread out and affect biota across many trophic levels or remain localised (i.e. are ecosystem-level changes likely)? • How long does it take a food web to return to its original configuration when perturbed? Stable (resilient) food webs can absorb more perturbation without undergoing wholesale reorganisation, tend to have low tendency for ecosystem-level trophic cascades (food-web perturbations remain local) and have short return times (Walker et al 2004).

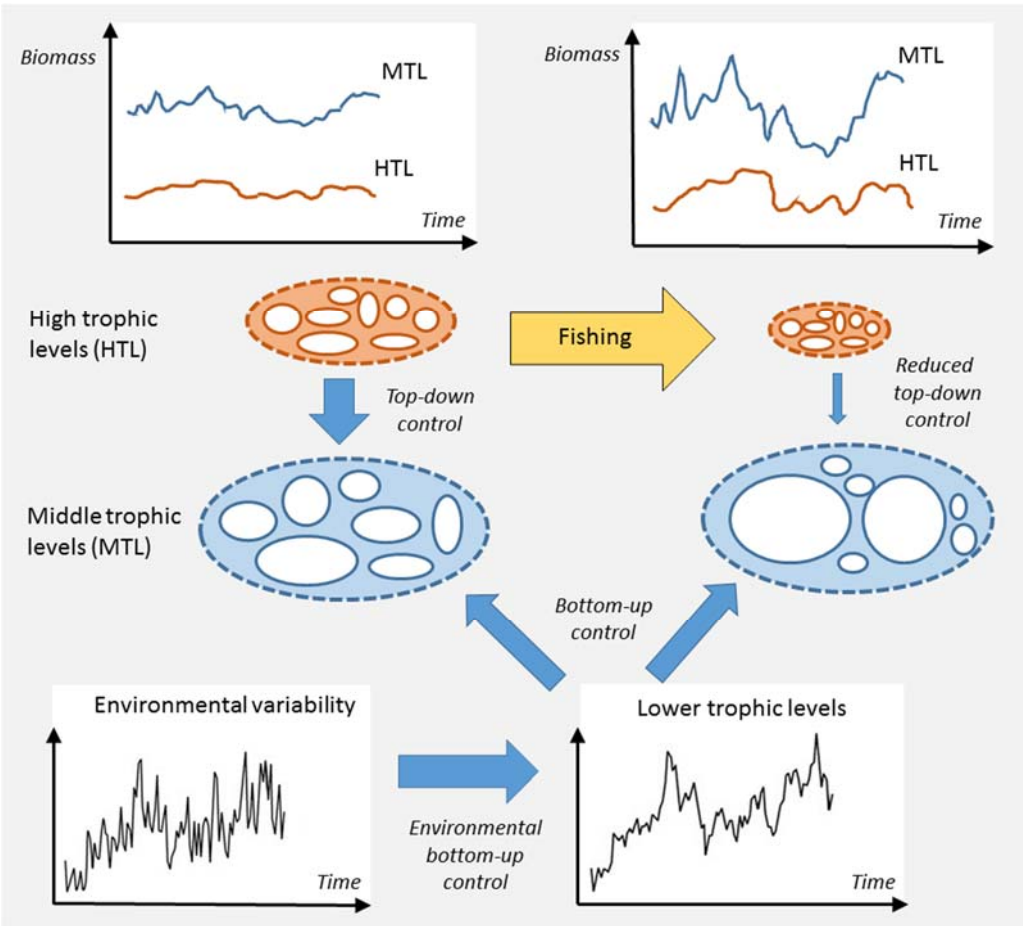

Figure 12.1: Schematic illustrating expected responses of unexploited and exploited marine ecosystems to climate forcing. Left side shows an unexploited ecosystem with multiple high trophic level (HTL) species which have relatively large abundances supported by several mid-trophic level (MTL) species, and how their aggregate biomasses vary through time (top left) in response to environmental variability acting on the lower food-web. The right side illustrates how that same climate forcing is experienced by an ecosystem which has been exploited (top right graph). The abundances of the high trophic level species have decreased due to fishing, weakening the top-down control on the MTL. This is hypothesized to make the mid-trophic level groups less even causing their aggregate biomass to track the environmental forcing more closely. [after Perry et al 2010]

12.3 WHAT TYPES OF ECOSYSTEM ARE LIKELY TO BE MOST AFFECTED?

12.3.1 GLOBAL UNDERSTANDING

The scale and significance of trophic and ecosystem-level effects depend on the particular characteristics of the ecosystem as well as on the drivers of change (Pace et al 1999; Brose et al 2005; Pascual & Dunne 2006; Brander 2010, Jennings & Brander 2010). Ecosystems appear to be prime examples of complex adaptive systems (Levin 1998, 1999); ecosystems typically have non-linear dynamics, with thresholds (also called tipping-points) and positive and negative feedback loops (Hsieh et al 2005). The complex behaviour of ecosystems over a wide range of time and space scales coupled with the myriad nature of stressors means that it is hard to forecast the response of ecosystems or establish quantitative estimates of tipping-points to guide management.

A number of multispecies or ecosystem models have been developed which can be used to investigate the potential for trophic and ecosystem-level effects in ecosystems (Plagányi 2007; Plagányi et al 2014). These include Ecopath with EcoSim (EwE, Christensen & Walters 2004), Atlantis (Fulton et al 2004, 2005), OSMOSE (Shin et al 2004; Travers et al 2009) and a range of models of intermediate complexity (MICE, Plagányi et al 2014). Multispecies and ecosystem models can provide useful strategic insights for fishery and resource managers (Plagányi 2007; Fulton et al 2005; Smith et al 2011). However, there are often differences in model predictions about ecosystem consequences (or lack thereof) of fishing, especially in ecosystem-scale models, so model outputs need to be used cautiously for tactical decisions (Smith et al 2011). MICE-models (where only part of the ecosystem is modelled) are likely to provide more robust guidance for tactical decision-making (Plagányi et al 2014).

There have also been attempts to use knowledge of the structure of the food-web to suggest types of behaviour and response to fishing and other changes as an alternative to dynamic ecosystem models (Ulanowicz & Puccia 1990; Libralato et al 2006; Pinkerton & Bradford-Grieve 2014). Rice (2001) concluded that trophic and ecosystem-level effects of fishing depend on the overall type of ecosystem forcing structure. Three patterns of ecosystem forcing structure have been described: (a) top-down forced, (b) bottom-up forced, or (c) forced from the middle outwards or wasp-waisted (Table 12.2). These patterns of ecosystem forcing have been the focus of hundreds of research articles. These three patterns should be considered as modes of forcing (rather like principal components); most real ecosystems will be a mixture of these types of forcing that may change over time (Rice 2001). Indeed, Pace et al (1999) cautions that "although there is some descriptive value in the use of top-down or bottom-up control, this motif also creates a false dichotomy." Nevertheless, identifying dominant patterns of ecosystem behaviour may help to predict or explain the types of trophic and ecosystem-level behaviour resulting from the combined effects of fisheries harvesting, climate variability/change and other human activities (Rice 2001). For example, Pinksy et al (2011) uncovered a high incidence of fisheries collapse among small, short-lived, middle trophic-level species of a type that are often the wasp-waist of the ecosystem. Even though short-lived species may recover quickly from excessive fishing mortality (Hutchings 2000), changes to them can have substantial impacts on the food web (Duffy 1983; Frederiksen et al 2004; Crawford 2007).

Table 12.2: Overall types of ecosystem forcing. [Continued on next page]

Bottom-up ecosystem forcing	If the ecosystem-level properties (i.e. across organisms at many trophic levels) respond strongly to changes in the environment (e.g. oceanography, water column structure), the ecosystem is said to show strong bottom-up forcing. There are many examples internationally of trophic and ecosystem-level effects occurring as a result of environmental changes at the bottom of the food-web (Mackinson et al 2009; Frank et al 2007; Schiermeier 2004).
Top-down ecosystem forcing	An ecosystem is said to show strong top-down forcing if it responds strongly to changes in the abundance of top predators (seabirds, marine mammals, high trophic level fishes). Understanding of how predators shape marine ecosystems has arisen largely from

experimental studies where the effect of predation is controlled either by removing predators or introducing them to the ecosystem under study, usually in the intertidal or nearshore subtidal zone (Hunt & McKinnell 2006 and references therein). In the open ocean, increases in prey populations upon the removal of their predators (e.g., by fisheries) have been taken as evidence of top-down limitation (e.g., Furness 2002; Worm & Myers 2003; Frank et al 2005). Other evidence of top-down regulation in a marine ecosystem appears where predators are abundant at one site, but largely absent from a similar, nearby site. For example, Birt et al (1987) found that small flatfish populations were depressed in a bay in Newfoundland that was frequented by cormorants compared to a bay that was located farther from the colony. In general, top-down ecosystem forcing is predicted to be stronger in aquatic than terrestrial ecosystems, and strongest in marine ecosystems where the predators are large and mobile with high metabolic rate, where prey species are long-lived, functional predator diversity is low, and predator intra-guild predation is weak or absent (Shurin et al 2002; Borer et al 2005; Heithaus et al 2008).

Middle-out forced (wasp-waisted) ecosystem

Wasp-waist control of energy flow in marine ecosystems occurs when one or a very few species have a substantial influence on the flow of energy through the mid-trophic levels. The term has most frequently been applied to the role of small pelagic fishes that transfer energy from the plankton to larger predatory fish, seabirds and marine mammals (Rice 1995; Bakun 2004; Cury et al 2000, 2004; Bakun 2006). Ecosystems with wasp-waist control are typically coastal, highly productive systems with relatively short food chains. However, waist-controlled ecosystems also include capelin in North Atlantic ecosystems (Lilly 1993; Bogstad & Mehl 1997; Leggett et al 1984; Taggert & Leggett 1987; MacKenzie & Leggett 1991; Fossum 1992), krill in the Antarctic (Murphy et al 1998) and, Calanus sp., when functioning as a "gatekeeper" (sensu Steele 1998). When the species at the waist declines abruptly, predators often cannot compensate, at least fully, and suffer reduced growth, survivorship, and reproduction (Mehl & Sunnana 1991; Kjesbu et al 1998; Dutil & Lambert 2000). Predators may control the wasp-waist when they are at intermediate population sizes (Bakun 2006). At other times, year-class strengths of species at the waist demonstrate strong, direct effects of environmental forcing. Wasp-waisted ecosystems typically follow from: (1) a food web containing a highly influential intermediate node which has a strong environmental signal in recruitment (Rice 2001) and/or (2) middle-trophic level fishery.

12.3.2 NEW ZEALAND

12.3.2.1 BOTTOM-UP FORCING

A New Zealand example of bottom-up forcing is the driver of mussel (*Perna canaliculus*) yield in Pelorus Sound in northern South Island. Though this example is from aquaculture, it is likely to also apply to wild mussels. Zeldis et al (2008) correlated physical, chemical and biological data collected within a 9-year time series. Starting in early 1999, farm production in the sound declined by about 25% in terms of per-capita meat yield, followed by yield recovery through to 2002. These changes resulted in substantial economic impacts within the industry. Over-grazing by mussels (i.e., top-down effects on mussel food availability) did not explain the yield minimum. Instead, bottom-up (environmental) effects of nitrogen supply from oceanic and river sources drove the variation by affecting the abundance of seston[5] for the filter-feeding mussels. A subsequent study (Zeldis et al 2013) provided quantitative models for Pelorus Sound mussel per-capita

[5] Organisms and non-living matter swimming or floating in a water body.

meat yield and elucidated the underlying oceanographic mechanisms. Yield was best predicted using biological variables, including the concentration of seston, based on measurements made next to the mussel farms, but it was also predictable using only physical variables that index large-scale environmental processes (Southern Oscillation Index, along-shelf winds, sea surface temperature and river flow).

12.3.2.2 TOP-DOWN FORCING

In moderately exposed coastal marine reserves in north-eastern New Zealand, predation by recovering populations of snapper (*Pagrus auratus*) and spiny lobsters (*Jasus edwardsii*) have gradually decreased the abundance of the grazing sea urchin (*Evechinus chloroticus*) and allowed turfing algae and kelp (*Ecklonia radiata*) to replace urchin grazed rock flats (Babcock et al 1999, Shears & Babcock 2002, 2003). This is indicative of top-down forcing in the ecosystem. In adjacent areas which are heavily fished there are more urchins, and areas free of turfing algae and kelp are common (Shears et al 2008). It seems that the occurrence of this trophic cascade varies at local and regional scales in relation to abiotic factors, implying some interplay with larger-scale bottom-up forcing (Shears et al 2008).

A long-term study of changes to the ecosystem of the Hauraki Gulf region developed five balanced, quantitative models of the food-web of the region (MPI project ZBD200505: Pinkerton 2012): (1) present day; (2) AD 1950, just prior to onset of industrial-scale fishing; (3) AD 1790, before European whaling and sealing; (4) AD 1500, early Maori settlement phase; (5) AD 1000, before human settlement in New Zealand. These models were used to estimate the strengths of trophic connections between different groups of organisms based on single-step and multiple step measures of trophic importance (Ulanowicz & Puccia 1990; Libralato et al 2006). Before humans arrived in New Zealand, the models suggest that cetaceans and fur seals/sea-lions were the most trophically-important groups in the Hauraki Gulf ecosystem, implying the potential for strong top-down ecosystem control. With the extirpation[6] of seals/sea-lions from the Hauraki Gulf ecosystem before the arrival of Europeans and the reduction in the abundance of cetaceans following European arrival, the trophic importance of these air-breathing predators drastically reduced. The trophic importance of other predators in the models of the Hauraki Gulf ecosystem also reduced over time as a result of human harvesting (rock lobsters and sharks especially) suggesting a transition to a more bottom-up controlled system.

12.3.2.3 MIDDLE-OUT (WASP-WAIST) FORCING

Research into deep-water ecosystems in the New Zealand EEZ is most advanced in the Chatham Rise region. Elevated primary production here is due to the convergence of Subantarctic and Subtropical water (Bradford-Grieve et al 1997; Boyd et al 1999; Murphy et al 2001; Sutton 2001) and supports valuable deep-water fisheries, an unusually rich benthic ecosystem (Probert et al 1996; McKnight & Probert 1997; Bowden 2011), and large seabird populations (Taylor 2000a,b). Ecosystem modelling of the Chatham Rise food-web has been underway since 2006, the most recent version being Pinkerton (2013) (Figure 12.2). Trophic impact matrices (Ulanowicz & Puccia 1990; Libralato et al 2006) were calculated from the balanced model to investigate patterns of trophic interactions. Middle trophic level groups, especially small demersal fishes and mesozooplankton, had some of the highest trophic importances amongst consumers. Mesopelagic fishes, hoki, and arthropods (benthic prawns and shrimps) also had high trophic importances (Pinkerton 2013). These patterns of trophic importance were robust to uncertainties in the model parameterisation and balancing (Pinkerton 2014b). These results suggest some degree of middle-out control in the system, though the number and function diversity of these groups is higher than in other systems characterised in this way.

[6] Made locally extinct

12.4 OVER WHAT SPATIAL SCALES DO TROPHIC AND ECOSYSTEM-LEVEL CHANGE OCCUR?

12.4.1 GLOBAL UNDERSTANDING

Delineating ecosystems is an important first step towards evaluating trophic and ecosystem-level effects of fishing. There are not usually clear spatial boundaries between different ecosystems. Instead, different parts of ecosystems vary on different spatial scales; higher trophic-level organisms usually move over a greater spatial extent than lower trophic-level organisms. For example, some seabirds and marine mammals may move large distances seasonally and move between different ecosystems. In contrast, most phytoplankton, smaller zooplankton and most benthic invertebrates will live and die within a few kilometres. Some fish move long distances, but others remain in a small area all their lives (e.g. on a reef). Marine ecosystems should hence be viewed as an interlocking matrix of the life ranges of different organisms. As such, it is difficult to unambiguously separate different ecosystems but a number of approaches have been developed to do so. These include: (a) defining ecosystems on the basis of their physical properties, either using a priori thresholds (e.g. fixed depth ranges) or by multivariate clustering of physical properties (Snelder et al 2005; Grant et al 2006); (b) using maps of species occurrence to map biological assemblages (e.g. Leathwick et al 2006); (c) relating community composition to environmental variables (e.g. generalised dissimilarity analysis, Ridgeway 2006, Leathwick et al 2009) and using these relationships to extrapolate spatially.

12.4.2 NEW ZEALAND

The importance of spatial scale in the study of the ecosystem effects of fisheries has been recognised in New Zealand (e.g. Leathwick et al 2006, 2009). In their assessment of the New Zealand hoki fishery for the Marine Stewardship Council (MSC) Akroyd & Pierre (2013) noted that there is currently no specific definition of "regional effects" but MSC is working on adding clarity to the definition of regions and bioregions as part of the work on their current benthic impacts project in recognition that some areas are more vulnerable to impact than others.

A number of approaches have been developed in New Zealand to identify or describe ecosystem types:

- MacDiarmid et al (2012) identified sixty-two distinct marine habitat types occurring within New Zealand's territorial seas and EEZ as part of an assessment of anthropogenic threats to New Zealand marine habitats. The approach taken by MacDiarmid et al (2012) was to build on Halpern et al's (2007) list of marine habitats used in a global assessment of anthropogenic impacts on the global marine environment.
- New Zealand's Department of Conservation, jointly with MPI, have used a marine habitat classification system based on four depth intervals (intertidal, 0–30 m, 30–200 m, more than 200 m), seven substrate classes (mud, sand, gravel, undefined substrate, mixed sediment and rock, rock, and biogenic), and three exposure categories (exposed, moderate, sheltered). This habitat classification was used to define 58 habitats in the territorial sea alone in order to meet the needs of biodiversity conservation (DOC-MPI 2011).

New Zealand Marine Environment Classification (MEC, Snelder et al 2005). The MEC is a physically-based classification, determined using multivariate clustering of several spatially explicit data layers that describe the physical environment (including depth, slope, orbital velocity at the sea floor, mean solar radiation, SST amplitude, SST gradient, winter SST, mean tidal current velocity). Large biological datasets were used to tune the classification so that the physically based classes maximised discrimination of variation in biological composition at various levels of classification detail. The classification was not optimised for a

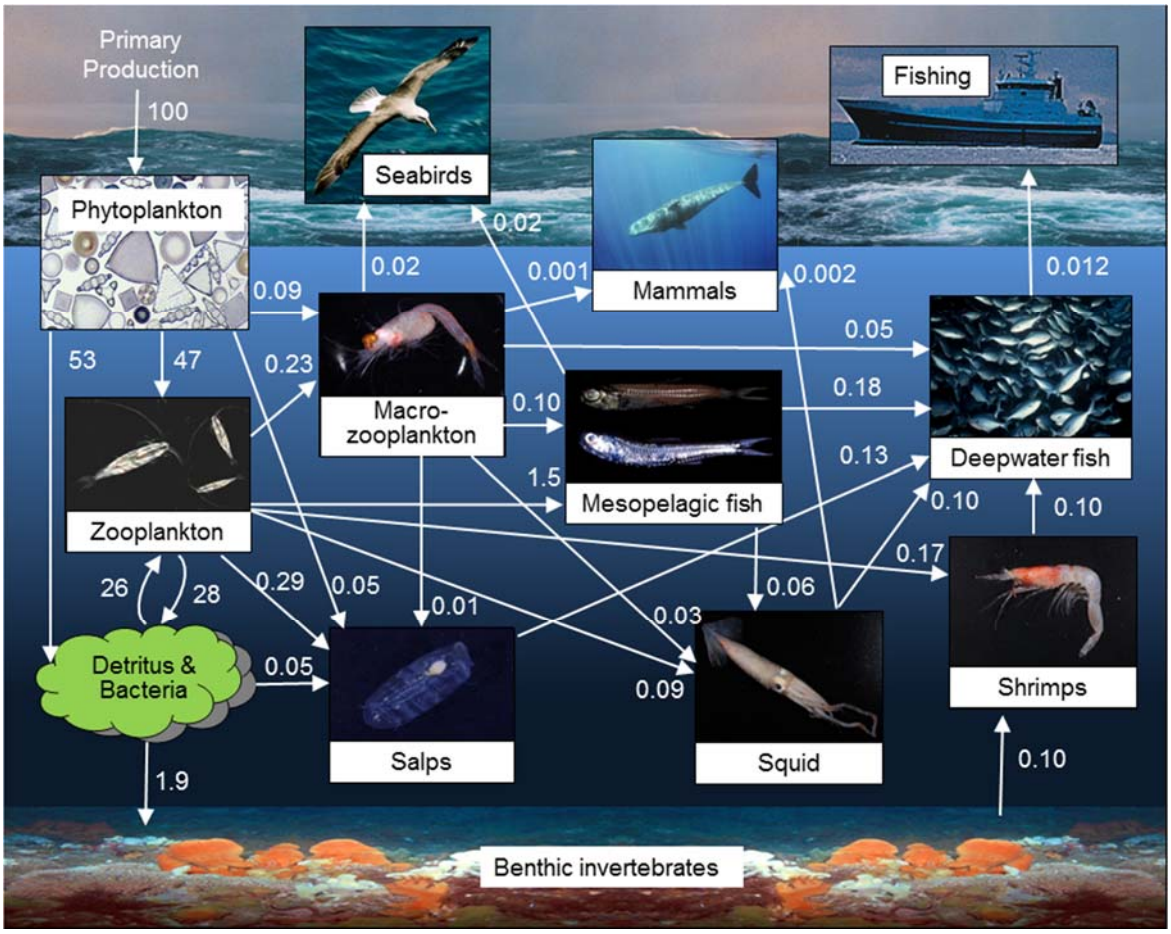

Figure 12.2: Simplified trophic model of the Chatham Rise, New Zealand (based on Pinkerton 2013). The growth of phytoplankton generates organic matter that is the fuel for the marine ecosystem. Figures show the annual flow of energy through unit area of the food-web normalised to a net primary productivity (NPP) of100, based on an equilibrium mass-balance model (similar to Ecopath).

- specific ecosystem component (e.g., fish communities or individual species) but sought to provide a general classification that had relevance to a broad range of biological groups. Depending on user requirements the MEC can provide two to 270 classes of classification.
- Leathwick et al (2006) demonstrated how spatial analysis using boosted regression trees could provide distribution maps of over 100 species of demersal fish. Fish were chosen as there were good quality distributional data available from a series of scientific trawl surveys in deep waters. The overall approach used by Leathwick et al (2006) was to fit statistical models relating the distributions of 122 fish species to a set of environmental variables, with the latter chosen for their functional relevance.
- A benthic optimised marine environment classification (BOMEC, Leathwick et al 2009) was developed specifically to identify New Zealand benthic bioregions that can be considered to be ecologically distinct to some degree. BOMEC was developed by combining data on the benthic community (made up of over 100 demersal fish species, and seven groups of invertebrates: asteroids, bryozoans, foraminifera, octocorals, polychaetes, scleractinian corals, sponges), and environmental data including sediment type. A multivariate technique for fitting community compositions to environmental data, Generalised Dissimilarity Analysis, was used (Leathwick et al 2009). BOMEC is restricted to depths less than 3000 m where reasonable amounts of scientific sampling have been conducted (Leathwick et al 2009).

- The Ocean Survey 20/20 Chatham-Challenger biotic habitat classification (Hewitt et al 2011) used benthic invertebrate and environmental data from the Chatham Rise and Challenger to delineate ecosystems in terms of their community and biogenic habitat associations.

Sharp et al (2007) summarised lessons learned from New Zealand's bioregionalisation experience for CCAMLR. The main conclusion was that bioregionalisations based on simple clustering of physical variables are likely to perform poorly in terms of separating assemblages of species (communities or ecosystems); measurements of the actual distributions and abundances of key organisms are needed to use physical environmental data to delineate bioregions effectively.

12.5 HOW CAN TROPHIC AND ECOSYSTEM-LEVEL EFFECTS BE DETECTED?

12.5.1 GLOBAL UNDERSTANDING

There has been increasing recognition over the last two decades that time series are essential to detect and potentially understand a trophic or ecosystem-level change in marine ecosystems. This has led to a high level of interest in the development and interpretation of indicators of the marine environment and its ecosystems. A huge number (more than 300) of marine ecosystem indicators are in use or proposed around the world (Cury et al 2005; Rochet & Rice 2005; Rice 2003), with consensus that a suite of indicators is needed to monitor and understand the impact of human activities on marine ecosystems (Cury & Christensen 2005; Rice & Rochet 2005). Give the multi-trophic nature of ecosystem-level effects, indicators are needed which span the ecosystem, including primary producers, the microbial system, middle trophic levels, fish communities, the benthic community and top predators. A summary of some recommended indicators is given below.

12.5.1.1 MARINE PRIMARY PRODUCTION

The growth of phytoplankton in the upper layers of the ocean provides the vast majority of the energy that fuels marine ecosystems, and most fisheries, worldwide. Only in some (predominantly coastal) areas are other primary producers important: macroalgae (seaweed), seagrass, mangroves, epiphytes, autotrophic periphytes, microphytobenthos and chemosynthesisers. Light, temperature, and nutrient concentrations are major factors controlling net[7] primary production (NPP) by phytoplankton growth in the ocean (Parsons et al 1977, Arrigo 2005). NPP can be measured accurately from ships (typically using radioactive carbon incubations), but because of the high spatial and temporal variability of NPP, ship-based sampling is not adequate for monitoring. Instead, remotely-sensed data from sensors on Earth-observing satellites are typically used to estimate NPP. There are significant differences between different methods of estimating NPP from satellite data (Campbell et al 2002). Often, the concentration of chlorophyll-a, the ubiquitous pigment in phytoplankton, is used as a proxy for phytoplankton biomass and NPP, because this can be measured remotely with better accuracy than NPP using ocean colour satellite sensors.

12.5.1.2 LOWER FOOD-WEB (MICROBIAL SYSTEM)

Rice (2001) notes that processes which make large alterations to the allocation of production between the microbial loop, benthic detrital pathways and mesopelagic consumers may have much more impact on the dynamics of higher trophic levels than processes which alter NPP. More recently, Friedland et al (2012) examined the relationships between NPP, fisheries yields, and parameters describing the transfer of organic matter through 52 large marine ecosystems and found that chlorophyll-a concentration, the particle-export ratio (p-ratio: the proportion of NPP exported from the surface layer of the ocean) and the ratio of mesozooplankton productivity to NPP (z-ratio) were all significantly related to fisheries yields. Stock & Dunne (2010) suggest that a warmer ocean will lead to lower z-ratio (less mesozooplankton for a given NPP) and Friedland et al (2012) show that lower z-ratios correspond to lower fisheries yields at basin scales.

[7] "Net" means after allowing for phytoplankton respiration.

12.5.1.3 MIDDLE TROPHIC LEVELS

Small mesopelagic[8] and hyperbenthic[9] organisms are an important part of marine ecosystems. They act as the link between the microbial/planktonic system and larger predators such as seabirds, marine mammals, and larger fish. These "middle trophic level" organisms are diverse, and include hard-bodied crustaceans (such as copepods, euphausiids, amphipods, prawns and shrimps), "jellies" (such as jellyfish and salps), cephalopods (squids and octopods), and a range of small fishes (including juveniles of larger species) living in the water column (especially myctophids or lanternfishes) or near the seabed. These species are likely to be affected both by fishing which may reduce top-down predation control, and by climate-driven changes in lower trophic food-web components (Frank et al 2007; Richardson 2008). Middle trophic level species have a key role in ocean ecology (e.g. Banse 1995; Marine Zooplankton Colloquium 2 2001; Smetacek et al 2004; Pinkerton 2013). Studying these middle trophic level organisms is challenging: they are typically diverse, with varied and complex life histories, can be hard to capture, and have abundances that vary over a wide range of space and time scales. Consequently, the factors that affect their dynamics are generally poorly understood. Two methods have been used for monitoring middle trophic levels. First, in other parts of the world, long time-series of measurements of the zooplankton community by the Continuous Plankton Recorder (CPR) has demonstrated change in marine ecosystem (Beaugrand et al 2002; Aebischer et al 1990; Reid et al 1998; Beare & McKenzie 1999), and been recommended as an effective way of monitoring the state of pelagic ecosystems (Beaugrand 2005). Second, multifrequency acoustics have been used to monitor abundances of mesopelagics over extended time and space scales (McClatchie & Dunford 2003; O'Driscoll et al 2009; Trenkel & Berger 2013).

[8] "Mesopelagic": inhabiting the intermediate depths of the sea, between about 200 and 1000 metres down.

[9] "Hyperbenthic": ecologically associated with the seabed, but living for some time in the lower water column.

12.5.1.4 DEMERSAL FISH COMMUNITIES

Most of the international effort on developing ecosystem indicators have focussed on those for the demersal fish community, usually based on commercial landings data or, less commonly, on catch data from fisheries surveys. Consequently, very many indicators have been proposed - a selection is discussed below.

- Marine Trophic Index: MTI is the mean trophic level of fisheries landings (Pauly & Watson 2005) and was recently recommended for use with commercial catch data by the United Nations Biodiversity Convention as a widely-applicable and cost-effective indicator for monitoring reductions in biodiversity loss in marine ecosystems (CBD 2004). A gradual decline in trophic level of about 0.2 since industrialised fishing began has been observed in many finfish fisheries around the world (Pauly et al 1998a; Christensen et al 2003), ascribed to fisheries targeting high trophic level species and moving on to lower trophic level species as these large species are depleted, a change called "fishing down the food web". Essington et al (2006) noted that "fishing through the food web", where higher trophic level fish landings are maintained but catch of lower trophic level species increases over time, may occur more often. MTI calculated from total commercial catch will vary with changes in the mix of species targeted by different fisheries over time, the relative importance of different fisheries sectors (e.g. finfish versus invertebrate fisheries), how much of the catch is reported, the quality of identification of species, and for other reasons not necessarily associated with effects of fishing (Caddy et al 1998; Pauly et al 1998b; Tuck et al 2009; Branch et al 2010). As such, MTI based on scientific surveys is likely to be a better indicator of change in fish communities (Branch et al 2010).
- Species-based indicators: Many indices of diversity have been applied to fish communities (e.g. Peet 1974; Warwick & Clarke 1995; Bianchi et al 2000; Greenstreet & Rogers 2006). These diversity indices are joint constructs of how many species are present (richness), and how similar their abundances are (evenness). Some indices give additional emphasis to the most important species in a community (dominance). Measures vary in the

relative weight given to each of these factors, and on the metric used for similarity between species (e.g. by including a measure of taxonomic distinctiveness or not; Warwick & Clarke 1995). Fishing rarely causes large-scale extirpation so that measures of total species richness are likely to be less sensitive to change in trophic or ecosystem-level properties than measures of evenness. Different measures of evenness respond variously to fishing; they can increase, reduce or be unaffected by fishing depending on the initial characteristics of the ecosystem. A community initially dominated by k-selected[10] species would be expected to become more even and show increasing diversity metrics due to fishing; fishing would be expected to allow the faster growing (initially minor species) to increase at the expense of the slower growing (initially dominant) species. In contrast, diversity and evenness metrics may be expected to decrease after fishing if the ecosystem were originally dominated by r-selected[11] species.

- Functional group based indicators: Changes to the relative abundance of different functional groups in an ecosystem can indicate trophic or ecosystem-level changes (Fulton et al 2005; Methratta & Link 2007; Shannon et al 2009). Functional groups can be based on various descriptors of ecological niche, such as position in the water column (e.g. pelagic, demersal, benthic), trophic guild / feeding type (e.g. piscivore, pelagic invertebrate feeder, benthic feeder, scavenger), taxonomy (e.g. elasmobranch, gadoid, macrourid), or a combination of multiple ecological and life-history traits (Methratta & Link 2007) which can be combined to suggest high or low resilience (Tuck et al 2009). A simple and commonly used index is the proportion of piscivorous fish to all fish caught. As piscivorous fish tend to be disproportionately impacted by fishing (Caddy & Garibaldi 2000), their relative abundance in fish assemblages is a measure of ecosystem state and may reveal a trophic or system-level impact of fishing.
- Size based indicators: Marine trophic processes tend to be strongly structured by size (Badalamenti et al 2002, Jennings et al 2002). Fishing may lead to substantial modifications in the size structure of exploited populations because (a) high-value, generally larger species are targeted by fisheries, (b) fishing gears are size selective, often designed to catch larger fish and let smaller ones escape, (c) the cumulative effect of fishing (over the life of a cohort) leads to fewer older (larger) fish, and (d) long-lived species tend to be affected more as they have lower potential rates of increase. Several size-based metrics have been used to detect trophic and ecosystem-level changes (e.g. Murawski & Idoine 1992; Pope et al 1987; Pope & Knights 1982; Rice & Gislason 1996). Size-based indicators can be applied at a species or community level. Applied to a given species, possible size-based indicators include: (a) mean length at age; (b) condition (weight at length, e.g. Winters & Wheeler 1994); (c) proportion of large fish; and (d) mean length at maturity in the population. Size-based methods at the community level include: (a) mean length in the community; (b) proportion of large individuals in the community; (c) the biomass size-spectrum; and (d) the diversity size spectrum (Rice & Gislason 1996).
- Spatial distributions: Fishing and climate/oceanographic variability/change can alter the geographic distribution of fish species (Perry et al 2010) and this can indicate an ecosystem-level change. The percentage area of a research survey in which most (typically 90%) of the population occurs has been used as an ecosystem indicator (e.g. Fisher & Frank 2004; Tuck et al 2009).
- Diet-based indicators: The change of diet (or trophic position) of a species of fish may reveal that trophic or ecosystem-level changes have occurred (e.g. Smith & Lucey 2014), but trophic position may change less than the underlying ecosystem structure (Badalamenti et al 2002). "Niche width" measured in terms of the range of

[10] Those which produce relatively low numbers of offspring, typically growing more slowly and maturing later.

[11] Those which produce high numbers of offspring, typically growing faster and maturing sooner.

carbon and nitrogen isotope ratios occupied by a species has also been suggested as indicative of trophic changes in a marine ecosystem especially in relation to upper trophic level predators (Layman et al 2007), but the utility of this has been questioned (Hoeinghaus & Zeug 2008).

12.5.1.5 TOP PREDATORS

Top predators (upper trophic level consumers) can be used in two ways as indicators of the state of marine ecosystems. First, an OECD core indicator is the overall ecological threat status of species in the ecosystem, often with an emphasis placed on top predators (OECD 2003). Second, particular ecological aspects of selected predator species can be used to indicate changes in ecosystems. For example, top predators are widely used in monitoring the ecosystem effects of fishing krill in the Southern Ocean (Reid et al 2005; Constable 2006), with information on the breeding of penguins, albatross, petrels, and seals collected, summarised and considered in management annually (CEMP 2004; Agnew 1997). Monitoring top predators as "bellweathers" of ecosystem health is also increasingly used elsewhere (Boyd et al 2006; Ainley 2002) as they are recognised as potentially useful downstream integrators of change in the marine ecosystem, exploit marine resources at similar spatial and temporal scales to humans, and receive high public interest. However, given that predators respond in complex ways to many factors simultaneously, ascertaining the appropriate management response to change of a predator-based indicator is difficult (Boyd et al 2006).

12.5.2 NEW ZEALAND

There has been much work in New Zealand on developing indicators of the marine environment. MPI have carried out a number of projects looking at indicators and time-series, including of oceanographic/climate variables (Hurst et al 2008; Dunn et al 2007; Pinkerton et al 2014a), demersal fish communities based on data from scientific trawls (Tuck et al 2009), and a suite of indicators relevant to deepwater fisheries (Tuck et al 2014). Other work in New Zealand on marine ecosystem indicators include reports under NIWA Core funding (Pinkerton 2010) and in relation to national environmental reporting (Gilbert et al 2000; Pinkerton 2007; Pinkerton 2014a).

12.5.2.1 MARINE PRIMARY PRODUCTION

Ocean colour satellite data have been used for more than a decade in New Zealand to investigate spatial and seasonal patterns in phytoplankton abundance and NPP (Murphy et al 2001; Pinkerton 2007). There is a limited amount of data available in New Zealand waters to develop locally-tuned estimates of NPP from satellite data, and the concentration of chlorophyll-a is preferred for the purposes of monitoring change in primary production over time (Pinkerton et al 2014a). Since 2002, mean concentrations of chlorophyll-a in the EEZ have decreased by an average of about 1% per year (Pinkerton, unpublished data). This is likely to be related, at least in part, to oceanographic cycles such as the Interdecadal Pacific Oscillation index[12] and the Southern Oscillation Index[13], as well as potentially to long-term climate change.

12.5.2.2 LOWER FOOD-WEB (MICROBIAL SYSTEM)

Changes to primary production also do not necessarily translate to less food available for higher trophic levels. Virtually all wild-caught seafood in New Zealand are carnivorous, with a mean trophic index of about 4.1 (MacDiarmid et al 2013) The trophic efficiency by which energy passes between trophic levels is often considered to be about 10% (Pauly & Christensen 1995), meaning that only about one tenth of the energy consumed by marine organisms is used to build new body mass. This means that each tonne of wild-caught seafood in New Zealand

[12] The Interdecadal Pacific Oscillation (also called the Pacific Decadal Oscillation) is a 15–30-year cycle that affects parts of the Pacific Basin, causing variability in climate and oceanography, and has substantial and long-lasting effects on regional ecosystems (Kennedy et al 2002).

[13] The Southern Oscillation Index is related to the strength of the trade winds in the Southern Hemisphere tropical Pacific (Mullan 1995) and SOI values for May-September are often used as an indicator of El Niño-La Niña Southern oscillation (ENSO).

has been supported by over a thousand tonnes of primary production that has been moved through at least two intermediate levels in the marine food web before being consumed by the target species. A change to the lower and middle parts of the New Zealand food-web hence have the potential to affect food availability for, and potentially yield of, commercially-important fish stocks. At present, there are no data available to monitor for changes in the functioning of the lower trophic levels of New Zealand's marine ecosystems.

12.5.2.3 MIDDLE TROPHIC LEVELS

Middle trophic level organisms in the New Zealand ocean are diverse (more than 21 species of myctophids occur on the Chatham Rise for example; Pinkerton, unpublished data). Although they form the basis of the diet of many commercially-important New Zealand fish species (Dunn et al 2009a), the basic abundance, distribution and ecology of key middle-trophic level groups like myctophids and hyperbenthic arthropods (prawns and shrimps) are generally poorly known. Two time-series of data for middle trophic level organisms in the New Zealand ocean may be useful to investigate trophic and ecosystem-level effects: (a) New Zealand acquired a Continuous Plankton Recorder (CPR) in 2008 and this has been deployed on a transit extending from Oamaru (approximately 45°S) to the Ross Sea annually since summer 2008/09; approximately 1200 km of this transect are in the Subantarctic New Zealand EEZ (Robinson et al 2013); (b) recent work has shown that multifrequency acoustic backscatter data taken from research vessels during the annual surveys of fish on the Chatham Rise can be used to derive indices of abundance of mesopelagic fish and invertebrates (McClatchie & Dunford 2003; O'Driscoll et al 2009; Oeffner et al 2014). Similar acoustic methods could provide time-series of middle trophic level species in the Hauraki Gulf and Subantarctic plateau in the near future.

12.5.2.4 DEMERSAL FISH COMMUNITIES

There are three series of scientific trawls in New Zealand waters that are particularly valuable for understanding ecosystem dynamics and for monitoring for trophic and ecosystem-level effects at the level of the demersal fish community (Tuck et al 2009): (a) a scientific trawl survey has been carried out on the Chatham Rise region approximately annually since 1992; (b) a similar survey has been carried out over the Subantarctic plateau over the same period but less frequently (Bagley & O'Driscoll 2012; Tuck et al 2009); (c) a total of 15 trawl surveys have also been carried out in the Hauraki Gulf region between 1980 and 2000. Each of these trawl surveys used a consistent methodology based on scientific bottom trawl gear. Tuck et al (2009) used these scientific surveys to investigate change in a series of indicators based on the demersal fish community.

Data from Chatham Rise trawl surveys between 1992 and 2007 showed evidence of increasing evenness (reducing diversity) but no evidence that species were being lost from the food-web (Tuck et al 2009). Some size characteristics of fish in research trawls on the Chatham Rise had changed, with fewer fish longer than 30 cm or heavier than 750 g being taken by trawl gear, although the median length of the catch did not change. Preliminary analysis of the mean trophic level index (MTI) in the demersal fish community of the Chatham Rise (Pinkerton 2010) indicated that this also decreased over the same period, and decreased more in the trawl survey data than in the commercial catch data. The proportion of piscivorous fish and of true demersal (rather than bentho-pelagic) species also declined over this period (Tuck et al 2009). Somewhat counterintuitively, threatened[14] species and species defined by Tuck et al (2009) as "low-resilience", such as dogfish and rays, have increased relative to other species on the Chatham Rise. This was confirmed by independent analyses of Chatham Rise trawl survey data (O'Driscoll et al 2011) and may be due to a combination of a lack of incentive to catch these species by the fishing fleet and an increase in offal and discards which benefit demersal scavengers. There were changes in the spatial distribution of fish species, with 16 out of 47 species showing changes in the proportion of the study area over which 90% of their abundance by weight was caught. Of these, half showed declining range and half showed increasing range. Tuck et al (2009) showed that on the Chatham Rise, the species showing contractions of range were generally the more abundant species whereas the species expanding in spatial range were generally the less abundant species. MPI project ZBD2004/02 (Dunn et al 2009a; Horn & Dunn 2010) examined whether there

[14] Species deemed more vulnerable according to the IUCN Red List (IUCN 2009); see Tuck et al (2009).

was evidence of change in the diet of hoki, hake or ling on the Chatham Rise between 1990 and 2009. It appears likely that the importance of fish (primarily myctophids) as a prey item for hoki has increased slightly but steadily between 1990 and 2009, while the importance of euphausiids has declined. In contrast, there were no obvious between-year differences or trends in hake diet from 1990 to 2009 (Horn & Dunn 2010). There were some marked between-year differences in ling diet in this period but no trends detected.

Discards and offal from fisheries is sometimes an important part of the diets of deepwater fish. For example, scavenged fishes accounted for up to a quarter of the diet of smooth skate (*Raja innominata*) in the Chatham Rise region (Dunn et al 2009a; Forman & Dunn 2012). Anderson & Smith (2005) estimated that 11 000–14 000 t per year of non-commercial species and 600–2100 t per year of hoki are discarded by the New Zealand hoki fishery annually, leading to the potential for a significant modification of the diet of scavenging species (Forman & Dunn 2012). Interpreting changes in diet from discards in a way that can inform fisheries management is not straightforward. For the Chatham Rise, the changes covered a period of declining hoki spawning biomass (McKenzie 2013) and occurred at the same times as evidence of climate variation, namely a shift the prevalence of Kidson weather types (Kidson 2000) between 1992 and 2007 (Hurst et al 2012). Disentangling these environmental and fishery drivers of changes to indicators of the demersal fish communities has not yet been attempted in New Zealand although the hypothesis that trophic or environmental factors were responsible for recent changes in hoki recruitment was investigated and was found not to be supported empirically (Francis et al 2006; Bradford-Grieve et al 2011).

12.5.2.5 TOP PREDATORS

Information on indicators of change in upper trophic levels in New Zealand are considered in Theme 1 of this report.

12.6 DISCUSSION

Marine ecosystems are complex, show non-linear dynamics (including potential tipping-points) and are subject to a wide range of impacts, including fishing, climate variability and change, coastal eutrophication and habitat change. Any activities that change the composition of species in the ecosystem (both in terms of size, functional group, ecosystem role, and diversity) will affect other groups in the ecosystem through trophic and other connections. A large range of trophic and ecosystem-level effects in marine systems have been documented internationally and these have generally been associated with negative impacts on fisheries (Garcia & Grainger 2005; Valdes et al 2009; Worm et al 2009). Understanding the scale and causes of these changes remains scientifically challenging (Rice 2001; Brander 2010, Jennings & Brander 2010, ter Hofstede et al 2010). There remains substantial debate about the true extent and magnitude of these changes (Hilborn 2007; Murawski et al 2007) and debate about how to allocate responsibility for these changes among different pressures, including fishing (Benoît & Swain 2008; Holt & Punt 2009; Kotta et al 2009; Noakes & Beamish 2009; Rijnsdorp et al 2009; Rice & Garcia 2011; Schiel 2013). Although ecosystem-level changes have rarely been ascribed solely to fisheries drivers, it appears that fishing is likely to make ecosystems less resilient to variability and change in climate/oceanographic forcing (Winder & Schindler 2004, Kirby et al 2008, 2009). Reduced ecosystem resilience is an ecosystem-level effect that may predominantly occur through trophic mechanisms. Reduced ecosystem resilience may affect the long-term sustainability of harvesting (Hughes et al 2005), increase ecosystem variability (Salomon et al 2010), make fisheries less predictable and harder to manage in a variable and changing climate (Badjeck et al 2010, Brander 2010, McIlgorm et al 2010), reduce the ability of ecosystems to recover from over-fishing (Neubauer et al 2013), and increase the likelihood or consequence of regime shifts or invasive species (Folke et al 2004, Salomon et al 2010).

To date, it has generally not proved possible to realistically (as opposed to theoretically) identify at what point fishing or other pressure may cause serious disruptions in resource productivity or ecosystem function through trophic or ecosystem-level effects. For multi-species fisheries which are managed at a stock level close to BMSY in a way that does not progressively degrade benthic habitat, it is not known whether it is necessary to take trophic and ecosystem-level effects into account more explicitly to ensure long term sustainability of fisheries (ICES 2005). Some studies (e.g. Jackson et al 2001; Jennings et al 2002; Branch 2009), model analyses (Walters et al 2005; Legovic et al 2010; Gecek & Legovic 2012; Legovic & Gecek 2012; Ghosh & Kar 2013), and

expert groups (Scientific Committee on Oceanographic Research/ Intergovernmental Oceanographic Commission working group on indicators, Cury & Christensen 2005) have concluded that harvesting many species in an ecosystem at B_{MSY}[15] can lead to increased chance of fisheries collapse in the medium to long term - an effect called "ecosystem erosion" or "ecosystem overfishing" (Murawski 2000; Coll et al 2008).

ICES (2005) concluded that, for fisheries managed at or close to BMSY, the priority was to avoid fishing practices that drastically changed benthic structure, trophic interactions, food-web structures or nutrient cycling (ICES 2005). This is consistent with the widespread consensus that fisheries should be managed within an ecosystem context and by adopting a precautionary approach which includes acknowledging the potentially synergistic effects of fishing and climate change (CBD 2009; Perry et al 2010; Rice & Garcia 2011). However, there is little consensus on what this actually means in practice (FAO 2008; Ecosystem Principles Advisory Panel 1999; Browman & Stergiou 2004, 2005; Garcia & Cochrane 2005; Murawski 2011). Work by NOAA fisheries (Marasco et al 2007) towards a pragmatic approach to ecosystem-based fishery management recommended:

- incorporating a broader array of societal goals and uses for ecosystem products and services within a multiple use multiple stressors framework;
- recognising the significance of ocean-climate conditions;
- emphasising food-web interactions (recognize that harvest of target species has profound impacts on ecosystem structure and function through trophic interactions);
- employing spatial representation (manage stocks consistent with spatial/habitat variation in productivity);
- increasing and expanding focus on characterising and maintaining viable fish habitats;
- expanding scope of research and monitoring (increased focus on understanding biological interactions/processes, and measuring total fishery removals of target and non-target species);
- acknowledging and responding to higher levels of uncertainty (realistically incorporate uncertainty due to trophic and food-web effects into management policy);
- reviewing and improving ecosystem modelling/research.

The role of no-take reserves or marine protected areas (MPAs) in guarding against trophic and ecosystem-level effects remains controversial. A full review of the value of MPAs in this regard is beyond the scope of the present chapter. Suffice to say that some scientists believe strongly that MPAs can be effective at providing an "ecological safety net" for trophic and ecosystem-level effects (Ballantine 2014; Edgar et al 2014) whereas other scientists believe MPAs are too few and too small to have any value in this regard (Kaiser 2005; Mora et al 2006). No-take marine reserves may have the most to contribute to our understanding of trophic and ecosystem effects by providing a "reference ecosystem" in which populations experience low fishing pressure but a full range of other stressors (such as environmental variability/change, sedimentation, and pollution). Ecosystem changes in the reserve can then be contrasted with adjacent ecosystems exposed to the full range of fishing and other impacts (Micheli et al 2005).

New Zealand is currently doing better than most countries with regard to many of the recommendations of Marasco et al (2007). Pitcher et al (2009) evaluated the performance of 33 countries for ecosystem-based management (EBM) of fisheries in three fields (principles, criteria and implementation). No country rated overall as "good", only four countries, including New Zealand were "adequate". Specific recommendations from Marasco et al (2007) are relevant to recent research initiatives in New Zealand. The newly announced Sustainable Seas research programme[16] aims to engage more closely with society to ensure that its goals and concerns are heard and addressed. Similarly, the MBIE Marine Futures project led by Dr Simon Thrush has used a multiple use framework to consider how ecosystem resilience can be promoted in the two focus areas of the Hauraki Gulf and Chatham Rise. Hurst et al (2012) and Dunn et al (2009b) considered the

[15] The biomass that allows the maximum sustainable yield to be taken.

[16] http://www.beehive.govt.nz/release/sustainable-seas-national-science-challenge-launched

impact of ocean-climate interactions on New Zealand fisheries. The Ocean Survey 20/20 voyages had an explicit focus on mapping the distribution of seafloor habitats important to fish stocks and associated species (Hewitt et al 2011). Ecosystem modelling of key New Zealand regions has been an ongoing focus of NIWA core-funded research since 2005, and includes co-funded ecosystem modelling work with MPI (e.g. ZBD2005/05). Data collection towards building up a comprehensive predator-prey database began with the ZBD2004/01 project (Dunn et al 2009) and continues on the Chatham Rise under NIWA core-funding, with a particular focus on middle trophic level organisms that are abundant. MfE aim to include multi-trophic indicators of marine ecological state in the National Environmental Reporting (Pinkerton et al 2014; Pinkerton 2014b), DOC are aiming to develop marine ecological integrity indicators (Freeman, pers. comm.), and MPI are actively developing indicators of change in fish communities (Tuck et al 2009; Tuck et al 2014).

Notwithstanding this progress, most New Zealand stocks are managed on a single-stock basis at close to BMSY (Ministry of Fisheries 2008) irrespective of their role in the ecosystem. The balance of evidence suggests that fishing close to BMSY and in particular using bottom trawling (which impacts on benthic ecosystem function (Thrush & Dayton 2002)) is likely to reduce ecosystem resilience and increase ecosystem variability by trophic and ecosystem-level effects (Brock & Carpenter 2006; Carpenter & Brock 2006; van Nes & Scheffer 2007; Guttal & Jayaprakash 2008) and could increase recruitment variability. Fishing is also likely to strengthen bottom-up control of marine ecosystems and make ecosystems more sensitive to the effects of climate change (Kirby et al 2009; Perry et al 2010). Greater sensitivity of marine ecosystems to climate variability implies a higher potential for regime shift which may or may not be reversible or desirable (Hsieh et al 2006). Stronger environmental (bottom-up) forcing of ecosystems suggests a greater likelihood of unexpected changes to fisheries due to extreme environmental events and that these changes may be more severe (Perry et al 2010; Kirby & Beaugrand 2009).

Time series measurements are crucial to understanding ecosystem function and monitoring for trophic and ecosystem-level effects of fishing. There would seem to be high value in maintaining regular and frequent (annual) surveys of the demersal fish communities of key New Zealand regions (such as the Chatham Rise, Hauraki Gulf and Subantarctic plateau). Information on the catches of all species by the fishing fleet is required to monitor for changes in trophically or ecologically important non-QMS species. A key knowledge gap is information to map and monitor abundances, trophic connections and community structure of middle trophic level species, especially mesozooplankton, mesopelagics and hyperbenthics in key fishing areas, such as the Chatham Rise, Hauraki Gulf and Subantarctic plateau. Knowledge of the abundance and trophic ecology of small demersal fishes in these regions is notably lacking.

12.7 CONCLUSIONS

1. A range of trophic and ecosystem-level effects in marine systems have been documented internationally, and these have generally been associated with negative impacts on fisheries.
2. Trophic and ecosystem-level effects are not usually brought about by fishing alone, but fishing (especially over-fishing but also at or close to BMSY) in multispecies fisheries can make ecosystems less resilient and more sensitive to the effects of environmental variability and change.
3. New Zealand's marine ecosystems are particularly diverse and this provides special challenges in monitoring, understanding and managing fisheries operating in them.
4. There is currently no evidence of a large-scale trophic or ecosystem-level effect impacting New Zealand's deepwater fisheries, but the cause of some changes in New Zealand's marine ecosystem EEZ are not known (e.g. changes to hoki recruitment (Francis et al 2006; Bradford-Grieve & Livingston 2011); trends in some demersal-fish indicators on the Chatham Rise and other areas (Tuck et al 2009).
5. It is likely that the reduction in the abundance of sea urchin predators on some rocky reef systems in north-eastern New Zealand due to fishing has contributed to an ecosystem-level effect in these areas, but this effect is unlikely to be widespread in New Zealand coastal areas (Schiel 2013).
6. Multi-species fishing at close to BMSY using predominantly bottom-trawling is likely to make New Zealand's marine ecosystems less

resilient (compared to fishing more conservatively compared to BMSY and not using predominantly bottom-trawling) to other anthropogenic disturbance and to environmental variability, including climate change, through trophic and ecosystem-level effects.

7. There are potential, but unknown, trophic and ecosystem-level consequences for fisheries management in New Zealand if populations of marine mammals, such as fur seals, rebuild to levels that some people have suggested existed before humans arrived in New Zealand (see Theme 1 of this report).
8. Time series monitoring of fish communities and middle trophic level species (mesozooplankton, mesopelagics, hyperbenthics) are crucial for understanding and monitoring for trophic and ecosystem-level effects, and the best current sources of these data are trawl surveys to the Chatham Rise, and Subantarctic plateau.

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13 HABITATS OF PARTICULAR SIGNIFICANCE FOR FISHERIES MANAGEMENT

Scope of chapter	This chapter highlights subject areas that might contribute to the management of HPSFM and hence provides a guide for future research in the absence of an approved policy definition of HPSFM
Area	All of the New Zealand EEZ and territorial sea (inclusive of the freshwater and estuarine areas).
Locality hotspots	None formally defined, but already identified likely candidates include areas of biogenic habitat, e.g. Separation Point and Wairoa Hard, and areas identified with large catches and/or vulnerable populations of juveniles, e.g. Hoki Management Areas, packhorse crayfish legislated closures and toheroa beaches.
Key issues	Defining and identifying likely HPSFM and potential threats to them.
Emerging issues	Connectivity and intra-population behaviour variability, multiple use
MPI Research (current)	Biogenic habitats as areas of particular significance for fisheries management (HAB2007/01), Toheroa abundance (TOH2007/03), Research on Biogenic Habitat-Forming Biota and their functional role in maintaining Biodiversity in the Inshore Region (5-150M Depths) (ZBD2008/01 – this is also part-funded by Oceans Survey 2020, NIWA and MBIE) , Habitats of particular significance for fisheries management: Kaipara Harbour (ENV2009/07), Habitats of particular significance for inshore finfish fisheries management (ENV2010/03) Spatial Mixing of GMU1 using Otolith Microchemistry (GMU2009/01).
NZ Government Research (current)	Ministry of Business, Innovation and Employment (MBIE) funded programmes (Coastal Conservation Management: protecting the functions of marine coastal habitats that support fish assemblages at local, regional and national scales (C01X0907) Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region (C01X1229) and Impacts of resource use on vulnerable deep-sea communities (C01X0906). NIWA Core funding in the 'Managing marine stressors' area under the 'Coasts and Oceans' centre, specifically the programme 'Managing marine resources' and the project 'Measuring mapping and conserving (C01X0505)'
Links to 2030 objectives	Under the Environment Outcome habitats of special significance to fisheries need to be protected.
Related chapters/issues	Land-based impacts on fisheries and supporting biodiversity, bycatch composition, marine environmental monitoring.

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

13.1 CONTEXT

The Fisheries Act 1996, in Section 9 (Environmental principles) states that:

"All persons exercising or performing functions, duties, or powers under this Act, in relation to the utilisation of fisheries resources or ensuring sustainability, shall take into account the following environmental principles:

a. Associated or dependent species should be maintained above a level that ensures their long-term viability:

b. Biological diversity of the aquatic environment should be maintained:

c. Habitat of particular significance for fisheries management should be protected."

No policy definition of habitat of particular significance for fisheries management (HPSFM) exists, although work is currently underway to generate one. Some guidance in terms of defining HPSFM is provided by Fisheries 2030

which specifies as an objective under the Environment Outcome that *"habitats of special significance to fisheries are protected"*. This wording suggests that a specific focus on habitats that are important for fisheries production should be taken rather than a more general focus that might also include other habitats that may be affected by fishing.

Fisheries 2030 re-emphasises that HPSFM should be protected. No specific strategic actions are proposed to implement this protection in Fisheries 2030; although Action 6.1 "To implement a revised MPA policy and legal framework" could potentially be relevant to protecting HPSFM. The management of activities other than fishing, such as land-use and vehicle traffic, are outside the control of the Ministry for Primary Industries but Fisheries 2030 specifies actions to "Improve fisheries sector input to processes that manage RMA-controlled effects on the marine and freshwater environment" (Action 8.1) and to "Promote the development and use of RMA national policy statements, environmental standards, and regional coastal and freshwater plans" (Action 8.2). This suggests that the cooperation of other parties outside of the fisheries sector may be necessary in some cases to protect HPSFM.

In the absence of a policy definition of HPSFM this chapter will focus on examples of habitats shown to be important for fisheries and concepts likely to be important to HPSFM. Examples of potential HPSFM include: sources of larvae; larval settlement sites; habitat for juveniles; habitat that supports important prey species; migration corridors; and spawning, pupping or egg-laying grounds. Some of these habitats may be important for only part of the life cycle of an organism, or for part of a year.

The relative importance of habitats, compared with other limiting factors, is largely unknown for most stocks. For example, some stocks may be primarily habitat limited, whereas others may be limited by oceanographic variability, food supply, predation rates (especially during juvenile phases), or a mixture of these and other factors. In the case of stocks that are habitat limited, a management goal might be to preserve or improve some aspect of the habitat for the stock.

Hundreds of legislated spatial fisheries restrictions already apply within New Zealand's territorial sea and exclusive economic zone (www.nabis.govt.nz), but until further policy work and research is conducted we cannot be sure of what contribution they make to protecting HPSFM. Examples of these are listed below:

- Separation Point in Tasman Bay, and the Wairoa Hard in Hawke Bay, were created to protect biogenic habitat which was believed to be important as juvenile habitat for a variety of fish species (Grange et al 2003).
- An area near North Cape is currently closed to packhorse lobster fishing to mitigate sub-legal handling disturbance in this area. This closure was established because of the small size of lobsters caught there and a tagging study which showed movement away from this area into nearby fished areas (Booth 1979).
- The largest legislated closures are the Benthic Protection Areas (BPAs) which protect about 1.2 million square km (about 31% of the EEZ) outside the territorial sea from contact of trawl and dredge gear with the bottom (Helson et al 2010).
- Commercial fishers must not use New Zealand fishing vessels or foreign-owned New Zealand fishing vessels over 46 m in overall length for trawling in the territorial sea.

In addition to legislated closures, a number of non-regulatory management measures exist. For example:

- Spatial closures:
  - Trawlers greater than 28 m in length are excluded from targeting hoki in four Hoki Management Areas – Cook Strait, Canterbury Banks, Mernoo Bank, and Puysegur Bank (Deep Water Group 2008). These areas were chosen because of the larger number of juveniles caught, relative to adults in these areas.
  - Trawling and pair trawling are both closed around Kapiti Island.
- Seasonal closures
  - A closure to trawling exists from 1st November until 30th April each year in Tasman Bay.
  - A closure to commercial potting exists for all of CRA 3 for the whole of the month of December each year.

The high-level objectives and actions in Fisheries 2030 have been interpreted in the highly migratory, deepwater

and middle-depths (deepwater) inshore national fish plans. The highly migratory fish plan addresses HPSFM in environment outcome 8.1 "Identify and where appropriate protect habitats of particular significance to highly migratory species, especially within New Zealand waters". In the deepwater fish plan the Ministry proposes in management objective 2.3 "to develop policy guidelines to determine what constitutes HPSFM then apply these policy guidelines to fisheries where necessary". Inshore fisheries management plans (freshwater, shellfish and finfish) all contain references to identifying and managing HPSFM. These plans recognise that not all impacts stem from fisheries activities, therefore managing them may include trying to influence others to better manage their impacts on HPSFM. Work is underway on a policy definition of HPSFM that will assist in implementing these outcomes and objectives.

13.2 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.

13.2.1 HABITATS PROTECTED ELSEWHERE FOR FISHERIES MANAGEMENT

Certain habitats have been identified as important for marine species including: shallow sea grass meadows, wetlands, seaweed beds, rivers, estuaries, rhodolith beds, rocky reefs, crevices, boulders, bryozoans, submarine canyons, seamounts, coral reefs, shell beds and shallow bays or inlets (Kamenos et al 2004; Caddy 2008, Clark 1999, Morato et al 2010a). Discrete habitats (or parts of these) may have extremely important ecological functions, and/or be especially vulnerable to degradation. For example, seabeds with high roughness are important for many fisheries and can be easily damaged by interaction with fishing gear (Caddy 2008). Examples of these include:

1. The *Oculina* coral banks off Florida were protected in 1994 as an experimental reserve in response to their perceived importance for reef fish populations (Rosenberg et al 2000). Later studies confirmed that this area is the only spawning aggregation site for gag (*Mycteroperca microlepis*) and scamp (*M. phenax*) (both groper species), and other economically important reef fish in that region (Koenig et al 2000). The size of the area within which bottom-tending gears were restricted was subsequently increased based on these findings (Rosenberg et al 2000).
2. Lophelia cold-water coral reefs are now protected in at least Norway (Fosså et al 2002), Sweden (Lundälv & Jonsson 2003) and the United Kingdom (European Commission 2003) due to their importance as habitat for many species of fish (Costello et al 2005).
3. The Western Pacific Regional Fishery Management Council identified all escarpments between 40 m and 280 m as Habitat Areas of Particular Concern (HAPC) for species in the bottom-fish assemblage. The water column to a depth of 1000 m above all shallow seamounts and banks was categorised as HAPC for pelagic species. Certain northwest Hawaiian Island banks shallower than 30 m were categorised as HAPC for crustaceans, and certain Hawaiian Island banks shallower than 30 m were classified as Essential Fish Habitat (EFH) for precious corals. Fishing is closely regulated in the precious-coral EFH, and harvest is only allowed with highly selective gear types which limit impacts, such as manned and unmanned submersibles (Western Pacific Fisheries Management Council 1998)

Examples of habitats protected for their freshwater fishery values also exist. For example, the U.S. Atlantic States Interstate fishery management plan (Atlantic States Marine Fisheries Commission 2000) notes the Sargasso Sea is important for spawning, and that seaweed harvesting provides a threat of unknown magnitude to eel spawning. Habitat alteration and destruction are also listed as probably impacting on continental shelves and estuaries/rivers, respectively, but the extent to which these are important is unknown.

It is also possible that HPSFM may be defined by the functional importance of an area to the fishery. For example, large spawning aggregations can happen in mid-water for set periods of time (Schumacher & Kendall 1991,

Livingston 1990) these could also potentially qualify as HPSFM.

13.2.2 CONCEPTS POTENTIALLY IMPORTANT FOR HPSFM

Many nations are now moving towards formalised habitat classifications for their coastal and ocean waters, which may include fish dynamics in the classifcation, and could potentially help to define HPSFM. Such systems help provide formal definitions for management purposes, and to 'rank' habitats in terms of their relative values and vulnerability to threats. Examples include the Essential Fish Habitat (EFH) framework being advanced in North America (Benaka 1999, Diaz et al 2004, Valavanis et al 2008), and in terms of habitat, the developing NOAA Coastal and Marine Ecological Classification Standard for North America (CMECS) (Madden et al 2005, Keefer et al 2008), and the European Marine Life Information Network (MarLIN) framework which has developed habitat classification and sensitivity definitions and rankings (Hiscock & Tyler-Walters 2006).

Habitat connectivity (the movement of species between habitats) operates across a range of spatial scales, and is a rapidly developing area in the understanding of fisheries stocks. These movements link together different habitats into 'habitat chains', which may also include 'habitat bottlenecks', where one or more spatially restricted habitats may act to constrain overall fish production (Werner et al 1984). Human driven degradation or loss of such bottleneck habitats may strongly reduce the overall productivity of populations, and hence ultimately reduce long-term sustainable fisheries yields. The most widely studied of these links is between juvenile nursery habitats and often spatially distant adult population areas. Most studies published have been focussed on species that use estuaries as juveniles; e.g. blue grouper *Achoerodus viridis* (a large wrasse) (Gillanders & Kingsford 1986) and snapper *Pagrus auratus* (Hamer et al 2005) in Australia; and gag (Mycteroperca Microlepis) in the United States (Ross & Moser 1995) which make unidirectional ontogenetic habitat shifts from estuaries and bays out to the open coast as they grow from juveniles to adults. The extent of wetland habitats in the Gulf of Mexico has also been linked to the yield of fishery species dependent on coastal bays and estuaries. Reduced fishery stock production (of shrimp and the fish menhaden) followed wetland losses and, conversely, stock gains followed increases in the area of wetlands (Turner & Boesch 1987). Juvenile production was limited by the amount of available habitat but, equally, reproduction, larval settlement, juvenile or adult survivorship, or other demographic factors could also be limited by habitat loss or degradation, and these could have knock-on effects to stock characteristics such as productivity and its variability. Other examples include movements which may be bidirectional and regular in nature e.g., seasonal migrations of adult fish to and from spawning and/or feeding grounds, e.g. grey mullet *Mugil cephalus* off Taiwan (Chang et al 2004).

How habitats are spatially configured to each other is also important to fish usage and associated fisheries production. For example, Nagelkerken et al (2001) showed that the presence of mangroves in tropical systems significantly increases species richness and abundance of fish assemblages in adjacent seagrass beds. Jelbart et al (2007) sampled Australian temperate seagrass beds close to (within 200 m) and distant from (more than 500 m from) mangroves. They found seagrass beds closer to mangroves had greater fish densities and diversities than more distant beds, especially of juveniles. Conversely, the densities of fish species in seagrass at low tide that were also found in mangroves at high tide were negatively correlated with the distance of the seagrass bed from the mangroves. This shows the important daily habitat connectivity that exists through tidal movements between mangrove and seagrass habitats. Similar dynamics may occur in more sub-tidal coastal systems at larger spatial and temporal scales. For example, Dorenbosch et al (2005) showed that adult densities of coral reef fish, whose juvenile phases were found in mangrove and seagrass nursery habitats, were much reduced or absent on coral reefs located far distant from such nursery habitats, relative to those in closer proximity.

A less studied, but increasingly recognised theme is the existence of intra-population variability in movement and other behavioural traits. Different behavioural phenotypes within a given population have been shown to be very common in land birds, insects, mammals, and other groups. An example of this is a phenomenon known as 'partial migration', where part of the overall population migrates each year, often over very large distances, while another component does not move and remains resident. By definition, this partial migration also results in differential use of habitats, often over large spatial scales. Recent work on white perch (*Morone americana*) in the

United States shows that this population is made up of two behavioural components: a resident natal freshwater contingent; and a dispersive brackish-water contingent (Kerr et al 2010). The divergence appears to be a response to early life history experiences which influence individuals' growth (Kerr 2008). The proportion of the overall population that becomes dispersive for a given year class ranges from 0% in drought years to 96% in high-flow years. Modelling of how differences in growth rates and recruitment strengths of each component contributed to the overall population found that the resident component contributed to long-term population persistence (stability), whereas the dispersive component contributed to population productivity and resilience (defined as rebuilding capacity) (Kerr et al 2010). Another species, winter flounder *Pseudopleuronectes americanus*, has also shown intra-population variability in spawning migrations; one group stays coastally resident while a second smaller group migrates into estuaries to spawn (DeCelles & Cadrin 2010). The authors went on to suggest that coastal waters in the Gulf of Maine should merit consideration in the assignment of Essential Fish Habitat for this species.

Kerr & Secor (2009) and Kerr et al (2010) argue that such phenotypic dynamics are probably very common in marine fish populations but have not yet been effectively researched and quantified. The existence of such dynamics would have important implications for fisheries management, including the possibility of spatial depletions of more resident forms and variability in the use of potential HPSFM between years. For instance, recent work on snapper in the Hauraki Gulf has shown that fish on reef habitats are more resident (ie have less propensity to migrate) than those of soft sediment habitats, and can experience higher fishing removals (Parsons et al 2011).

The most effective means of protecting a HPSFM in terms of the benefit to the fishery may differ depending on the life-history characteristics of the fish. A variety of modelling, theoretical, and observational approaches have led to the conclusion that spatial protection performs best at enhancing species whose adults are relatively sedentary but whose larvae are broadcast widely (Chiappone & Sealey 2000, Murawski et al 2000, Roberts 2000, Warner et al 2000). The sedentary habit of adults allows the stock to accrue the maximum benefit from the protection, whereas the broadcasting of larvae helps 'seed' segments of the population outside the protection. However, the role of spatial protection in directly protecting juveniles after they have settled to seafloor habitats (via habitat protection/recovery, and/or reduced juvenile bycatch), or their interaction with non-fisheries impacts has not yet been explicitly considered.

13.3 STATE OF KNOWLEDGE IN NEW ZEALAND

13.3.1 POTENTIAL HPSFM IN NEW ZEALAND

Important areas for spawning, pupping, and egg-laying are potential HPSFM. These areas (insofar as these are known) have been identified and described using science literature and fisheries databases and summarised within two atlases, one coastal (less than 200 m) and one deepwater (more than 200 m). Coastally, these HPSFM areas were identified for 35 important fish species by Hurst et al (2000b). This report concluded that virtually all coastal areas were important for these functions for one species or another. The report also noted that some coastal species use deeper areas for these functions, either as juveniles, or to spawn (e.g., red cod, giant stargazer) and some coastal areas are important for juveniles of deeper spawning species (e.g., hake and ling). Some species groupings were apparent from this analysis. Elephant fish, rig, and school shark all preferred to pup or lay eggs in shallow water, and very young juveniles of these species were found in shallow coastal areas. Juvenile barracouta, jack mackerel (*Trachurus novaezelandiae*), kahawai, rig, and snapper were all relatively abundant (at least occasionally) in the inner Hauraki Gulf. Important areas for spawning, pupping, and egg-laying were identified for 32 important deepwater fish species (200 to 1500 m depth), 4 pelagic fish species, 45 invertebrate groups, and 5 seaweeds (O'Driscoll et al 2003). This study concluded that all areas to 1500 m deep were important for either spawning or for juveniles of one or more species studied. The relative significance of areas was hard to gauge because of the variability in the data, however the Chatham Rise was identified as a "hotspot".

Areas of high juvenile abundances of certain species may be useful indicators of HPSFM for some species. A third atlas (Hurst et al 2000b) details species distributions (mainly commercial) of adult and immature stages from trawl, midwater trawl and tuna longline where adequate size information was collected. No conclusions are made

in this document, and generalisations across species are inherently difficult, therefore like the previous two atlases, this document is probably best examined for potential HPSFM in a species specific way.

Certain locations within New Zealand already seem likely to qualify as HPSFM under any likely definition. The Kaipara Harbour has been identified as particularly important for the SNA 8 stock. Analysis of otolith chemistry showed that, for the 2003 year-class, a very high proportion of new snapper recruits to the SNA 8 stock were sourced as juveniles from the Kaipara Harbour (Morrison et al 2008). This result is likely to be broadly applicable into the future as the Kaipara provides most of the biogenic habitat available for juvenile snapper on this coast. The Kaipara and Raglan harbours also showed large catches of juvenile rig and the Waitemata, Tamaki and Porirua harbours moderate catches (Francis et al 2012). Recent extensive fish-habitat sampling within the Kaipara harbour in 2010 as part of the MBIE Coastal Conservation Management programme showed juvenile snapper to be strongly associated with sub-tidal seagrass, horse mussels, sponges, and an introduced bryozoan. Negative impacts on such habitats have the potential to have far-field effects in terms of subsequent fisheries yields from coastal locations well distant from the Kaipara Harbour. Beaches that still retain substantive toheroa populations, e.g. Dargaville and Oreti beaches, may also potentially qualify as HPSFM (Beentjes 2010).

Consistent with the international literature, biogenic (living, habitat forming) habitats have been found to be particularly important juvenile habitat for some coastal fish species in New Zealand. For example: bryozoan mounds in Tasman Bay are known nursery grounds for snapper, tarakihi and john dory (Vooren 1975); northern subtidal seagrass meadows fulfil the same role for a range of fish including snapper, trevally, parore, garfish and spotties (Francis et al 2005, Morrison et al 2008, Schwarz et al 2006, Vooren 1975); northern horse mussel beds for snapper and trevally (Morrison et al 2009); and mangrove forests for grey mullet, short-finned eels, and parore (Morrisey et al 2010). Many other types of biogenic habitats exist, and some of their locations are known (e.g. see Davidson et al 2010 for biogenic habitats in the Marlborough Sounds), but their precise role as HPSFM remains to be quantified. Examples include open coast bryozoan fields, rhodoliths, polychaete (worm) species ranging in collective form from low swathes to large high mounds, sea pens and sea whips, sponges, hydroids, gorgonians, and many forms of algae, ranging from low benthic forms such as Caulerpa spp. (sea rimu) through to giant kelp (*Macrocystis pyrifera*) forests in cooler southern waters. Similarly, seamounts are well-known to host reef-like formations of deep-sea stony corals (e.g., Tracey et al 2011), as well as being major spawning or feeding areas for commercial deepwater species such as orange roughy and oreos (e.g., Clark 1999, O'Driscoll & Clark 2005). However, the role of these benthic communities on seamounts in supporting fish stocks is uncertain, as spawning aggregations continue to form even if the coral habitat is removed by trawling (Clark & Dunn 2012). Hence the oceanography or physical characteristics of the seamount and water column may be the key drivers of spawning or early life-history stage development, rather than the biogenic habitat.

Freshwater eels are reliant upon rivers as well as coastal and oceanic environments. GIS modelling estimates that for longfin eels, about 30% of longfin habitat in the North Island and 34% in the South Island is either in a reserve or in rarely/non-fished areas, with about 49% of the national longfin stock estimate of about 12 000 tonnes being contained in these waterways (Graynoth et al 2008). More regional examination of the situation for eels also exists, e.g., for the Waikato Catchment (Allen 2010). Shortfin eels prefer slower-flowing coastal habitats such as lagoons, estuaries, and lower reaches of rims (Beentjes et al 2005). In-stream cover (such as logs and debris) has been identified as important habitat, particularly in terms of influencing the survival of large juvenile eels (Graynoth et al 2008). Short-fin eel juveniles and adults have also been found to be relatively common in estuarine mangrove forests, and their abundance positively correlated with structural complexity (seedlings, saplings, and tree densities) (Morrisey et al 2010). In addition oceanic spawning locations are clearly important for eels, the location of these are unknown, although it has been suggested that these may be northeast of Samoa and east of Tonga for shortfins and longfins respectively (Jellyman 1994).

Many of the potential HPSFM are threatened by either fisheries or land-based effects, the reader should look to the land-based effects chapter in this document and the eel section of the Stock assessment plenary report for further details.

13.3.2 HABITAT CLASSIFICATION AND PREDICTION OF BIOLOGICAL CHARACTERISTICS

Habitat classification schemes focused upon biodiversity protection have been developed in New Zealand at both national and regional scales, these may help identify larger habitats which HPSFM may be selected from, but are unlikely to be useful in isolation for determining HPSFM. The Marine Environment Classification (MEC), the demersal fish MEC and the benthic optimised MEC (BOMEC) are national scale classification schemes that have been developed with the goal of aiding biodiversity protection (Leathwick et al 2004, 2006, 2012). A classification scheme also exists for New Zealand's rivers and streams based on their biodiversity values to support the Department of Conservations Waters of National Importance (WONI) project (Leathwick & Julian 2008). Regional classification schemes also exist such as ones mapping the Marine habitats of Northland, or Canterbury in order to assist in Marine Protected Area planning (Benn 2009; Kerr 2010).

Another tool which may help in terms of identifying HPSFM is the predictions of richness, occurrence and abundance of small fish in New Zealand estuaries (Francis et al 2011). This paper contains richness predictions for 380 estuaries and occurrence predictions for 16 species. This could help minimise the need to undertake expensive field surveys to inform resource management, although environmental sampling may still be needed to drive some models.

13.3.3 CURRENT RESEARCH

Prior to 2007 research within New Zealand was not explicitly focused on identifying HPSFM. However, in line with international trends, this situation has changed in recent times, with recognition of some of the wider aspects of fisheries management and the move towards an ecosystem approach foreshadowed in Fisheries 2030.

A number of Ministry and other research projects were commissioned concerning HPSFM in the 2010/11 year. Project ENV200907, "Habitat of particular significance to fisheries management: Kaipara Harbour", is underway and has the overall objective of identifying and mapping areas and habitats of particular significance in the Kaipara Harbour which support coastal fisheries; and identifying and assessing threats to these habitats. Included in this work is the reconstruction of environmental histories through interviews of long time local residents who have experience of the harbour, and associated collation and integration of historical data sources (e.g., catch records, photographs, diaries, maps, and fishing logs). Another output of this work will be recommendations on the best habitats and methods of monitoring to detect change to HPSFM within Kaipara harbour.

Biogenic habitats on the continental shelf from about 5 to 150 m depths are currently being characterised and mapped through the biodiversity project ZBD2008/01, this will also provide new information on fisheries species utilisation of these habitats. Interviews with 50 retired fishers have provided valuable information on biogenic habitat around New Zealand. A national survey to examine the present occurrences and extents of these biogenic habitats was completed in 2011 in collaboration with Oceans Survey 2020, NIWA and Ministry of Business, Innovation and Employment (MBIE) funding.

A number of other national scale projects are also underway. A desktop review is collating information on the importance of biogenic habitats to fisheries across the entire Territorial Sea and Exclusive Economic Zone (project HAB2007/01). A project has been approved to review the literature and recommend the relative urgency of research on habitats of particular significance for inshore finfish species (project ENV2010/03).

The Ministry of Business, Innovation and Employment (MBIE) funded project Coastal Conservation Management started in 2009 and runs for six years. This programme aims to integrate and add to existing fish-habitat association work to develop a national scale marine fish-habitat classification and predictive model framework. This project will also attempt to develop threat assessments at local, regional and national scales. MPI is maximising the synergies between its planned research and this project. As part of this synergy, work on the connectivity and stock structure of grey mullet (Mugil cephalus) is underway in collaboration with MPI project GMU2009/01. Otolith chemistry is being assessed for its utility in partitioning the GMU 1 stock into more biologically meaningful management units, and in quantifying the suspected existence of source and sink

dynamics between the various estuaries that hold juvenile grey mullet nursery habitats.

In 2012 MBIE also funded the three year project delivered by NIWA entitled "Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region". The development of predictive models of species occurrence under this project may also aid in identifying HPSFM. Identification of biogenic habitat has been part of the MBIE project "Vulnerable deep-sea communities" since 2009 (and its predecessor seamount programme) which includes surveys of a range of habitats that may be important for various life-history stages of commercial fish species: seamounts, canyons, continental slope, hydrothermal vents and seeps.

13.4 INDICATORS AND TRENDS

As no HPSFM are defined this section cannot be completed.

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14 LAND-BASED EFFECTS ON FISHERIES, AQUACULTURE AND SUPPORTING BIODIVERSITY

Scope of chapter	This chapter outlines the main known threats from land-based activities to fisheries, aquaculture and supporting biodiversity. It also describes the present status and trends in land-based impacts.
Area	All of the New Zealand freshwater, EEZ and territorial sea.
Focal localities	Freshwater habitats and areas closest to the coast are likely to be most impacted; this will be exacerbated in areas with low water movement. Anthropogenically increased sediment run-off is particularly high from the Waiapu and Waipaoa river catchments on the east coast of the North Island. Areas of intense urbanisation or agricultural use of catchments are also likely to be impacted by bacteria, viruses, heavy metals or nutrients, or some combination of these.
Key issues	Habitat modification, sedimentation, aquaculture, shellfish, terrestrial land-use change (particularly for urbanisation, forestry or agriculture) water quality and quantity, contamination, consequences to seafood production of increased pollutants, freshwater management and demand.
Emerging issues	Impacts on habitats of particular significance to fisheries management (HPSFM), linkages through rainfall patterns to climate change, shellfish bed closures, habitat remediation, domestic animal diseases in protected marine species, proposed aquaculture expansion, water abstraction impacts.
MPI Research (current)	Research on Biogenic Habitat-Forming Biota and their functional role in maintaining Biodiversity in the Inshore Region, 5–150m depths (ZBD2008/01 – this is also part-funded by Oceans Survey 2020, NIWA and MBIE).
NZ Government Research (current)	NZ Government Research (current) Ministry of Business, Innovation and Employment (MBIE) funded programmes: After the outfall: recovery from eutrophication in degraded New Zealand estuaries (UOCX0902) and "Management of Cumulative Effects of Stressors in Aquatic Ecosystems" (CO1X1005). NIWA core-funded research on this topic occurs in two areas. Firstly, the "Managing marine ecosystems" programme, specifically the projects "Measuring mapping and conserving", "Ecosystem-based management of coasts and estuaries", "Coastal management" (C01X0907) and "Marine Futures" (C01X0227) (Note that the latter two finish 30 September 2014). Secondly, in the "Fisheries" Centre, the EAFM programme deals with ecosytem-based management approaches in conjunction with the "Coasts and Oceans" centre. Some funding within these areas will be aligned to the Sustainable Seas Science Challenge in the near future in which the focus is on ecosystem based management of the marine environment.
Links to 2030 objectives	Objective 8: Improve Fisheries/RMA interface. Objective 4: Support aquaculture development
Related chapters/issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring.

Note: This chapter has not been updated since AEBAR 2014.

14.1 CONTEXT

Land-based activities that may have impacts on seafood production are primarily regulated under the Resource Management Act 1991 (and subsequent amendments). Fisheries are controlled under the Fisheries Act 1996, this includes marine and freshwater responsibilities regarding aquatic life (under Part 2 of the Fisheries Act). Fisheries 2030 is a long-term policy strategy and direction paper of the Ministry for Primary Industries. It was released in 2009

and states that improving the Fisheries/Resource Management Act interface is a priority (objective 8). Strategic actions to achieve this priority are listed as:

> 8.1 Improve fisheries sector input to processes that manage RMA-controlled effects on the marine and freshwater environment.
>
> 8.2 Promote the development and use of RMA national policy statements, environmental standards, and regional coastal and freshwater plans.

The Government's 'Fresh Start for Freshwater Programme[1]' (led by MfE and MPI) aims to create a water management system that allows us to make more transparent and better targeted and informed decisions on fresh water. Businesses and water users will have more certainty so that they can plan and invest. All New Zealanders will have a greater say on the water quality they want for their lakes and rivers. The Coastal Policy Statement (2010) also has relevance to matters of fisheries interest, e.g. Policy 20(1) (paraphrased) controls the use of vehicles on beaches where (b) harm to shellfish beds may result. MPI also works with other agencies, principally DOC, MfE and regional councils and through the Natural Resource Cluster to influence these processes to ensure consideration of land-based impacts upon seafood production. The New Zealand aquaculture industry has an objective of developing into a billion dollar industry by 2025[2]. Government supports well-planned and sustainable aquaculture through its *Aquaculture Strategy and Five-year Plan*. One of the desired outcomes of actions by the New Zealand Government is to enable more space to be made available for aquaculture. This outcome is likely to heighten the potential for conflict between aquaculture proponents and those creating negative land-based effects.

A MPI funded survey of scientific experts (MacDiarmid et al 2012) addressed the vulnerability to a number of threats of marine habitat types within the New Zealand's Territorial Sea and Exclusive Economic Zone (EEZ). Each vulnerability score was based on an assessment of five factors including the spatial scale, frequency and functional impact of the threat in the given habitat as well as the susceptibility of the habitat to the threat and the recovery time of the habitat following disturbance from that threat. The study found that the number of threats and their severity were generally considered to decrease with depth, particularly below 50 m. Reef, sand, and mud habitats in harbours and estuaries and along sheltered and exposed coasts were considered to be the most highly threatened habitats. The study also reported that over half of the twenty-six top threats fully, or in part, stemmed from human activities external to the marine environment itself. The top six threats in order were:

1.	ocean acidification,
2.	rising sea temperatures resulting from global climate change,
3rd equal.	bottom trawling fishing,
3rd equal.	increased sediment loadings from river inputs
5th equal.	change in currents from climate change
5th equal.	increased storminess from climate change

The reader is guided to MacDiarmid et al (2012) for more detail including tables of threats-by-habitat and habitats-by-threat. Climate change and ocean acidification, although they can be considered land-based effects, are covered under the Chapters in this document called "New Zealand Regional climate and oceanic setting" and "Biodiversity".

Land-based effects on seafood production and biodiversity in this context are defined as resulting either from the inputs of contaminants from terrestrial sources or through engineering structures (e.g., breakwaters, causeways, bridges), that change the nature and characteristics of coastal habitats and modify hydrodynamics. The major route for entry of land-based contaminants into the marine environment is associated with freshwater flows (rivers, streams, direct runoff and ground water), although contaminants may enter the marine environment via direct inputs (e.g., landslides) or atmospheric transport processes.

The most important land-based effect in New Zealand is arguably increased sediment deposition around our coasts (Morrison et al 2009; MacDiarmid et al 2012). This deposition has been accelerated due to increased erosion from land-use, which causes gully and channel erosion and

[1] http://www.mfe.govt.nz/issues/water/freshwater/fresh-start-for-fresh-water/
[2] http://aquaculture.org.nz/about-us/strategy/

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 about 1% of the estimated global detrital input to the oceans (Carter et al 1996). By contrast New Zealand represents only about 0.3% of the land area that drains into the oceans (Griffiths & Glasby 1985, Milliman & Syvitski 1992).

Different land use effects act over different scales; for example localised effects act on small streams and adjacent estuarine habitats, large scale effects extend to coastal embayments and shelf ecosystems. Associated risks will vary according to location and depend on the relevant ecosystem services (e.g. high value commercial fishery stocks) and their perceived sensitivities. The risk from stormwater pollutants will be more important near urban areas and the effects of nutrient enrichment will be more important near intensively farmed rural areas.

The risk from land-based impacts for seafood production is that they will limit the productivity of a stock or stocks. For example, the bryozoan beds around Separation Point in Golden Bay, were protected from fishing in 1980, partly because of their perceived role as nursery grounds for a variety of coastal fish species (Grange et al 2003). Recent work has suggested that the main threat to these bryozoans is now sedimentation from the Motueka River, which may inhibit recovery of any damaged bryozoans (Grange et al 2003, Morrison et al 2009). Any declines in this bryozoan bed and associated ecological communities could also affect the productivity of adjacent fishery stocks.

MPI mainly manages in the marine environment, therefore this topic area will be dealt with first. The main freshwater fisheries management MPI is involved in is the freshwater eel fishery; this will be dealt in later sections, as relevant.

14.2 GLOBAL UNDERSTANDING

14.2.1 LAND-BASED INFLUENCES

It has been acknowledged for some time now that land-based activities can have important effects on seafood production. The main threats to the quality and use of the world's oceans are (GESAMP 2001):

- alteration and destruction of habitats and ecosystems;
- effects of sewage on human health;
- widespread and increased eutrophication;
- decline of fish stocks and other renewable resources; and
- changes in sediment flows due to hydrological changes.

Coastal development is projected to impact 91% of all inhabited coasts by 2050 and will contribute to more than 80% of all marine pollution (Nellemann et al 2008). The importance of different land-based influences differ regionally but the South Pacific Regional Environmental Programme (SPREP, which includes New Zealand) defines waste management and pollution control as one of its four strategic priorities for 2011–2015 (SPREP 2010).

Influences, including land-based influences, seldom work in isolation; for example the development of farming and fishing over the last hundred years has meant that increased sediment and nutrient runoff has to some degree occurred simultaneously with increased fishing pressure. However, the impact of these influences has often been studied in isolation. In a review on coastal eutrophication, Cloern (2001) stated that *"Our view of the problem [eutrophication] is narrow because it continues to focus on one signal of change in the coastal zone, as though nutrient enrichment operates as an independent stressor; it does not reflect a broad ecosystem-scale view that considers nutrient enrichment in the context of all the other stressors that cause change in coastal ecosystems"*. These influences (in isolation or combination) can also cause indirect effects, such as decreasing species diversity which then lessens resistance to invasion by non-indigenous species or species with different life-history strategies (Balata et al 2007, Kneitel & Perrault 2006, Piola & Johnston 2008). Studies that research a realistic mix of influences are rare, but valuable.

Sediment deposition can be an important influence, particularly in areas of high rainfall, tectonic uplift, and forest clearances, or areas where these activities coincide. Sediments are known to erode from the land at an increased rate in response to human use, for example, estimates from a largely deforested tropical highland suggest erosion rates 10–100 times faster than pre-clearance rates (Hewawasam et al 2003). Increased sediment either deposited on the seafloor or suspended in

the water column can negatively impact upon invertebrates in a number of ways including: burial, scour, inhibiting settlement, decreasing filter-feeding efficiency and decreasing light penetration, generally leading to less diverse communities, with a decrease in suspension feeders (Thrush et al 2004). These impacts can affect the structure, composition and dynamics of benthic communities (Airoldi 2003, Thrush et al 2004). Effects of this increased sediment movement and deposition on finfish are mostly known from freshwater fish and can range from behavioural (such as decreased feeding rates) to sublethal (e.g., gill tissue disruption) and lethal as well as having effects on habitat important to fishes (Morrison et al 2009). These effects differ by species and life-stage and are dependant upon factors that include the duration, frequency and magnitude of exposure, temperature, and other environmental variables (Servizi & Martens 1992).

Increased nutrient addition to the aquatic environment can initially increase production, but with increasing nutrients there is an increasing likelihood of harmful algal blooms and cascades of effects damaging to most communities above the level of the plankton (Kennish 2002; Heisler et al 2008). This excess of nutrients is termed eutrophication. Eutrophication can stimulate phytoplankton growth which can decrease the light availability and subsequently lead to losses in benthic production from seagrass, microalgae or macroalgae and their associated animal communities. Algal blooms then die and their decay depletes oxygen and blankets the seafloor. The lack of oxygen in the bed and water column can lead to losses of finfish and benthic communities. These effects are likely to be location specific and are influenced by a number of factors including: water transparency, distribution of vascular plants and biomass of macroalgae, sediment biogeochemistry and nutrient cycling, nutrient ratios and their regulation of phytoplankton community composition, frequency of toxic/harmful algal blooms, habitat quality for metazoans, reproduction/growth/survival of pelagic and benthic invertebrates, and subtle changes such as shifts in the seasonality of ecosystems (Cloern 2001). The effects of eutrophication abound in the literature, for example, the formation of dead (or anoxic) zones is exacerbated by eutrophication, although oceanographic conditions also play a key role (Diaz & Rosenberg 2008). Dead zones have now been reported from more than 400 systems, affecting a total area of more than 245 000 square kilometres (Diaz & Rosenberg 2008). This includes anoxic events from New Zealand in coastal north-eastern New Zealand and Stewart Island (Taylor et al 1985, Morrissey 2000).

Other pollutants such as heavy metals and organic chemicals can have severe effects, but are more localised in extent than sediment or nutrient pollution (Castro and Huber 2003, Kennish 2002). Fortunately the concentration of these pollutants in most New Zealand aquatic environments is relatively low, with a few known exceptions. Examples of this include naturally elevated levels of arsenic in Northland[3], cadmium levels in Foveaux Strait oysters (Frew et al 1996) and levels of nickel and chromium within the Motueka river plume in Tasman Bay (Forrest et al 2007). The high cadmium levels have caused market access issues for Foveaux Strait oysters. Some anthropogenically generated pollutants such as copper, lead, zinc and PCBs are high in localised hotspots within urban watersheds. In the Auckland region these hotspots tend to be in muddy estuarine sites and tidal creeks that receive runoff from older urban catchments[4]. There is a lack of knowledge on the impacts of these pollutants upon fisheries.

Climate change is likely to interact with the effect of land-based impacts as the main delivery of land-based influences is through rainfall and subsequent freshwater flows. Global climate change projections include changes in the amount and regional distribution of rainfall over New Zealand (IPCC 2007). More regional predictions include increasing frequency of heavy rainfall events over New Zealand (Whetton et al 1996). This is likely to exacerbate the impact of some land-based influences as delivery peaks at times of high rainfall, e.g. sediment delivery (Morrison et al 2009).

Physical alterations of the coast are generally, but not exclusively (e.g. wetland reclamation for agriculture), concentrated around urban areas and can have a number of consequences on the marine environment (Bulleri & Chapman 2010). Changes in diversity, habitat fragmentation or loss and increased invasion susceptibility

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

[4] 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

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.

An area of emerging interest internationally is infectious diseases from land-based animals affecting marine populations. Perhaps the most well-known example of this is the canine distemper outbreak in Caspian seals that caused a mass mortality in the Caspian sea in 2000 (Kennedy et al 2000).

14.2.2 HABITAT RESTORATION

Habitat restoration or rehabilitation has been the subject of much recent research. Habitat restoration or rehabilitation rarely, if ever, replaces what was lost and is most applicable in estuarine or enclosed coastal areas as opposed to exposed coastal or open ocean habitats (Elliott et al 2007). Connectivity of populations is a key consideration when evaluating the effectiveness of any marine restoration or rehabilitation (Lipcius et al 2008). In the marine area, seagrass replanting methodologies are being developed to ensure the best survival success (Bell et al 2008) and artificial reefs can improve fisheries catches, although whether artificial reefs boost population numbers or merely attract fish is unclear (Seaman 2007). In addition, the incorporation of habitat elements in engineering structures, e.g., artificial rockpools in seawalls, shows promise in terms of ameliorating the impacts of physical alterations (Bulleri 2006). Spatial approaches to managing land-use impacts, such as marine reserves, will be covered under the section about HPSFM.

Freshwater rehabilitation has been reviewed by Roni et al (2008). Habitat reconnection, floodplain rehabilitation and instream habitat improvement are all suggested for improving habitat and local fish abundances. Riparian rehabilitation, sediment reduction, dam removal, and restoration of natural flood regimes have shown promise for restoring natural processes that create and maintain habitats, but there is a lack of long-term studies to gauge their success. Wild eel fisheries in America and Europe have declined over time (Allen et al 2006, Atlantic States Marine Fisheries Commission 2000, Haro et al 2000). Declines in wild eel fisheries have been linked to a number of factors including: barriers to migration; hydro turbine mortality; and habitat loss or alteration. Information to quantitatively assess these linkages is however often lacking (Haro et al 2000).

14.3 STATE OF KNOWLEDGE IN NEW ZEALAND

Land-based effects will be most pronounced closest to the land, therefore freshwater, estuarine, coastal, middle depths and deepwater fisheries, will be affected in decreasing order. The scale of land-use effects will, however, differ depending upon the particular influence. The most localised are likely to be direct physical impacts; for example, the replacement of natural shorelines with seawalls; although even direct physical impacts can have larger scale impacts, such as affecting sediment transport and hence beach erosion, or contributing to cumulative effects upon ecosystem responses. Point-source discharges are likely to have a variable scale of influence, and this influence is likely to increase where a number of point-sources discharge, particularly when this occurs into an embayed, low-current environment. An example of this is Waitemata harbour in Auckland where there are multiple stormwater discharges (Hayward et al 2006). The influences on the largest scale can be from diffuse-source discharges such as nutrients or sediment (Kennish 2002). For example, the influence of diffuse-source materials from the Motueka river catchment in Golden Bay on subtidal sediments and assemblages and shellfish quality can extend up to tens of kilometres offshore (Tuckey et al 2006; Forrest et al 2007), with even a moderate storm event extending a plume greater than 6 km offshore (Cornelisen et al 2011). Terrestrial influences on New Zealand's marine environment can, at times, be detected by satellites from differences in ocean colour and turbidity extending many kilometres offshore from river mouths (Gibbs et al 2006).

All coastal areas are unlikely to suffer from land-based impacts in the same way. The quantities of pollutants or structures differ spatially. Stormwater pollutants, seawalls and jetties are more likely to be concentrated around urban areas. Nutrient inputs are likely to be concentrated either around sewage outlets or associated with areas of intensive agriculture or horticulture. Sediment production has been mapped around the country and is greatest around the west coast of the South Island and the East coast of the North Island (Griffiths & Glasby 1985, Hicks & Shankar 2003, Hicks et al 2011). Notably the catchments

where improved land management may result in the biggest changes to sediment delivery to coastal environments are likely to be the Waiapu and Waipaoa river catchments on the East coast of the North Island. In addition to this, the sensitivity of receiving environments is also likely to differ; this will be covered in subsequent sections.

A MPI funded project (IPA2007/07) reviewed the impacts of land based influences on coastal biodiversity and fisheries (Morrison et al 2009). This review used a number of lines of evidence to conclude that in this context, sedimentation is probably New Zealand's most important pollutant. The negative impacts of sediment include decreasing efficiency of filter-feeding shellfish (such as cockles, pipi, and scallops), reduced settlement success and survival of larval and juvenile phases (e.g., paua, kina), and reductions in the foraging abilities of finfish (e.g., juvenile snapper). Indirect effects include the modification or loss of important nursery habitats, particularly biogenic habitats (green-lipped and horse mussel beds, seagrass meadows, bryozoan and tubeworm mounds, sponge gardens, kelps/seaweeds, and a range of other structurally complex species). Inshore filter-feeding bivalves and biogenic habitats were identified as the most likely to be adversely affected by sedimentation. Eutrophication was also identified as a potential threat from experience overseas. This review identified knowledge gaps and made suggestions for more relevant research on these influences:

- identification of fisheries species/habitat associations for different life stages, including consideration of how changing habitat landscapes may change fisheries production;
- better knowledge of connectivity between habitats and ecosystems at large spatial scales;
- the role of river plumes;
- the effects of land-based influences both directly on fished species, and indirectly through impacts on nursery habitats;
- a better spatially-based understanding, mapping and synthesis of the integrated impacts of land-based and marine-based influences on coastal marine ecosystems.

The locations where addressing land-based impacts is likely to result in a lowering in risk to seafood production or increased seafood production, excluding those already mentioned, are undefined.

A national scale threat analysis has been completed for biogenic habitats, given their likely importance for fisheries management as nursery areas (Morrison et al 2014b). The sparse data available (often anecdotal accounts), shows that strong declines in biogenic habitats have occurred, which appear largely attributable to land-based effects (e.g., sedimentation and elevated nutrient levels), and fishing impacts. Examples include the extensive loss of seagrass meadows (e.g. large areas in Whangarei, Waitemata, Manukau, Tauranga and Avon-Heathcote estuaries), green-lipped mussel beds (about 500 km2 in the Hauraki Gulf), bryozoan beds (about 80 km2 in Torrent Bay, about 800 km2 in Foveaux Strait), and deep-water coral thickets on sea-mounts. Cumulatively, the magnitude and extent of biogenic habitat losses are likely to have been very substantial, but are unknown, and probably will never be able to be calculated. Other biogenic habitat species for which evidence points to historical losses include horse mussels, kelp forests, oyster beds, and sponges, both in assemblages where they tend to dominate, and as part of mixed biogenic habitat assemblages. A better understanding of the threats to these biogenic habitats is recommended.

The Kaipara Harbour has been identified as a system which supports important fisheries functions both for the harbour proper, and for the wider west coast North Island ecosystem (Morrison et al 2014a). This report detailed fish-habitat associations in the harbour and concluded that increased sedimentation, and to a lesser extent the possibility of eutrophication, was probably the greatest threat to these fisheries.

The threat of sedimentation has prompted much concern and action by land managers and local communities (Morrison et al 2014a). For example, in the Kaipara Harbour the southern subtidal seagrass meadows area is especially important as a juvenile nursery for snapper and trevally and based on its high value as a juvenile fish nursery habitat, the Auckland Council has listed this area as an Ecologically Significant Area (ESA) in its draft unitary plan. There are significant collaborative CRI / Northland Regional Council / Auckland Council sediment erosion and transport research programmes currently under way in Kaipara Harbour catchment and the harbour itself. There are also local initiatives around tree planting and the

improvement of riparian and other forms of land management. The fish/fisheries habitat work described here engages and collaborates with the IKHMG and Kaipara Research Advisory Group (KRAG), and this type of collaboration/interaction between fisheries habitat research, other scientific research programmes, and management agencies is one promising way for these issues to be addressed.

Another study investigated correlations between environmental variables and flounder abundance for the Manukau and Mahurangi Harbours (McKenzie et al 2013). Consistent correlations were obtained for a variety of environmental variables for juvenile sand and yellowbelly flounder (YBF) in the Manukau, but not in Mahurangi Harbour. The influence of environmental variables on adult YBF catch in the Manukau Harbour was even more evident. These correlations suggested that decreasing oxygen and increasing ammonia and turbidity may have negatively affected yellowbelly flounder recruitment success. When these results were considered alongside the declining trends in flatfish abundance in the FLA 1 fishery, estuarine water quality may be a significant factor affecting the sustainability of the flatfish fishery.

Marine restoration studies published in New Zealand have focused on the New Zealand cockle Austrovenus stutchburyi. The first of these studies identified a tagging methodology to aid relocation of transplanted individuals (Stewart & Creese 2002). Subsequent studies stressed the use of adults in restoration and the importance of site selection, either from theoretical or modelling viewpoints (Lundquist et al 2009, Marsden & Adkins 2009). Detailed restoration methodology has been investigated in Whangarei Harbour and recommends replanting adults at densities between 222 and 832 m-2 (Cummings et al 2007).

Multiple influences in areas relevant to seafood production in New Zealand have been addressed by three studies. A field experiment near Auckland showed greater effects on infaunal colonisation of intertidal estuarine sediments when three heavy metals (copper, lead and zinc) were in combination compared to each in isolation (Fukunaga et al 2010). A survey approach looking at the interaction of sediment grain size, organic content and heavy metal contamination upon densities of 46 macrofaunal taxa across the Auckland region also showed a predominance of multiplicative effects (Thrush et al 2008). However influences can work in unexpected directions; as in a study on large suspension feeding bivalves off estuary mouths where the anticipated negative impacts from sediment were not observed and these species benefited from food resources generated from the estuaries (Savage et al 2012).

Toheroa populations are currently closed to all but customary harvesting but have failed to recover to former population levels even though periodic (and sometimes substantial) pulses in young recruits have been detected in both Northland and Southland (Beentjes 2010, Morrison & Parkinson 2008). Current thinking suggests that a mix of influences are probably responsible for these declines including over-harvesting, land-use changes leading to changes in freshwater seeps on the beaches, and vehicle traffic (Morrison et al 2009, Williams at al 2013). A number of discrete pieces of research have been completed in this area. A review of the wider impact of vehicles on beaches and sandy dunes has been completed, and suggested that more research was needed on the impacts of vehicle traffic on the intertidal (Stephenson 1999). A four day study over a fishing contest on Ninety Mile Beach showed the potential of traffic to produce immediate mortalities of juvenile toheroa, but the temporal importance of this could not be gauged (Hooker & Redfearn 1998). Mortalities of toheroa from the Burt Munro Classic motorcycle race on Oreti beach have been quantified and recommendations made for how to minimise these, but again the importance of vehicle traffic for toheroa survival over longer time periods was unclear (Moller et al 2009). Notably, similar negative impacts from driving were observed on juvenile tuatua (Paphies donacina) on a Pegasus Bay beach (Marsden & Taylor 2010). The impact of a range of influences upon toheroa at Ninety Mile Beach has been investigated by Williams et al. (2013). The main factors identified that potentially affect toheroa abundance were food availability, climate and weather, sand smothering/sediment instability, toxic algal blooms, predation, harvesting, vehicle impacts, and land use change. To investigate the causal mechanisms operating, a combination of monitoring, experimental, and modelling studies may be necessary.

Rhodolith beds have been surveyed in the Bay of Islands and high diversity was reported even in areas of abundant fine sediments (Nelson et al 2012). It is unclear if the increasing sedimentation occurring in the Te Rawhiti Reach is negatively impacting rhodoliths and whether this

atypical rhodolith bed (i.e., with abundant fine sediments) is at risk if current sedimentation and mobilisation rates continue.

The protozoan *Toxoplasma gondii* has been identified as the cause of death for 7 of 28 Hector's and Maui's dolphins examined since 2007 (W. Roe, Massey University, unpubl. data, 31 July 2012). Land-based runoff containing cat faeces is believed to be the means by which *Toxoplasma gondii* enters the marine environment (Hill & Dubey 2002). A Hector's dolphin has also tested positive for Brucella abortus (or a similar organism) a pathogen of terrestrial mammals that can cause late pregnancy abortion, and has been seen in a range of cetacean species elsewhere [5]. This resulted in the Department of Conservations suggested research priorities in the "Review of the Maui's dolphin Threat management plan: Consultation paper" including objectives to determine the presence, pathways and possible mitigation of the threat from *Toxoplasmosis gondii*[6]. The recently established Maui dolphin Research Advisory Group[7] confirmed risk factors to Maui dolphin from *Toxoplasma gondii* as a priority area for future research.

The effects of large-scale habitat loss and modification on eels in New Zealand are clearly significant, but difficult to quantify (Beentjes et al 2005). Significant non-fisheries mortality of New Zealand freshwater longfin and shortfin eels are caused by mechanical clearance of drainage channels, and damage by hydro-electric turbines and flood control pumping. Eels prefer habitat that offers cover and in modified drains aquatic weed provides both daytime cover and nighttime foraging areas. Loss of weed and natural debris can thus result in significant displacement of eels to other areas. In addition, wetlands drainage has resulted in greatly reduced available habitat for eels, particularly shortfins which prefer slower-flowing coastal habitats such as lagoons, estuaries, and lower reaches of rims. Water abstraction is one of a number of information requirements identified in Beentjes et al (2005). to better define the effects on eel populations.

A number of Integrated Catchment Management (ICM) projects are underway in New Zealand. These take a holistic view to land management incorporating aquatic effects; this approach could help restore water quality of both fresh and coastal waters. An overview of these projects is given in a Ministry for the Environment Report on integrated catchment management (Environmental Communications Limited 2010). Many of these projects employ restoration techniques such as riparian planting, but few assessments of the effectiveness of riparian planting exist. One assessment of the effect of nine riparian zone planting schemes in the North Island on water quality, physical and ecological indicators concluded that riparian planting could improve stream quality; in particular rapid improvements were seen in terms of visual clarity and channel stability (Parkyn et al 2003). Nutrient and faecal contamination results were more variable. Improvement in macroinvertebrate communities did not occur in most streams and the three factors needed for these were canopy closure (which decreased stream temperature), long lengths of riparian planting and protection of headwater tributaries. A modelling study also demonstrated the long time lag needed to grow large trees which then provide wood debris to structure channels which achieves the best stream rehabilitation results (Davies-Colley et al 2009). Although some of these studies extend into the marine realm (at least in terms of monitoring) it is difficult to gauge the impact of these activities upon fisheries or aquaculture, particularly on wider scales because ICM studies have been localised at small scales.

14.3.1 CURRENT RESEARCH

A MPI biodiversity project also has components that address land-based effects; the threats to biogenic habitats are addressed in project ZBD2008/01 (for more detail see the Marine Biodiversity chapter).

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

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

[7] http://www.doc.govt.nz/conservation/native-animals/marine-mammals/dolphins/mauis-dolphin/docs-work/maui-dolphin-research-advisory-group/

A Ministry of Business, Innovation and Employment (MBIE) funded project[8] of particular relevance is "Nitrogen reduction and benthic recovery" (UOCX0902, University of Canterbury). This research aims to determine the trajectories and thresholds of coastal ecosystem recovery following removal of excessive nutrient loading (called "eutrophication") and earthquake impacts. This will be achieved by monitoring the effects of diverting all of Christchurch's treated wastewater discharge from the eutrophied Avon-Heathcote (Ihutai) Estuary and the subsequent earthquake induced disturbances to this diversion.

14.4 INDICATORS AND TRENDS

A national view of the impacts of land-based influences upon seafood production does not exist; this could be facilitated by better coordination and planning of the many disparate marine monitoring programmes operating around the country. Monitoring of marine water quality and associated communities is carried out through a variety of organisations, including universities, regional councils and aquaculture or shellfisheries operations. Regional council monitoring of water quality and associated biological communities is often reported through web sites such as the Auckland Regional Council environmental monitoring data which is available on the internet[9], or summary reports such as the Hauraki Gulf state of the Environment 2011 report[10]. Water quality and associated marine communities may also be monitored for a regional council as part of a consent application or as a stipulation for a particular marine development. However the data from aquaculture and shellfisheries water quality monitoring is not generally available.

Improved coordination and planning of marine monitoring has been achieved in some countries, e.g., the United Kingdom[11]. The Marine Environmental Monitoring Programme (ZBD2010-42), is a step towards this goal, more information is available on this project in the Biodiversity chapter of this document. This project identifies remote sensing of sea surface particulate matter in nearshore waters as a possible indicator of changes in sediment inputs in the future, but this requires algorithm validation for New Zealand waters. Possible national scale proxies for coastal faecal contamination may exist after collating information from sanitation area monitoring for shellfish harvesting and/or coastal bathing beaches[12].

High faecal coliform counts (primarily from mammal or bird faeces) can impact upon the value gained from shellfish fisheries and aquaculture. Area closures to commercial harvesting usually depend on an area's rainfall/runoff relationship and areas closer to significant farming areas or urban concentrations are likely to be closed more frequently, due to high faecal coliform counts, than areas where the catchment is unfarmed or not heavily populated. For example, Inner Pelorus sound is likely to be closed more frequently than outer Pelorus Sound (Marlborough Sounds) F For coastal areas of the Marlborough Sounds, the Coromandel Peninsula and Northland closures can range from a few days to over 50 percent of the time in a given year[13]. Certain fisheries may be limited by the amount of time where water quality is sufficient to allow harvesting, e.g. the cockle fishery in COC 1A (Snake bank in Whangarei harbour) was closed for 101, 96, 167, 86, 117 and 118 days for the 2006–07, 2007–08, 2008–09, 2009–10, 2010–11 and 2011–12 fishing years respectively, due to high faecal coliform counts from sewage spills or runoff[14]. Models also now exist that allow real-time prediction of E. coli pulses associated with storm events, e.g. Wilkinson et al (2011),

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

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

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

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

[12] http://www.mfe.govt.nz/environmental-reporting/fresh-water/suitability-for-swimming-indicator/index

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

[14] Statistics supplied by New Zealand Food Safety Authority in Whangarei. Notably the fishery has not been operating since November 2012.

which may help harvesters to better cope with water quality issues.

The Ministry for the Environment (MfE) also reports on freshwater quality. River water quality indicators that have been assessed have direct relevance to the eel, and other freshwater fisheries, and this water will flow through estuaries and enter the marine environment. The National River Water Quality Network (NRWQN) has national coverage, and has been running for over 20 years and has recently reported upon the following eight variables: temperature, dissolved oxygen, visual clarity, dissolved reactive and total phosphorous, and ammoniacal, oxidised and total nitrogen (Ballantine & Davies-Colley 2009). Dissolved oxygen showed few meaningful trends and the ammoniacal nitrogen data suffered from a processing artefact. An upward, although not significant trend in temperature and an improvement of water clarity were seen at the national scale. However, a negative correlation was seen between water clarity and percent of catchment in pasture, which suggests that any expansion of pasture lands may have impacts on clarity. Strong increasing trends over time were seen in oxidised nitrogen, total nitrogen, total phosphorous and dissolved reactive phosphorous. These latter trends all signify deteriorating water quality and are mainly attributable to increased diffuse-source pollution from the expansion and intensification of pastoral agriculture.

Total nitrogen and phosphorous loads to the coast in New Zealand have been modelled and were estimated at 167 300 and 63 100 t yr-1, respectively (Elliot et al 2005)[15]. The main sources of nitrogen and phosphorous were from pastoralism (70%) and erosion (53%), respectively. Dairying contributes 37% of the nitrogen load from only 6.8% of the land. The total amount of land used for dairy farms increased by 47% (1.4 to 2.0 million hectares) from 1986 to 2002 [16]. These statistics provide strong circumstantial evidence that the expansion in dairying is primarily responsible for the observed declines in water quality from agricultural sources.

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

[16] http://www3.stats.govt.nz/environment/Fertiliser_use_and_the_environment_Aug06.pdf

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15 ECOLOGICAL EFFECTS OF MARINE AQUACULTURE

Scope of chapter	The known effects of current impacts from aquaculture operations in New Zealand.
Area	All of the New Zealand EEZ and territorial sea, although presently aquaculture operations are located coastally.
Focal localities	Northland, Coromandel, Auckland, Marlborough Sounds, Tasman and Golden Bays, Canterbury, Southland.
Key issues	Uncertainty in predictions, cumulative effects, levels of nitrogen loading in coastal areas that will cause adverse effects
Emerging issues	Marine spatial planning, Integration of monitoring datasets.
MPI Research (current)	ENV2012-01 Nitrogen levels and adverse marine ecological effects Aquaculture Planning Fund 12/03 Marine Management Model (Waikato Regional Council) 12/04 Guidance for aquaculture monitoring in the Waikato region 13/01 Marlborough Sounds Hydrodynamic & Ecological Modelling 13/02 Aquaculture Zoning in the Southland Region
NZ Research (current)	C01X0904 NIWA Sustainable Aquaculture
Links to 2030 objectives	Objective 4 Support aquaculture development Objective 6: Manage impacts of fishing and aquaculture
Related issues	Land-based effects, marine biodiversity, habitats of particular significance for fisheries management

Note: This chapter has not been updated since AEBAR 2013.

15.1 CONTEXT

Aquaculture is the world's fastest growing primary industry and in 2011 supplied 41.2 percent of the supply of seafood globally, including 12.5 percent from marine aquaculture in the same year (FAO 2012). Fish convert a greater proportion of the food they eat into body mass than livestock and therefore the environmental demands per unit biomass or protein produced are lower (Hall et al 2011). The production of 1 kilogram of finfish protein requires less than 14 kilograms of grain compared to 62 kilograms of grain for beef protein and 38 kilograms for pork protein. However, although farmed fish may convert food more efficiently than livestock there are important issues globally with respect to farming carnivorous fish species, which places demands on the use of capture fisheries for animal feeds.

In 2011 the Oceania region (which includes New Zealand and Australia) produced only 0.3 percent of the world's aquaculture production (183 516 t); globally nearly 60 million tonnes were produced (FAO 2012). The average annual value of New Zealand aquaculture exports from 2008 to 2012 has been dominated by green-lipped mussels ($197 million), Salmon ($61 million) and Pacific oysters ($16 million) (Aquaculture New Zealand 2012). As of December 2011, aquaculture activities in New Zealand take place within approximately 19 268 ha of allocated water space (Aquaculture New Zealand 2012). This space can be categorised as below (Aquaculture New Zealand 2012):

- 7743 ha is granted to the aquaculture industry with the right to farm for a defined term, and is in known productive growing areas;
- 8960 ha is in open-ocean sites where productivity is yet to be proven;
- 1195 ha is in near shore sites yet to be developed;
- 1370 ha is undeveloped space in interim Aquaculture Management Areas (AMAs).

In New Zealand, the majority of aquaculture activities are located in the coastal marine environment, and the main current aquaculture locations are shown in Figure 15.1.

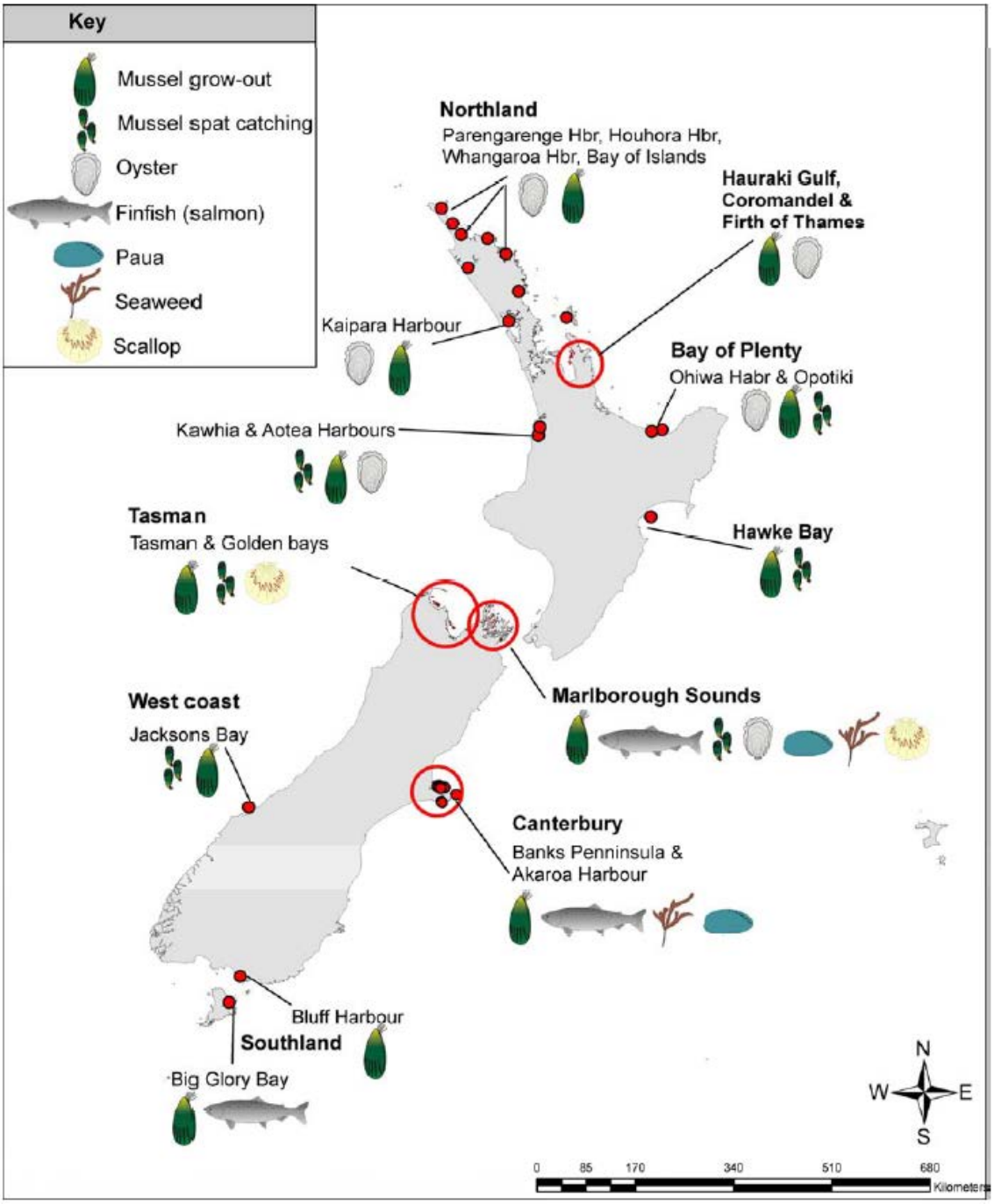

Figure 15.1: Geographic locations of main marine farming areas in New Zealand (Keeley et al 2009).

The New Zealand aquaculture industry has a current estimated value in excess of $400 million and an objective of developing into a billion dollar industry by 2025 (Aquaculture New Zealand 2012). This ambition has been supported by the New Zealand Government through the establishment of the Aquaculture Unit (now within the Ministry for Primary Industries (MPI)), the release of Government's Aquaculture Strategy and 5-Year Action Plan to support aquaculture, the 2011 aquaculture legislation reforms, and ongoing reforms of the Resource Management Act (RMA). One of the desired outcomes of these actions was to improve the consenting process to enable more space to be made available for aquaculture. To this end a number of Aquaculture Planning Fund projects have been initiated to address factors limiting aquaculture growth regionally. It is however recognised that aquaculture development, along with all other activities controlled by the RMA, needs to be ecologically sustainable.

Sustainable development of aquaculture in New Zealand needs to be supported by good quality information on

ecological effects to enable appropriate decision making. The aquaculture unit of MPI therefore funded a collaborative project between NIWA and the Cawthron Institute to review the ecological effects of aquaculture (PRM2010-36). This chapter largely summarises the findings of that larger document (MPI 2013) which should be referred to for further details, references or clarification.

15.2 GLOBAL UNDERSTANDING

It is known that the environmental effects of aquaculture vary by country, region, production system and species (Hall et al 2011). Ninety-one percent of the world's aquaculture production comes from Asia and only 0.3 percent from Oceania (Hall et al 2011); therefore global reports on the environmental impacts of aquaculture tend to focus on Asia. The relevant (as judged by the authors of MPI (2013)) references to New Zealand from overseas literature will hence be included in the following Section (15.3).

15.3 STATE OF KNOWLEDGE IN NEW ZEALAND

A 2009 survey of experts assessed the relative importance of 62 threats on 65 of New Zealand's marine habitats (MacDiarmid et al 2012). Threat scores were categorised as extreme if the score was 3 or more, major if the score was 2–2.9, moderate if the score was 1–1.9, minor if the score was 0.5–1.0, and trivial if the score was less than 0.5. For example, the three top threats identified across all habitats were ocean acidification, increased sea temperatures from climate change and bottom trawling which scored mean impacts across all habitats of 2.6 (major), 1.6 (moderate) and 1.5 (moderate) respectively. The study considered three threats posed by aquaculture activities: benthic accumulation of debris (shells, faeces, food material), a decrease in the availability of primary production downstream of the marine farm (particularly mussel farms) and an increase in habitat complexity that may be detrimental to some species. The benthic accumulation of shells, food and faeces from aquaculture ranked 19th equal with a score of 0.7 (minor). The two other aquaculture threats were ranked 36th equal with a score of only 0.4 (trivial). Notably this is an average score across all habitats, however the highest scores attained for any of these aquaculture threats in particular habitats were 2.6 and 2.3 for the benthic accumulation of debris (shells, faeces, food material) in muddy sediment on sheltered coasts (2–9 m) and seagrass meadows in harbours and estuaries, respectively. The benthic accumulation of debris was the fourth most highly scoring threat in sheltered muddy coasts (2–9 m deep) and the third most highly scoring threat in seagrass meadows in harbours and estuaries.

The actual and potential effects of filter feeding and feed added culture are shown diagrammatically in Figure 15.2 and Figure 15.3.

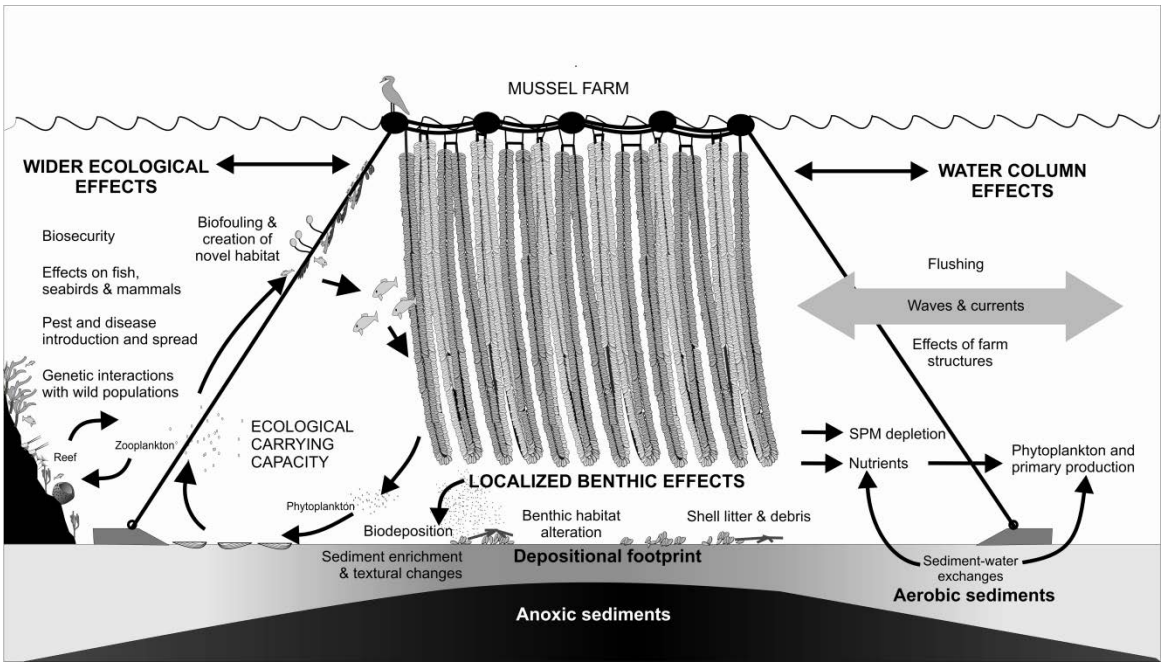

Figure 15.2: Schematic of actual and potential ecological effects from mussel farming (Keeley et al 2009).

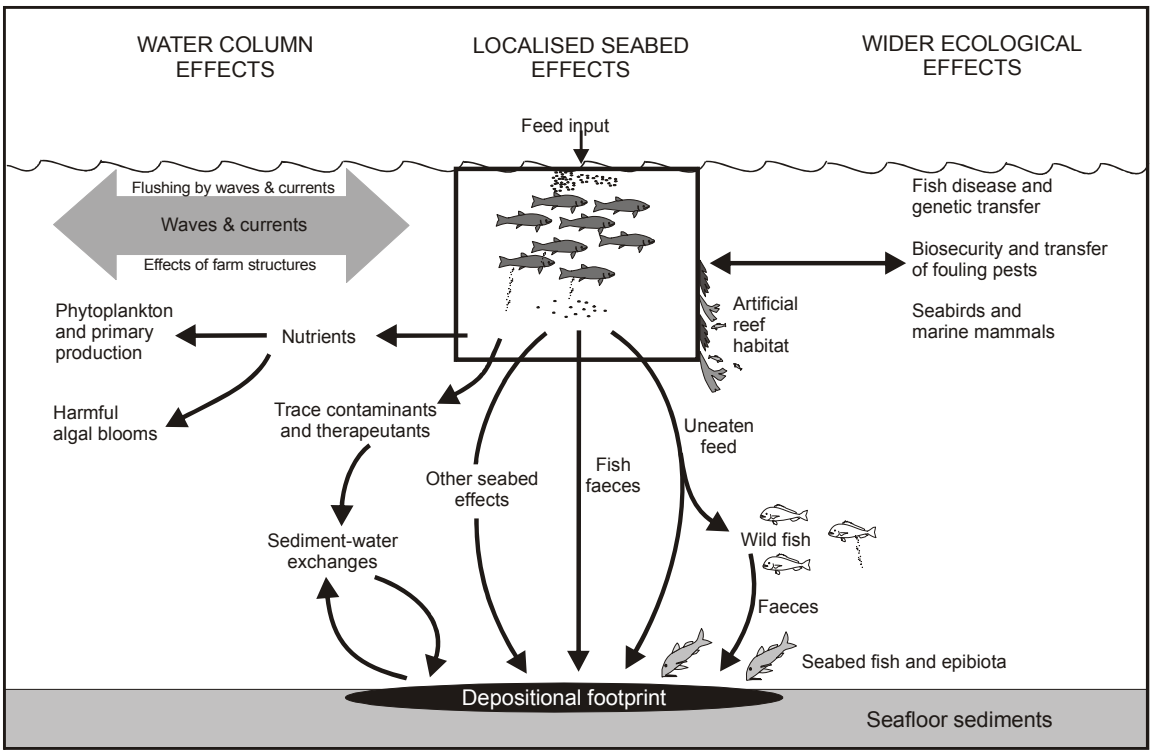

Figure 15.3: Schematic of actual and potential ecological effects from feed-added farming (Forrest et al 2007c).

An expert panel approach was also used to trial a method for prioritising the ecological threats from aquaculture (Stoklosa et al 2012). This process brought together 17 knowledgeable participants from across a range of interested parties (central and local government, aquaculture industry and scientists), to attempt to gain consensus on the relative importance of a range of ecological threats from aquaculture. The results of this process are only indicative but for both feed-added and filter-feeding species the same three issues were identified as most important; these were (in decreasing order of importance): biosecurity threats, pelagic effects and marine mammal interactions (Table 15.1). Notably the score for the threat from biosecurity was more than 50% greater than the next highest score and the threat of pelagic effects was rated as markedly higher for feed-added species than it was for filter-feeders. Other potential ecological threats considered were of lesser importance and are listed bullet pointed below the top three, along with an explanatory sentence about what was considered under each term (in no particular order). Interactions between threats and large scale effects were not covered within this prioritisation exercise.

1. Biosecurity threats – how aquaculture may influence risks associated with pests and diseases.
2. Pelagic effects - aquaculture effects on the water column (excluding those explicitly dealt with by other chapters in the MPI 2013 literature review) at approximately the scale of the farm.
3. Marine mammal interactions - aquaculture effects on marine mammals.

- Benthic effects - aquaculture effects on the seafloor.
- Seabird interactions - aquaculture effects on birds.
- Effects from additives - The effect of chemicals used in aquaculture upon the environment.
- Escapee effects - the effects of escaped farmed species upon the environment.
- Wild fish interactions - aquaculture effects on non-farmed fish populations.
- Hydrodynamic alteration of flows - aquaculture effects on the water movement at scales greater than the farm scale.

Table 15.1: Trial prioritisation of potential classes of aquaculture effects from Stoklosa et al (2012). Results of pair-wise comparisons using the Analytical Hierarchy Process (Saaty 1987) from the phase two workshop of the Aquaculture Ecological Guidance Project. RIW = relative importance weight. Order is decreasing in importance for the feed-added species[1].

	Feed-added species		Filter-feeder species	
Potential ecological effects	RIW	Rank	RIW	Rank
Biosecurity threats	0.360	1	0.373	1
Pelagic effects	0.236	2	0.143	2
Marine mammal interactions	0.118	3	0.135	3
Benthic effects	0.090	4	0.088	5
Seabird interactions	0.079	5	0.092	4
Additive effects	0.042	6	0.019	9
Escapee effects	0.029	7	0.088	5
Wild fish interactions	0.026	8	0.021	8
Hydrodynamic alteration of flows	0.019	9	0.041	7

These topic areas will be discussed further under each of their headings below (in the order above). In addition, note that stressors do not act in isolation, and any aquaculture impacts will occur within the context of (and potentially interacting with) other anthropogenic stressors and natural ongoing natural processes (see Figure 13.4 for an example of this). The interacting and cumulative effects of aquaculture will be discussed in Section 15.3.10 of this chapter.

15.3.1 BIOSECURITY THREATS

Aquaculture biosecurity has recently been covered by the reviews of Forrest et al (2011) for finfish and Keeley et al (2009) for other species, and then compiled and summarised in MPI (2013), this section draws heavily from those sources, and the reader is referred to them for more detail.

15.3.1.1 INTRODUCTION

The Ministry of Agriculture and Forestry (MAF) Biosecurity Strategy defines biosecurity as "the exclusion, eradication or effective management of risks posed by pests and diseases" (Biosecurity Council 2003). Biosecurity risk organisms include animals, plants and micro-organisms capable of causing diseases (e.g., the ostreid herpes virus in Pacific oysters) or otherwise adversely affecting New Zealand's natural, traditional or economic values (e.g. the sea squirt *Styela clava*, and the red seaweed *Grataloupia turuturu*). In an aquaculture context, biosecurity also encompasses the protection of hatchery or culture operations from parasites, microscopic pathogens[2] or biotoxin-producing microalgae. These organisms may include indigenous species already present in the environment that become enhanced as a result of culture operations (Forrest et al 2011).

The primary source of entry for biosecurity risk organisms into New Zealand is through international shipping (Cranfield et al 1998, Kospartov et al 2010). However, aquaculture production systems may increase biosecurity risk, through acting as reservoirs or exacerbators (Okamura & Feist 2011, Peeler & Taylor 2011). Reservoirs host risk-organisms that can then spread by either natural or human-mediated mechanisms. Exacerbators create incubators/stepping stones for otherwise benign or low impact pests, pathogens or parasites (both native and exotic species).

Considerable effort is placed on preventing incursions of pests, parasites and diseases into the New Zealand environment. This is because the introduction, proliferation and spread of risk species in New Zealand can have effects on marine and freshwater environments that are often difficult to manage, resulting in permanent and irreversible impacts (Forrest et al 2011). The few successful efforts to eradicate aquatic invasive species (AIS) have several common elements (Locke et al 2009b) which are unlikely to occur in combination:

[1] Notably there was a chapter in MPI (2013) on the potential effects from genetic manipulation and polyploidy. However, genetic manipulation is controlled by the Environmental Protection Authority (EPA) and is not authorised for use in aquaculture. Polyploidy was also considered by the risk assessment workshop participants to be relatively rare in aquaculture and therefore this topic area was not considered by the prioritisation.

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

- early detection and correct identification of the invader,
- pre-existing authority to take action,
- the ability to sequester the AIS to prevent dispersal, (or else the AIS had very limited dispersal capabilities),
- political and public support for eradication,
- acceptance of some collateral environmental damage,
- follow-up monitoring to verify the completeness of the eradication.

Environmental factors including depth, wave climate, temperature regime, and currents that influence dispersal of waste, disease agents, and pests play a significant role in determining the potential biosecurity risk for a given site.

The hydrodynamics (water movement patterns which are dependent on depth, wave climate and currents) at a site play an important role on several levels. Hydrodynamics can influence the mineralisation of wastes and nutrient release through oxygen supply to the sediment and also dispersion of pathogens and pests and parasites in the water column (Zeldis et al 2011b). For example, individual farms within any one Aquaculture Management Area (AMA) in Nelson Bays could function as a source of infection to other AMAs in Golden Bay (Zeldis et al 2011b) via the transfer of viral or bacterial pathogens. Dispersion potential (within farms, between farms or between blocks of farms), which is largely controlled by hydrodynamics, will also be influenced by temperature, as temperature can regulate metabolic growth and the proliferation of bacteria/viruses etc. that are shed as free-living single-celled organisms (Zeldis et al 2011b).

Temperature and salinity can also affect the associated biosecurity risks associated with individual species by controlling their range. For example in the case of the proliferation of invasive Pacific oysters, the southern distribution is limited to Nelson/Marlborough, as water temperatures further south are too low for successful reproduction (Quale 1969, Askew 1972, Dinamani 1974). Salinity can vary with season, climatic variation (Scavia et al 2002), and the catchment rainfall, with catchments that are dry in summer producing less runoff, elevating coastal salinities which then affect the distribution of fouling species (Handley unpub. data). Farm stocks that may be susceptible to biosecurity risks are usually at greatest risk in summer. Summer is when temperatures, and hence metabolic rates of farmed animals, are highest, dissolved oxygen levels in the water are lowest (hence the risk of oxygen deprivation is highest), and the proliferation of fouling populations is also greatest (Handley, unpub. data.).

Over the last decade aquaculture space allocation in New Zealand has predominantly been driven by constraint mapping, allocating space in areas that do not conflict with other users and stakeholders (e.g. Handley & Jeffs 2002). This strategy increases potential biosecurity risks by encouraging development of aquaculture at environmentally less favourable sites The use of ecosystem based approaches to aquaculture development that incorporate tools like GIS can incorporate biosecurity risks (if known) to optimise site selection even in cases of data poor environments (Aguilar-Manjarrez et al 2010, Soto et al 2008, Silva et al 2011).

15.3.1.2 SIGNIFICANCE OF EFFECTS

It is generally recognised that adverse ecological effects arising from pests, parasites and pathogenic species associated with aquaculture can result in a range of level of threat including (Molnar et al 2008):

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

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

1. act as a reservoir for subsequent spread to natural ecosystems,
2. increase drag on cages and anchoring systems in high current areas, which in turn increases the chance of escapee effects if stocks are infected with pathogens or parasites (Forrest et al 2011)

3. significantly reduce the flow of water (in areas of lower current velocity), carrying vital food and oxygen to cultured species.

Examples of significant effects from pest fouling organisms on aquaculture activities in New Zealand include documented impacts from infestation of marine farms with *Undaria* and the colonial tunicate *Didemnum vexillum* (e.g. Forrest & Taylor 2002 and L. Fletcher, Cawthron, unpubl. data). As well as attached fouling organisms, aquaculture structures may also act as recruitment substrata for mobile pelagic or benthic species (e.g. jellyfish, ctenophores, sea star *Asterias amurensis*, sea cucumbers, or the crab *Carcinus maenas*, Forrest et al 2009, 2011).

Any attempt to assess the significance of potential effects of invasive pests, pathogens or parasites in terms of their magnitude will be limited by the lack of robust information on the affected environments, inherent difficulties in making reliable predictions regarding the invasiveness of difference species, and hence inferences regarding their direct or indirect effects (Forrest et al 2011). An example of the ecological effects stemming from a pathogen is the outbreak of pilchard herpes virus that was thought to have stemmed from pilchards imported for tuna aquaculture feed in South Australia. This event caused starvation and the recruitment failure of little penguins which prey on pilchards (Dann et al 2000). The potential effects of pests and pathogens are illustrated in Table 15.3 for finfish aquaculture in the Waikato region.

Table 15.2: Matrix illustrating the often unknown effects of pests, pathogens and parasites associated with finfish aquaculture in the Waikato Region. Examples are given of direct interactions (shaded cells) between potential biosecurity hazards and values in the Waikato region, and indirect effects (I). Direct interactions designated as: likely to be new and important (***), may be an important incremental risk above that already occurring (**), and probably a minor incremental risk (*). ? = direct interaction possible but significance unknown. From Forrest et al (2011).

Potentially affected uses and values	Component directly affected	Marine pests			Pathogens or parasites		
		Fouling	Predation	HABS	Virus	Monogeanean	Digenean
Ecological							
Habitats and their biodiversity	Unstructured soft-sediment habitats	*	**	?			
	Structured soft-sediment habitats (physical or biogenic)	**	**	?			
	Zostera meadows	*		?			
	Saltmarsh			?			
	Rocky reef	**	**	?			
	Water column (plankton communities)			?			
Wildlife of conservation importance	Wading and seabirds	I	I	I	?+I		?
	Marine mammals	I	I	I	?+I		?
Wild fishery resources and fishing							
Finfish populations of commercial, recreational or customary importance	Conspecific finfish populations (kingfish or hapuku)			?	?	*	*
	Pelagic finfish populations (e.g. snapper, kahawai)			?	?	*	*
	Benthic finfish (e.g. flatfish) or reef-fish populations	I	I	?	?	*	*
Shellfish populations of commercial, recreational or customary importance	Infaunal soft-sediment shellfish (e.g. cockles, tuatua)	*	?	?	?		?
	Epibenthic soft-sediment shellfish (e.g. scallops)	**	?	?	?		?
	Reef-associated non-finfish species (e.g. paua, crayfish)	**	?	?	?		?
Harvesting of fish/shellfish (interference)	Pelagic finfish populations (e.g. snapper, kahawai)						
	Benthic finfish (e.g. flatfish) or reef-fish populations	*	*				
	Infaunal soft-sediment shellfish (e.g. cockles, tuatua)		*				
	Epibenthic soft-sediment shellfish (e.g. scallops)	**	*				
	Reef-associated non-finfish species (e.g. paua, crayfish)	*	*				
Harvesting of fish/shellfish (contamination)	Finfish or shellfish harvestability for human consumption			?	?	?	?

15.3.1.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Biosecurity control of aquaculture activities currently occurs through: resource consent conditions, farm practices and import health standards. The resource consenting process under the Resource Management Act (RMA) considers biosecurity via factors such as farm spacing, zoning[3], staged development and epidemiological units. Best farm practices are often described by industry codes of practice (NZMIC 2001, NZOIA 2007, NZSFA 2007). Import health standards are controlled by the Ministry for Primary Industries (MPI) and include requirements that must be met in the exporting country, during transit and on arrival. For example, existing standards cover:

- import of juvenile yellowtail kingfish (*Seriola lalandi*) from Australia,
- import of fish food and fish bait from all countries.

Possible prevention approaches that could be considered are summarised here as pathway management or on-farm management Forrest et al (2011).

Pathway management should focus on controls and surveillance on pathways from:

i. international source regions or pathways that are novel,
ii. pathways from domestic source regions known to be infected by recognised high-risk pests,
iii. pathways along which the frequency of transfers is considerably greater than that occurring as a result of other human activities.

Broadly there are two approaches to management of pathway risk (Forrest & Blakemore 2002), either a) avoid transfers on high risk pathways, or b) treat pathways to minimise risk. Both pathway management strategies have been used, for example, in relation to the New Zealand mussel industry (Forrest et al 2011). Surveillance strategies for pathways can focus on entry surveillance, routine surveillance or targeted surveillance of high risk areas. Entry surveillance includes activities such as routine screening at airports, ports and mail centres. MPI also commissions routine surveillance in ports and harbours around New Zealand. Targeted surveillance may be undertaken when activities such as harvest, grading or transfer of stock from hatcheries or between sites is undertaken.

Good on-farm management is often guided by industry codes of practice (NZMIC 2001, NZOIA 2007, NZSFA 2007). These should include farm cleaning and surveillance (MPI 2013). Farm cleaning guidelines should deal with factors such as frequency and waste disposal. Routine surveillance, undertaken on and around marine farms is often the first point of detection of pests, pathogens and diseases.

Recent New Zealand experience suggests that even when pest organisms become well-established, the benefits gained from even limited management success have the potential to greatly outweigh the consequences of uncontrolled fouling (Forrest 2007). To be effective, however, management requires buy-in from all marine stakeholders whose activities can spread pest organisms. Aquaculture companies can assist by:

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

For vectors of spread such as service vessels and farm equipment, preventative management options include:

i. maintenance of effective antifouling coatings,
ii. hull inspections and hull cleaning as necessary,
iii. early eradication of pests from farm structures before they become well established.

[3] The World Organisation for Animal Health's (OIE) online aquatic animal health code (http://www.oie.int/en/international-standard-setting/aquatic-code/access-online/) suggests establishing zones and using compartmentalization (through geographical separation) to manage biosecurity and epidemiological risks.

However, once incursions have occurred, the use of eradication treatments is only advised if the risk of re-invasion can be managed. Many eradication treatments have been used in an attempt to control fouling and pests either directly (Carver et al 2003, Coutts & Forrest 2005, Locke et al 2009a, Morrisey et al 2009), indirectly (Handley & Jeffs 2002, Handley 2002, Handley & Bergquist 1997) or via biological control agents (NRC 2010, Hidu et al 1981, Enright et al 1983, 1993, Cigarria et al 1998).

Perhaps the best method for controlling the spread of disease is through the use of management practices that call for the pathological inspection of animals to ensure that infected animals are not moved into areas that do not currently have endemic infections (WWF 2010). In New Zealand, in the absence of enforced stock transfer protocols, management of gear and vessel transfers between geographic zones by voluntary codes of practice developed by industry could be used to minimize risks, e.g., the New Zealand Mussel Industry Council Ltd. code of practice for transfer of mussel seed (NZMIC 2001).

The different prospective farmed groups: feed-added (referred to as finfish), filter-feeders (referred to as shellfish), and lower trophic level species (Undaria and sea cucumbers) and their potential impacts and management measures were covered in the literature review (MPI 2013) and are summarised in Table 15.3.

Table 15.3: Matrix of biosecurity management options and their relevance to key aquaculture groups (MPI 2013).

Management measure	Description	Finfish	Shellfish	Undaria	Sea cucumbers
Harvest					
Isolate waste streams from growing areas	Prevent reintroduction of pests/pathogens to harvested sites	y	y	y	y
Fallow Sites	Reduce opportunities for reintroduction of pests/pathogens from intermediate hosts	y	y	y	y
Education					
Codes of practice	Educate and alert staff to biosecurity requirements	y	y	y	y
Public notification	Alert public to biosecurity risks	y	y	y	y
Eradication					
Culling	Cull diseased stock to remove pathogen/ pest	y	y	y	y
Fallowing	Remove stock from an area to allow host mediated pathogen to die out	y	y	y	y
Manual removal of macroscopic organisms	Eradication of individual pest organisms early in the invasion process	y	y	y	y
Treatment technologies	Treatment of whole farms or bays to remove pests	y	y	y	y
Pharmaceutical treatment	Treatment of individual affected stocks to remove pathogen/parasite	y	n	n	n

Table 15.3: Continued ... Matrix of biosecutriy management options and their relevance to key aquaculture groups (MPI 2013).

Management measure	Description	Finfish	Shellfish	Undaria	Sea cucumbers
Import					
Import health standards	For import of seedstock	y	n	n	n
Boarder Surveillance	Prevent import of macroscopic pests	y	y	y	y
Regulations on fouling on vessels/bilge water release	Prevent import of macroscopic pests/ fouling organisms/ harmful algae	y	y	y	y
Planning and development					
Site selection	Sites with appropriate environment for biological requirements of stock	y	y	y	y
Zoning	Sites location in relation to pathogen risks – other farms, processing plants, rivers, sewerage discharge	y	y	y	y
Vessel berthing	Segregate local vessels from vessels that move regionally (commercial or recreational)	y	y	y	y
Targeted surveillance	Routine monitoring for pre-determined range of species	y	y	y	y
Farm practices					
Fouling					
Management of nets, and equipment to minimise fouling	Regularly remove fouling organisms from equipment	y	y	n	n
Anti-fouling	Treat equipment with chemicals to prevent fouling	y	?	n	n
Transfer of equipment between sites/ regions	Prevent transfer of potentially contaminated equipment between sites				
Husbandry					
Appropriate stock husbandry	Minimise stress = reduce risk of disease becoming established	y	y	y	y
Management of feed so as not to attract birds/fish	Limit opportunity for transfer between sites/wild stocks through direct contact	y	n	n	n
Routine environmental monitoring linked to husbandry activities	Manage stock within environmental limits	y	y	y	y
Remove mortalities	Limit opportunity for reservoir of disease to accumulate	y	n	n	n
	Reduce attraction of predators	y	n	n	n
Use of processed feeds	Feeds heat treated to kill pests/pathogens	y	n	n	y
Surveillance	Observe and record mortality causes, unusual fouling etc.	y	y	y	y
Stock transfer		y	y	y	y
Hatchery testing for disease	Prevent diseased stock being sent to sites	y	y	y	y
Single year-class sites	Prevent disease transmission between year classes	y	n	y	y

15.3.2 PELAGIC EFFECTS

There is a large volume of international literature on the effects of shellfish and salmon farming on the pelagic environment and much of this material is referenced in three local reviews: finfish (Forrest et al 2007a), shellfish (Keeley et al 2009) and oysters (Forrest et al 2007b) and summarised in MPI (2013), the reader is referred to these for more detail.

15.3.2.1 INTRODUCTION

This section deals with near-field (approximately at the scale of the farm) pelagic effects (those seen in the water column). This should be read in conjunction with the benthic effects (where wastes from the pelagic zone settle) and the cumulative effects sections (where far-field pelagic effects are seen).

The pelagic zone is the zone where:

- Filter-feeders extract phytoplankton, microzooplankton and organic particulates from

the water column, which can reduce food available to other consumers (Zeldis et al 2004).

- Dissolved oxygen (DO) is extracted by respiration of farmed organisms and this can potentially lead to DO depletion when cages are heavily stocked or where they are located in shallow sites with weak flushing (La Rosa et al 2002). Excessive DO depletion in the water column could potentially stress or kill the fish and other animals, with sediment DO depletion resulting in the release of toxic by-products (e.g. hydrogen sulphide) into the water, which can also have adverse effects on fish and other organisms (Forrest et al 2007a).
- Fish pellets and the excretory products and waste products of cultured and fouling organisms are received. Wastes excreted can either be as a particulate "cloud" that disperses rapidly, in the case of fin-fish, or be bound in long strands composed of digested and undigested plankton, in the case of filter-feeders (Reid 2007). The difference in shellfish and finfish faeces can result in different biochemical impacts on the pelagic zone (Reid 2007). Dissolved farm waste has the potential to increase ambient DIN (Dissolved Inorganic Nitrogen), the potential effects of this are usually experienced away from the farm so will be dealt with in the cumulative effects section.

15.3.2.2 SIGNIFICANCE OF EFFECTS

The significance of these key primary impacts depends on the assimilation capacity (or carrying capacity) of the environment. Local hydrodynamics, water depth and ambient oxygen levels are the most critical criteria for determining the pelagic impacts of aquaculture (Zeldis 2008a, Zeldis et al 2010, 2011a). In shallow areas with slow currents, effects will be more pronounced compared to a deep site with strong flow and good flushing. In the New Zealand situation where most shellfish farms are located in well flushed areas, nutrient enrichment beyond the farm boundaries is presently difficult to detect (Zeldis 2008a). In addition there are a number of design and management factors that will greatly influence potential impacts:

- Density of farms in a unit volume of water; more farms will generally have more effect.
- Stocking density; higher stocking densities will generally have more effect, this may differ seasonally.
- Feed conversion ratio (FCR for feed-added species): FCR is a measure of the efficiency of growth relative to feed used, the global range is 1.1 to 1.7 on average (Reid 2007). The lower the FCR the less waste will be produced.
- Cage designs and orientation to prevailing current direction. This will impact on drag on passing water masses, flushing of cages and settlement of biofouling organisms.

Undaria and sea cucumbers have less significant ecological effects on the pelagic environment since seaweeds utilise dissolved nutrients for growth (mainly dissolved inorganic nutrients (DIN)) and sea cucumbers feed on organic material on the surface of the seabed (MPI 2013). The reader is guided to the document MPI (2013) for coverage of the specific threats created via farming *Undaria* and sea cucumbers.

15.3.2.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Pelagic effects can be partially controlled through carefully selecting sites, deep sites (more than 25 m) with high currents are preferable. The farm design, orientation and stocking rates should then be appropriate to that site. Good farm management (e.g. compliance with The New Zealand Finfish Aquaculture Environmental Code of Practice (2007)[4]) should include reducing biofouling on nets by regular cleaning and removal of biofouling waste. Monitoring, adaptive management and the use of Integrated Multi Trophic aquaculture (IMTA) are also potential mitigation measures (see the cumulative effects section for more discussion of these). Notably pelagic effects are reversible upon removal of the farm.

Models are an important component in determining pelagic effects at a site and a number of potential model improvements are identified in MPI (2013), including improved methods for determining ecological carrying capacity.

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

15.3.3 MARINE MAMMALS

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

15.3.3.1 INTRODUCTION

Several overseas studies (Würsig & Gailey 2002, Kemper et al 2003, Wright 2008) have characterised the possible interactions between marine mammals and aquaculture, which include:

- competition for space (habitat modification or exclusion),
- potential for entanglement,
- underwater noise disturbance,
- attraction to artificial lighting,
- possible flow-on effects due to alterations in trophic pathways.

The physical location of the farm within important habitats or migration routes of New Zealand marine mammal species is the main factor that leads to potentially adverse interactions or avoidance issues. Once a farm is within the habitat or migration route of a species, the types of gear and equipment employed, as well as operational procedures around regular farm activities, influence the probability and scale of the impacts discussed above.

15.3.3.2 SIGNIFICANCE OF EFFECTS

Incidences of marine mammal entanglement with aquaculture operations are very few in New Zealand despite over 25 years of sea-cage salmon farming, due in part to the relatively small scale of this industry and operational procedures that minimise entanglement risk at New Zealand farms (Forrest et al 2007c). Studies in New Zealand have so far only addressed interactions between mussel farms with Hector's (Slooten et al 2001) and dusky dolphins (Markowitz et al 2004, Vaughn & Würsig 2006, Duprey 2007, Pearson et al 2007). Collectively, these works suggest that while some marine mammal species are not completely displaced from regions as a whole, they do not appear to be utilising habitats occupied by shellfish farms in the same manner as prior to the farms' establishment.

These effects may need to be reconsidered in relation to any larger scale and offshore developments in New Zealand waters (MPI 2013). For instance, as multiple farms or several types of aquaculture begin to overlap or enlarge in their locations, marine mammal populations may be excluded from particular bays or regions depending on the species and its sensitivity to such activities. In the case of depleted populations (e.g., southern right whales), the issues of low population size and a fairly isolated population structure make these species more vulnerable to such impacts than other species. This large variation in the significance of aquaculture impacts (depending on the size of the affected populations) on New Zealand marine mammals makes developing and implementing one set of effective management guidelines or standards extremely difficult.

15.3.3.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Farm locations need to be carefully selected to minimise the likelihood of overlap with marine mammal migration routes and/or known habitats. In Admiralty Bay, where overlap with dusky dolphins was a concern, and distribution patterns were not well known, three years worth of presence monitoring was required prior to commencement of aquaculture development (Mulcahy & Peart 2012). The risks associated with physical interactions can be further minimised by adopting maintenance and operational guidelines and standards for farm structures as well as any noise-generating equipment (BCSGA 2001, SAD 2011). Some examples include enclosing predator nets at the bottom, keeping nets taut, using mesh sizes of less than 6 centimetres (Kemper et al 2003), keeping nets well maintained (e.g., repairing holes), and reducing feed waste. In Admiralty Bay surface lines were removed from the water over winter to minimise interactions when dolphins are more active foragers (Mulcahy & Peart 2012).

Unfortunately, detailed information on abundance, distribution and critical habitats is available for only a handful of New Zealand's marine mammals. Monitoring records of the presence (and absence) of marine mammal species in the vicinity or general region of the farm site along with any detailed observations of their time spent under or around the farm structure should be compiled when possible. Future research needs to focus on those species most likely to come in contact with aquaculture in the future. In addition, ongoing research into the types of design and maintenance features and operational procedures that minimise entanglement risk should be

supported. For example, cage technology in South Australia has developed and improved to the point where predators are excluded by the cage structures themselves (Taylor et al 2010).

15.3.4 BENTHIC EFFECTS

This area is covered by the review of Forrest et al (2007c) and summarised in MPI (2013), the reader is referred there for more detail.

15.3.4.1 INTRODUCTION

The benthic effects of aquaculture can be classified as:

- Organic enrichment and smothering which can lead to (Forrest et al 2007c):
  - localised biodeposition leading to enrichment of the seabed and associated microbial processes, and chemical and biological changes (including to infauna and epifauna, e.g. Christensen et al 2003, Keeley et al 2009);
  - in the case of intensive filter-feeder cultivation widespread biodeposition can potentially lead to a reduction in natural deposition rates;
  - smothering of benthic organisms and changes in sediment physical composition;
  - widespread biodeposition leading to mild enrichment in naturally depositional areas which has the potential for effects on reefs, inshore habitats and sensitive taxa;
  - sediment contamination (copper and zinc, covered in the additives section).
- Biofouling and drop-off of debris which can lead to:
  - smothering and changes to physical composition of sediments (Keeley et al 2009);
  - creation of habitat structure (Davidson & Brown 1999) and aggregations of predators and scavengers (Inglis & Gust 2003).
- Seabed shading by structures which can change localised productivity under the farm (Huxham et al 2006).

The magnitude and spatial extent of seabed effects from finfish farms are a function of a number of inter-related factors, which can be broadly considered as farm attributes and physical environment attributes.

Farm attributes that can affect the mass load of organic material deposited to the seabed include the following:

- fish stocking density and settling velocities of fish faeces (Magill et al 2006);
- the type of feed and feeding systems, the feeding efficiency of the fish stock and the settling velocities of waste feed pellets;
- the type of cage structure can also influence depositional effects through differences in fish holding capacity, which affects feed loadings and may affect feeding efficiencies. Furthermore, cage design and position may affect the site's hydrodynamics; any reductions in flow will reduce waste dispersal and flushing, potentially resulting in depositional effects that are more localised but also more pronounced.

The capacity of the environment to disperse and assimilate farm wastes is a function of the attributes of the site (primarily water depth and current speeds), although assimilative capacity may also vary seasonally in relation to factors such as water temperature. Consequently, sites located in deep water (more than 30 m) and exposed to strong water currents (more than 15 cm s-1 on average) will have more widely dispersed depositional footprints with less intense enrichment than shallow, less well-flushed sites (e.g. Molina Dominguez et al 2001, Pearson & Black 2001, Aguado-Gimenez & Garcia-Garcia 2004).

15.3.4.2 SIGNIFICANCE OF EFFECTS

In general, benthic effects from feed-added and filter-feeder aquaculture are similar as they are caused by debris and waste falling to the seafloor generally in close proximity to the farm. However the higher volume of waste and the uneaten food involved in feed-added farming and its more particulate nature generally means that effects from feed-added aquaculture are greater than those seen from filter-feeder aquaculture, and can be seen further away (within 1 km for feed-added species as opposed to within 100 m for filter-feeders (Forrest et al 2007c)). In extreme cases this can lead to anoxia and outgassing of hydrogen sulphide and methane. At low flow sites very little resuspension occurs and effects are largely constrained to the local environment (Forrest et al 2007). At high flow sites, however, the majority of the biodeposits are resuspended, exported and eventually deposited in a very diffuse form in neighbouring low flow

areas (e.g. in blind bays). If depositional inputs are sufficiently elevated then there is potential for effects in the form of increased far-field deposition. This may result in very mild, but potentially spatially extensive organic enrichment. The ecological effects of farming Undaria and sea cucumbers are likely to be less severe on the benthos then those from feed-added or filter-feeding species (Keeley et al 2009).

Fish farm and mussel farm studies in New Zealand and overseas indicate timescales of recovery ranging from a few months in well-flushed areas where effects are minor, to a few years in poorly flushed areas where moderate/strong enrichment has occurred (references within MPI 2013).

15.3.4.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Management measures for mitigating benthic impacts for aquaculture are similar to those for mitigating pelagic impacts (Section 15.3.2.3). Site selection is important for the same reasons, to maximise the dispersive properties of the site, but should also try to avoid potentially sensitive/valuable benthic habitats (conservation areas, reefs etc.). The fine scale positioning of the cages should optimise the dispersal of wastes and minimise impacts on potentially sensitive habitats. Depositional modelling should be used to predict benthic effects from a range of farming scenarios to inform decisions regarding optimum (sustainable) site-specific feed capacities. The use of Environmental Quality standards (EQS), staged development and a Modelling-Ongrowing-Monitoring (MOM) approach are also potentially beneficial (MPI 2013).

15.3.5 SEABIRD INTERACTIONS

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

15.3.5.1 INTRODUCTION

In New Zealand, the generally perceived negative effects of both feed-added aquaculture and filter feeder aquaculture have centred on entanglement (resulting in birds drowning) and habitat exclusion and displacement from feeding grounds. The location of the farm within the range of seabirds and the conservation status (which is a measure of the risk of extinction) of these seabird species are the main factors that may lead to issues of sustainability and conservation concern. Of particular concern are the location of farms in relation to breeding and feeding sites and the operational procedures of regular farm activities (which can affect things like likelihood of entanglement).

Potential negative effects may include disturbance of breeding colonies and birds feeding, blockage of the digestive tract following ingestion of foreign objects, injury or death following collision with farm structures and the spread of pathogens or pest species. In contrast, a potential beneficial effect includes the provision of roost sites closer to foraging areas (Lalas 2001), saving energy and enabling more efficient foraging; this is most likely to benefit shags, gulls and terns (MPI 2013). Likewise, the attraction and aggregation of small fish around marine farm structures (Grange 2002) may provide enhanced feeding opportunities for piscivorous seabirds.

15.3.5.2 SIGNIFICANCE OF EFFECTS

Siting of a farm close to a seabird breeding colony is very likely to have an immediate adverse effect that will continue as long as the duration of the farm. However, there are no reports of seabird deaths as a result of entanglement in aquaculture facilities in New Zealand (Butler 2003, Lloyd 2003) as the use of top-nets over sea cages in New Zealand appears to effectively exclude seabirds (MPI 2013). The potential effects of habitat exclusion by feed-added farms in New Zealand are considered to be insignificant given the small area occupied in relation to the large total area of suitable habitat available for foraging seabirds (MPI 2013).

15.3.5.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

At present, potential risks are identified on a case-by-case basis. The most obvious is the choice of site for a farm to avoid disturbance to sensitive breeding colonies of seabirds. Good operating practices (for feed-added farms) such as enclosing predator nets above and below cages, controlling litter, minimising the use of lights at night, keeping nets taut and using mesh sizes less than 6 centimetres, all minimise the chances of negative seabird interactions. Given the current relatively small size of the

aquaculture industry in New Zealand, the overlap of farming activities with the feeding areas of seabirds is unlikely to present significant issues (MPI 2013).

There are significant knowledge gaps concerning almost all seabird species in New Zealand. Detailed information on the time-specific distribution, abundance and critical habitats is lacking. Also missing is information on key prey species of seabirds, particularly those that may be affected by aquaculture. In addition, there should be ongoing monitoring (where an issue is identified) and research into the operation, design and maintenance of farm structures that minimise disturbance and entanglement risks. Little is known about the exclusion distance needed from different species of foraging and feeding seabirds, for example, proposed exclusion distances for king shags in the Marlborough Sounds range from 100 to 1000 m (Davidson et al 1995, Taylor 2000), but more recently, Lalas (2001) noted that king shags resting ashore or on emergent objects only flew off when approached to within 30 metres.

15.3.6 EFFECTS FROM ADDITIVES

Background data on the use and impact of chemicals locally are from research on salmon aquaculture and have been reviewed previously (Forrest et al 2007c, Wilson et al 2009, Burridge et al 2010, Clement et al 2010, Forrest et al 2011, MPI 2013), the reader is referred there for more detail.

15.3.6.1 INTRODUCTION

The main intentional use of additives is as antibiotics, antibacterials and other therapeutants (MPI 2013). The concern with therapeutants is their potential to affect non-target organisms (phyto- and zooplankton, sediment bacteria) and the rise of resistant bacteria and/or parasites (GESAMP 1997, Forrest et al 2007c, Forrest et al 2011). The main unintentional additions are from zinc in fish feed and copper when used as an antifouling agent on structures (MPI 2013). The main concern with metals is their toxicity to animals (Forrest et al 2007c, Clement et al 2010, Forrest et al 2010).

15.3.6.2 SIGNIFICANCE OF EFFECTS

Currently, there is minimal use of chemicals such as antibiotics, antibacterials and other therapeutants intentionally added to the marine environment by the New Zealand aquaculture industry; however, culture of native species may lead to the emergence of diseases that may require new treatments.

Recent assessments at salmon farming sites in the Marlborough Sounds revealed locally elevated copper and zinc levels (with maxima exceeding ANZECC (2000) sediment quality guideline values between 2005 and 2010 (Hopkins et al 2006)). Potential adverse effects from high zinc exposures range from interference with growth at low concentrations to behavioural abnormalities at high concentrations (Eisler 1993, Burridge et al 2010); but elevated metal concentrations do not necessarily indicate adverse ecological effects as they may not be bioavailable (Forrest et al 2007c).

15.3.6.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

All species cultured for human consumption from aquaculture have to meet strict food safety standards, which regulate the acceptable concentrations of metals, chemicals and additives in food products. New Zealand salmon farmers must also comply with the New Zealand Salmon Farmers Association's Finfish Aquaculture Environmental Code of Practice, with harvesting and processing in accordance with New Zealand food safety standards.

No chemical/additives are known to be used in the farming of bivalves and lower trophic level species. If these are used in the future 'best management practice', should minimise food wastage and the use of therapeutants, and hence help mitigate potential effects. The most important means to reduce and manage the overall antibiotic usage would be to support development of targeted disease management strategies and alternative therapies, in particular vaccines, which are not presently licensed for use, nor used, in New Zealand.

The potential for environmental issues from therapeutant use in the future will need to be assessed on a case-by-case basis. Use of therapeutants in New Zealand is low, but their persistence in the environment, the induction of resistance of targeted organisms and the effects on non-target organisms are the main knowledge gaps. Studies on the bioavailability and forms of the metals will give better understanding of their toxicity; a focus is needed on sub-

lethal effects on individual species and the broader effects on benthic communities.

15.3.7 ESCAPEE EFFECTS

The subject of escapee effects from aquaculture is well covered for finfish by the reviews of Forrest et al (2007c) for New Zealand and Jensen et al (2010) for Norway, and for shellfish by Keeley et al (2009) and summarised in MPI (2013). The reader is referred to these sources for more detail.

15.3.7.1 INTRODUCTION

It is useful to recognise that the human-mediated transfer of numerous marine organisms to New Zealand and around the coastline is an issue with a long history that continues today. Historically, this reflects deliberate transplants of marine organisms (including salmon), and more recently the inadvertent transfer of a range of native and non-indigenous marine species (including fish), especially via vessel movements (e.g., Hayward 1997, Cranfield et al 1998). The alteration to marine ecosystems and transfer of fish diseases via these unmanaged mechanisms is well recognised (Ruiz et al 2000, Hilliard 2004), and hence any incremental risk from finfish culture should be considered within this broader context.

The effects of escapees from aquaculture vary considerably in relation to the following factors (Forrest et al 2007c):

- the numbers involved in the escape episode,
- the location of the farm in relation to wild populations and its size, distribution and health,
- whether the species is native (hapuku, kingfish) or introduced (salmon),
- whether the brood stock is hatchery bred or wild sourced,
- the fish harvest size in relation to reproductive maturity and the ability of gametes to survive and develop in the wild,
- the ability of escapees to survive and reproduce in the wild, as determined by their ability to feed successfully and interbreed with wild stocks.

The main effects of escapees (Forrest et al 2007c) for feed-added species are in terms of:

- competition for resources with wild fish and related ecosystem effects from escapee fish (e.g., through predation),
- alteration of the genetic structure of wild fish populations by escapee fish and potential loss of genetic integrity in the wild populations,
- transmission of pathogens from farmed stocks to wild fish populations.

The main factors controlling the number of fish escaping, and their subsequent effects are the integrity of the nets used to contain the fish and the amount of difference between the wild fish and farmed fish in terms of their genetics and their pests and diseases.

15.3.7.2 SIGNIFICANCE OF EFFECTS

The likelihood of escapee effects in New Zealand is low, based on the current small size of the industry, limited overlap of wild and farmed populations (in terms of salmon, Deans et al 2004) and the broad home range (in terms of kingfish and hapuku) and likelihood of high genetic diversity in these native species (Paul 2002, Forrest et al 2007c). If escapee effects are seen on wild populations they are, however, likely to be irreversible and could potentially be at a national scale.

15.3.7.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Management strategies to minimise escapees are usually based upon maintaining net integrity. In Norway reporting of escapes, and estimation of numbers escaped is mandatory and therefore provides a baseline to improve upon (Jensen et al 2010). In New Zealand escapee events are not reported to any central authority. At this time no knowledge is available on the potential effect that escaped farmed kingfish or hapuku could have upon the wild populations.

15.3.8 EFFECTS ON WILD FISH

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

15.3.8.1 INTRODUCTION

A potential immediate effect on wild fish populations from the development of a finfish farm is the degradation or loss of habitat beneath or within close proximity to new farm structures (e.g., spatial overlap with species' critical spawning grounds and/or migration routes). By adding three-dimensional structures to the marine environment, finfish farms provide habitat for colonisation by fouling organisms and associated biota (Glasby 1999, Connell 2000, Dealteris et al 2004). These newly colonised structures and the habitat they create tend to attract wild fish species seeking foraging habitat, detrital food sources and/or refuge from predators (e.g., Dealteris et al 2004). Submerged artificial lighting at night is frequently used on finfish farms to control maturation and increase productivity (e.g., Porter et al 1999). The lighting can enhance the attraction of wild fish to farm structures (Cornelisen & Quarterman 2010).

The main effects associated with the creation of artificial habitats, and attraction of wild fish species to aquaculture structures, include the following:

- enhanced predation on wild fish by higher trophic level predators (e.g., seals) and predation by cultured fish on wild fish trapped within cage structures,
- consumption of waste feed by wild fish (Felsing et al 2004, Dempster et al 2005),
- changes in recreational fishing patterns and pressure (N. Keeley, pers. obs.) which could affect wild fish populations differently than in the absence of the structures,
- larval fish depletion by filter-feeders (as observed by Davenport et al (2000) and Lehane & Davenport (2002)) and/or potential trophic interactions (e.g., alteration of plankton composition and food availability).

15.3.8.2 SIGNIFICANCE OF EFFECTS

In general, the effects of aquaculture on wild fish populations are likely to be small in comparison with the effects on other aspects of the marine ecosystem, such as effects on the seabed. The effects of farming hapuku or kingfish on wild fish are expected to be generally similar to those from farming of king salmon already in New Zealand. Modelling of larval egg depletion (Broekhuizen et al 2002) and other work suggest that while the feeding of fish in farms could have an impact on recruitment to fisheries; the scale of this effect will largely be governed by the extent of the culture, the behaviour and characteristics of larvae and the flow dynamics of the regions in question (MPI 2013).

The effects of farming filter-feeders are likely to be less than those of farming feed-added species (due to the lack of food added as an attractant), but shell-drop is likely to create a (lesser) attraction. The extent of impacts from the farming of Undaria and sea cucumbers is likely to have a lesser impact than feed-added or filter-feeding aquaculture, as they neither require feed nor exhibit shell drop (MPI 2013).

15.3.8.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

Management options identified in MPI (2013) for minimising effects on wild fish include proper site selection, which requires assessment of potential impacts of farm developments on wild fish stocks. Assessments should identify proximity and impact to critical, sensitive or protected habitats and species, with particular reference to potential impacts on spawning grounds or juvenile habitats. Careful management of feed quality and feeding practices should minimise waste feed inputs to the surrounding environment and minimise effects on wild fish populations. The effects of finfish farms on wild fish populations in New Zealand are not well documented and knowledge gaps exist, particularly with regard to the effects of finfish farms on fish movements and various reproductive stages (e.g., larval settlement).

15.3.9 HYDRODYNAMIC EFFECTS

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

15.3.9.1 INTRODUCTION

Hydrodynamic conditions are an important determinant of the suitability of a site for aquaculture, as well as the spatial size and magnitude of the environmental effects. Here, hydrodynamics refers to the physical attributes of the water including:

- currents,

- stratification, and
- waves.

Current speed is a key factor determining the exchange of water through the cage, areas over which deposition occurs, where the dissolved material is transported and how it is dispersed and the re-suspension of material. Stratification refers to the layering of water caused by differences in temperature and salinity. Stratification can play a strong role in oxygen depletion by restricting vertical transport of oxygen from the surface to deeper waters. Waves can break-up stratification, play a key role in determining which species can inhabit an area and can re-suspend material.

15.3.9.2 SIGNIFICANCE OF EFFECTS

Aquaculture operations can have a number of effects on hydrodynamics. The drag from cages can affect currents, causing wakes, turbulence and flow diversion (Helsley & Kim 2005, Venayagamoorthy et al 2011). Low velocity areas have a higher probability of issues of deposition, oxygen depletion and ammonium build-up. There are likely to be interactions between stratification and fish cages in the form of selective blocking, restricted underflow, generation of internal waves and vertical mixing (Plew et al 2006). Fish swimming may also play a role in enhancing mixing and causing upwelling within cages (Chacon-Torres et al 1988). Wave energy is attenuated by fish cages, and this will result in a shadow of reduced wave activity behind the farmed areas (Chan & Lee 2001, Lader et al 2007).

While some physical effects may affect other physical processes directly, for example attenuation of wave energy affecting surf or coastal sediment transport; it is generally more important to consider how physical effects influence ecological processes. For example, the physical effect of reduced current speeds caused by drag from aquaculture structures (Helsley & Kim 2005, Venayagamoorthy et al 2011) may result in an increase in the flushing time of a bay (Plew 2011). This in turn may lead to increased nutrient concentrations. Reductions in wave energy near the coast may change the mix of species inhabiting an area.

15.3.9.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

The physical hydrodynamic effects will interact strongly with pelagic and benthic processes. Selection of suitable indicators for physical changes should ideally be based on their relative importance in determining the habitat for ecological communities in an area. However, it is this link between the physical and ecological changes that is often the least understood area of hydrodynamic impacts.

15.3.10 CUMULATIVE IMPACTS

The following section draws heavily on previous reviews of the environmental effects of finfish (Forrest et al 2007c) and non-finfish aquaculture (Keeley et al 2009). Complementary information on the wider ecosystem effects of aquaculture in relation to the water column is provided in Section 15.3.2: Pelagic Effects. The reader is referred to MPI 2013 (and references therein) for more detail.

15.3.10.1 INTRODUCTION

The previous sections (15.3.1–15.3.9) have focused on issue-specific ecological effects of aquaculture developments on the marine environment. Our understanding of these effects is largely based on farm-scale assessments and monitoring; the potential for wider-ecosystem effects (e.g. far-field benthic enrichment, effects on fish populations, migrating mammals, etc) is acknowledged but is far less well understood. As aquaculture develops and the number of farms in coastal waters increases, wider-ecosystem issues become more important to consider due to the cumulative environmental effects that could arise from multiple farms combined with additional anthropogenic stressors affecting, and possibly interacting with natural marine processes (see Figure 15.4 for an example of multiple stressors interacting with natural processes).

Within the context of aquaculture development in the marine environment, cumulative effects are defined here as:

> *Ecological effects in the marine environment that result from the incremental, accumulating and interacting effects of an aquaculture development when added to other stressors from anthropogenic activities affecting the marine environment (past, present and future activities) and foreseeable changes in ocean conditions (i.e. in response to climate change).*

A number of examples of potential cumulative impacts of aquaculture exist, three of these will be given here to illustrate the definition above:

- Drop off of mussels, shells and biofouling organisms onto the seabed beneath mussel farms, can lead to the creation of reef-like habitat, and alter the composition and abundance of benthic organisms beneath farms (see Section 15.3.4). Where this occurs in high densities such as the ribbon-like developments in the Marlborough Sounds, this could lead to additive (cumulative) effects on the wider ecosystem due to alteration of a larger proportion of the benthos.
- In the case of farm structures, aquaculture involving numerous farms situated along the coast could also have cumulative effects on nearshore currents and waves, which in turn could affect important processes (e.g. larval transport, nutrient exchange) along the shoreline (see Section 15.3.9). As aquaculture development intensifies, there is likely to be an increase in man-made structures and boat traffic, increasing the risk of invasion and establishment of pests. Cumulative degradation of the marine environment from multiple stressors compromises habitat quality and could enhance biosecurity risks by increasing productivity and proliferation of pest species such as invasive macroalage (e.g. *Undaria*) and invertebrates (e.g. the bivalve *Theora lubrica* and tunicate *Styela clava*) that thrive on the benthos under conditions of high organic enrichment (Section 15.3.1 provides comprehensive information on methods for minimising biosecurity risk that are applicable to wider, regional scales).

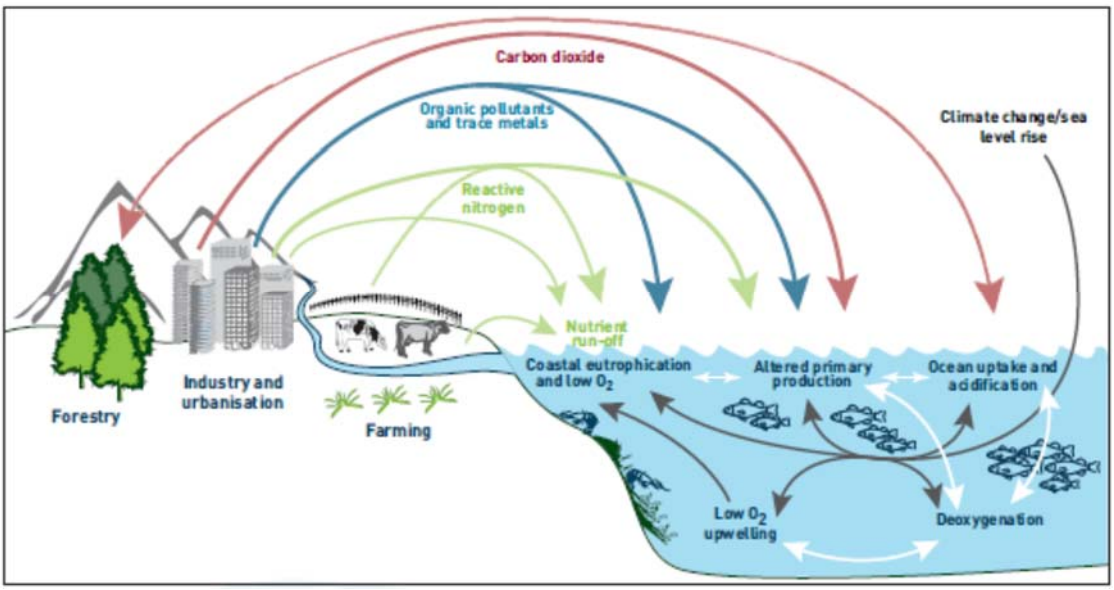

Figure 15.4: Conceptual diagram of anthropogenic influence in marine ecosystems.

Limited resources and uncertainty in understanding all of the potentially complex interactions between aquaculture, other stressors and the environment necessitates the need to focus on those aspects of aquaculture most likely to contribute to cumulative environmental change. Hence, increasing emphasis has been placed on assessing the contribution of aquaculture to cumulative changes in nutrient conditions and primary production, and in turn the knock-on effects on the wider ecosystem (see Hargrave et al 2005, Volkman et al 2009 and chapters therein). All forms of aquaculture addressed in this report contribute to these nutrient effects, whether through nutrient emissions to the water column and seabed, or the net extraction of plankton (filter-feeding bivalves) and nutrients (nutrient uptake by macroalgae) from the water column. The following sections focus on the potential far-field nutrient implications of aquaculture.

15.3.10.2 SIGNIFICANCE OF EFFECTS

The particular concern with the potential expansion of fish farms is the potential risk of eutrophication (SEPA 2000,

Hargrave et al 2005, Diaz et al 2012). Eutrophication is the process where excessive nutrient inputs to a water body result in accelerated primary production (phytoplankton and macroalgae growth) and flow-on effects to the wider environment such as reduced water clarity, physical smothering of biota, or extreme reductions in DO because of microbial decay (Degobbis 1989, Cloern 2001, Paerl 2006). On a global scale, runoff from land-based agriculture has been identified as the primary driver of intense eutrophication of coastal environments, however, feed-added forms of aquaculture have been singled out as an important emerging contributor to nutrient enrichment (Diaz et al 2012).

Nutrients of varying particulate and dissolved organic and inorganic forms are added to the environment as a result of feed-added aquaculture. Particulate organic nitrogen (PON) and phosphorus (POP) are primarily deposited onto the seabed as fish faeces but also as waste feed pellets and particles. Farmed fish also excrete dissolved inorganic nutrients such as ammonium (NH4). Smaller particles of feed in the water column (through the addition of feed and/or via resuspension) can be consumed by other organisms such as zooplankton and shellfish, which, through subsequent excretion, in turn contribute to the dissolved nutrient pool. The dissolved inorganic nutrients from feed-added aquaculture combined with other sources of nutrient inputs can fuel the growth of phytoplankton (Wu et al 1994) and at high concentrations can cause harmful phytoplankton blooms (Sorokin et al 1996). In New Zealand's temperate waters, nitrogen may be the nutrient limiting phytoplankton growth under certain conditions e.g. when concentrations are generally low and light is plentiful (MacKenzie 2004, Howarth & Marino 2006). Complicating matters is the fact that nutrients from finfish farms are only one source of nutrients in the marine environment, and, like other sources, their inputs vary over time, e.g. salmon farms in the Marlborough Sounds increase feed levels by about 50% during summer months, which is also the period of greatest light availability for primary production. Internationally there have been experiences of blooms of species that produce biotoxins, some of which can be directly toxic to fish, and others which can accumulate in shellfish and affect consumers. As far as is known to date salmon farming in New Zealand has not given rise to any harmful phytoplankton blooms and such effects are unlikely in the near future unless considerable new development occurs (Forrest et al 2007c).

The risk of exceeding the assimilative capacity and accelerating eutrophication will be dictated by the physical characteristics of a region, such as retention time, water depth and ambient nutrient concentrations, combined with the intensity and types of existing and planned aquaculture and upstream land-based developments. There is compelling evidence that bivalve aquaculture can affect nutrient cycling and the quantity and quality of food (plankton) across a range of spatial scales from local to system-wide (Prins et al 1998, Cerco & Noel 2007, Coen et al 2007). In turn, the quantity and quality of food available to other consumers could be affected (Prins et al 1998, Dupuy et al 2000, Pietros & Rice 2003, Leguerrier et al 2004), with consequences for local populations of higher trophic level organisms such as fish.

In some regions where numerous farms with high-density cultures occur, there is the potential risk of exceeding the region's capacity to sustain high shellfish production and the wider ecosystem itself. An example is Pelorus Sound, where questions around the concept of carrying capacity arose following observed decreases of about 25% in Greenshell mussel yields between 1999 and 2002 (Zeldis et al 2008). These reductions were attributed to climatic forcing conditions and inter-annual variability in phytoplankton biomass over multi-year time scales (Zeldis et al 2008). This suggests that this region is close to sustainable production limits during years of naturally low primary production.

15.3.10.3 MANAGEMENT OPTIONS AND KNOWLEDGE GAPS

The management of cumulative effects in the marine environment can be addressed using a two-tiered approach that not only considers the contribution of effects from individual developments, but also an overall regional assessment of wider environmental change in response to the many stressors impacting on the marine environment (e.g. Dubé 2003). Critical to regional assessments of cumulative effects in the marine environment is accessibility and coordination of datasets, including those derived from consent monitoring at individual farms, and long-term State of the Environment (SoE) monitoring programmes. Standardised monitoring requirements for aquaculture is an important step in ensuring the usefulness of consent monitoring datasets within broader-scale assessments. The requirements for assessing and managing cumulative effects fall beyond the

scope of a single consent applicant or industry and are best dealt with through regional councils (e.g. Dubé 2003, Hargrave et al 2005, Zeldis 2008a,b) or central government departments (Morrisey et al 2009, Zeldis et al 2011a,b).

Two ongoing projects will help address monitoring requirements for aquaculture. An ongoing MPI Biodiversity project "Marine Environmental Monitoring Programme" (ZBD2010-42) is seeking to address the following two objectives:

4. prepare an online inventory of repeated biological and abiotic marine observations/datasets in New Zealand,
5. review, evaluate fitness for purpose, and identify gaps in the utility and interoperability of these datasets for inclusion in a Marine Environmental Monitoring Programme (MEMP) from both science and policy perspectives.

Therefore any attempts to standardise monitoring datasets for aquaculture should try to learn from the experience or recommendations of this project. In addition the Aquaculture Planning Fund project 12/04 "Guidance for aquaculture monitoring in the Waikato Region" will develop an environmental monitoring framework to manage environmental change from aquaculture growth that will incorporate SOE monitoring, consent monitoring and predictive monitoring and have application to other regions.

Spatial modelling tools offer a way of estimating the extent to which the cumulative effects of aquaculture may be approaching ecological carrying capacity on "bay-wide" and "regional" scales. However, knowledge gaps are still evident in these models; particularly in the biological aspects (e.g. feeding behaviour and growth of the shellfish) which are still areas of active research (particularly within the Sustainable Aquaculture MBIE funded programme CO10X0904).

Some generalisations have been proposed in terms of carrying capacity, but these are not always in agreement. Using 'sustainability performance indicators', Gibbs (2007) suggests that the retention (flushing) time for a water body should not exceed 5% of the clearance time of farmed mussels in order to minimise cumulative effects on the wider ecosystem. Whilst recently proposed bivalve aquaculture standards suggest that if the clearance time for the farmed bivalves divided by the retention time of the water body is less than 1 and the area occupied by the farms is less than 10 percent of the total area of the water body then ecological impacts are likely to be acceptable (Bivalve Aquaculture Dialogue 2010).

ECOPATH modelling (Christensen et al 2000) was applied to assess the potential of Tasman Bay for mussel aquaculture development. This indicated that significant ecosystem energy flow changes occurred at mussel biomass levels less than 20% of a mussel dominated ecosystem, thus implying that ecological carrying capacity limits may be much lower than production carrying capacity limits (Jiang & Gibbs 2005). Typically modelling is therefore used to determine the ecological carrying capacity of each system. An ongoing MPI project "Nitrogen levels and adverse marine ecological effects" (ENV2012-01) is seeking to determine to what extent knowledge from overseas about the adverse effects of nitrogen on the marine environment can be applied here.

In the case of cumulative effects related to eutrophication, there is currently a very limited scientific understanding of the transport, fate and ecological consequences of nutrient loading from different sources and, in turn, how they cumulatively affect marine ecosystems (Olsen et al 2008). Managing cumulative effects to achieve sustainability ultimately requires regional approaches to managing developments and activities in a holistic, ecosystem-based management (EBM) framework which utilises spatial planning (Crain et al 2008).

In the absence of over-arching EBM programmes and a robust scientific base for adaptive management in response to cumulative effects, a precautionary approach is warranted in future developments of feed-added aquaculture. Using a precautionary approach, development should be conducted in a staged manner based on conservative limits of expansion. Important tools and components of a precautionary approach include:

6. The use of models and existing data to gauge limits to development[5] within the context of a region's assimilation capacity (i.e. ecological carrying capacity).

7. Establishment of wider-ecosystem, long-term monitoring programmes that include establishment of baseline conditions of a region and adoption of limits of acceptable change.
8. Mitigation of effects through continual improvement of on-farm practices, potentially including improved feed technologies and the use of Integrated Multitrophic Aquaculture (IMTA, Figure 15.5). IMTA combines farming of different species to potentially ameliorate environmental effects.
9. Targeted monitoring and research for validating and improving accuracy of predictive models and understanding the role of feed-added aquaculture in driving cumulative effects.

In New Zealand the Limits of Acceptable Change (LAC) adaptive framework has been applied in the 3000 ha Wilson Bay Aquaculture Management Area (AMA), in the eastern Firth of Thame[6]. This involved stakeholders agreeing both to levels of acceptable change in indicators, and to management responses to apply if monitoring showed that these changes have been exceeded. An overseas example of the precautionary approach is the M-O-M system (Modelling–Ongrowing fish farms–Monitoring), which has been undertaken in Norway to provide information for adaptive management of salmon farming (Ervick et al 1997, Hansen et al 2001).

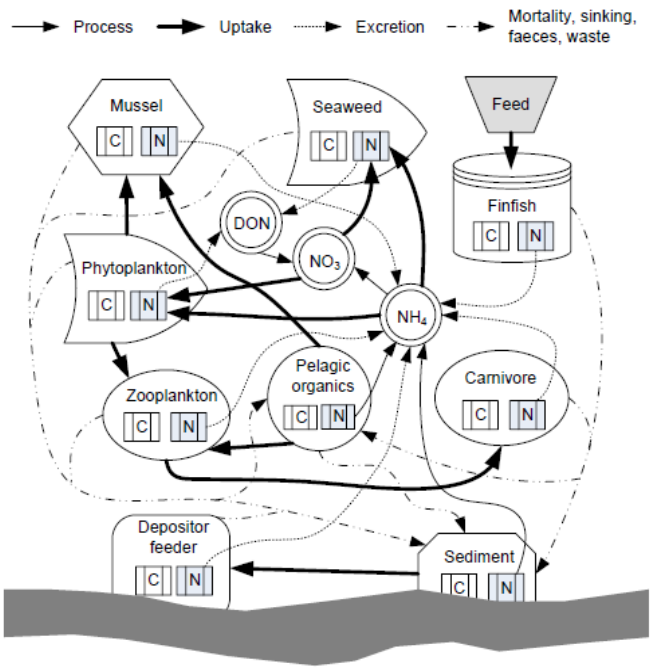

Figure 15.5: Conceptual diagram of IMTA model in terms of carbon (C) and nitrogen (N) biomass (from Ren pers. comm.).

A precautionary approach necessitates establishment of conservative thresholds or limits to minimise risks and the extent of cumulative effects. Minimising risk of eutrophication by setting a limit (or cap) on nutrient loads in a coastal receiving environment would be similar to the approach taken in restoring the Rotorua Lakes. Nutrient mass-balance models can provide guidance on nutrient loading rates in a region under various scenarios, and on gauging proximity to conservative critical nutrient loading rates or CNLRs (Olsen et al 2008). The mass-balance approach has facilitated the development of system-wide nutrient budgets and estimates of carrying capacity for feed-added aquaculture in Golden and Tasman Bays (Zeldis 2008b, Zeldis et al 2011a, b) and the Firth of Thames (Zeldis 2008a, Zeldis et al 2010).

Internationally, there is a very limited understanding of the cumulative effects of multiple stressors on marine ecosystems in the long-term. A critical requirement for understanding these effects is having good information on existing environmental conditions, and continued monitoring to provide long time-series datasets from which to validate models and quantify and forecast changes occurring in the wider environment.

Modelling has an important role to play in understanding, predicting and managing cumulative effects and New

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

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

Zealand has access to extensive modelling capability; yet in most cases the uncertainty in model accuracy remains high due to insufficient field data for their calibration and validation. For example, underlying hydrodynamic models require sufficient time-series data on currents and water column stratification, while more advanced biogeochemical models require validated estimates of inputs (e.g. surface water, groundwater, marine) and losses (denitrification, burial rates) of nutrients specific to New Zealand's coastal waters.

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THEME 5: MARINE BIODIVERSITY

BIODIVERSITY

Scope of chapter	Provides an overview of the MPI Biodiversity Programme and describes the national and global context for marine biodiversity research in New Zealand; summarises the research findings and progress of the MPI Biodiversity Research Programme from 2000–2014; including one-off, whole-of-government research initiatives administered under this programme (e.g. Ocean Survey 20/20 Biodiversity and Fisheries projects; International Polar Year Census of Antarctic Marine Life project).
Area	New Zealand Territorial Seas, EEZ and Continental shelf extension (BioInfo); South-west Pacific Region associated with South Pacific Regional Fisheries Management Organisation (SPRFMO);Southern Ocean and Ross Sea region (BioRoss)
Focal issues	• New Zealand seas have globally significant levels of endemic marine biodiversity, particularly in coastal habitats, offshore island habitats and on underwater topographical features such as seamounts, and canyons. • Mapping and documenting the identity, abundance and distribution patterns of New Zealand's marine biodiversity in our extremely large area of responsibility (~5.8 million km^2) is far from complete. Identifying biodiversity hotspots remains a challenge, particularly for environmental impact assessment or assessing response to climate change scenarios. • The state of marine biodiversity in New Zealand (and whether or not it is declining) is not reported nationally. • Selecting suitable ecosystem indicators and monitoring of marine biodiversity remains challenging globally and in New Zealand. In addition to extinctions or reduction in species richness and abundance, proxies such as environmental degradation species invasion and hybridisations, habitats that have been diminished or removed, and the disruption of ecosystem structure and function, as well as ecological processes (e.g. biological cycling of water, nutrients and energy) could be used as indicators • The efficacy of current spatial measures and management actions to protect sea life in "halting the decline of biodiversity" in New Zealand seas is not known due to inadequate sampleing effort. • Climate change effects on the ocean are occurring in New Zealand, and as these continue, the likely consequences for marine biodiversity and productivity are significant. • Marine biodiversity has not become an integral part of business or strategic planning across relevant government agencies. The functional role of marine biodiversity and ecosystem services in providing a healthy ecosystem, maintaining environmental limits and maintaining sustainability are not well recognised.
Key progress 2014–15	• Deep sea cold water corals have been kept alive for over 2 years now under laboratory conditions and are enabling a world-first experimental project to examine their response to projected acidification conditions in the deep (ZBD2013-05). • Ocean acidification issues have been picked up by MPI managers and resulted in an industry-science workshop with the US to "Future proof New Zealand's aquaculture and shellfish industry" (Capson and Guinnotte, 2014). • Biodiversity survey results from the Chatham Rise area have contributed significant evidence about the environment for the Chatham Rock Phosphate development and deepwater fisheries (ZBD2012-03) and have identified gaps and uncertainties in knowledge. • Marine Environmental Monitoring: metadata on marine environmental monitoring programmes (bio-physical) throughout New Zealand is now publicly available; we are one step closer to developing Tier 1 Statistics for marine biodiversity and for ocean related climate change. The results from the study are being used to feed

	into New Zealand's environmental reporting bill (ZBD2010-41, ZBD2012-01, ZBD2012-02) • The landmark "Taking Stock" project has been completed with the first multidisciplinary investigation of change in New Zealand's marine ecosystem over the last 1000 years (ZBD2005-05). The results are of particular interest to the Hauraki Gulf Forum. • Six new projects began in the 2014-15 financial year: ZBD2014-01, Live DW coral experiment phase 2; ZBD2013-08 , NZ-Ross sea connectivity Humpback whales; ZBD2014-10, BPA biodiversity; ZBD2014-03, Sublethal effects of environment change on fish populations; ZBD2014-04 , Isoscapes for trophic studies; ZBD2014-05, Ocean acidification modelling; ZBD2014-06; Macroalgae mapping and potential as national scale indicators; ZBD2014-07 , Southern coralline algae shellfish habitat; ZBD2014-09 , Climate change risks and opportunities.
Emerging issues and gaps	• The combined effects of multiple stressors arising from climate change and a range of other anthropogenic activities on biodiversity and marine ecosystems (structure and function) are likely to be large and complex. • Ecosystem approaches to marine resource management are urgently needed, particularly with the renewed interest in developing the marine economy through marine mining and extraction activities. • The nature and functional role of marine microbial biodiversity in large scale biogeochemical and ecosystem processes may be crucial to productivity in our seas, but are not well understood. • Genetic and life-history stage connectivity between and within large scale habitats are likely to be important to the size and placement of marine protection zones and to their success. • Long-term observations (e.g. decadal to millennia timeframes) of variability and change in the marine environment (including biodiversity) are not yet generally available at geographic scales appropriate for national reporting. • Metrics for assessing the effectiveness of current protection measures in safeguarding marine biodiversity and aquatic ecosystem health in New Zealand and the Ross Sea region are inadequate. • Economic value of ecosystem goods and services provided by marine biodiversity to current and future generations are not yet addressed in extractive business models. • Conservation of marine biodiversity, monitoring, reduction of loss and enhancement are emerging requirements for signatories (including New Zealand) to the CBD Aichi-Nagoya Agreement 2010. • Geo-engineering methods including ocean fertilisation continues to be advocated in some areas of international climate change mitigation • Meeting New Zealand international responsibilities includes participation in international data collection programmes and long-term commitment, e.g. SAHFOS, IMOS, SOCPR ARGO, BIO-ARGO. • Biodiversity indicators that can be used to evaluate the health of the marine ecosystem and biodiversity loss need to be consolidated. • Marine debris and pollution are increasing in NZ waters, particularly in the coastal zone • The effects of land-use practices on coastal ecosystems are still not fully addressed by management agencies (see Chapter 13). • Validation data to support habitat suitability models is inadequate for most species in most of the EEZ, therefore there is a need for more robust methods that can work with limited data.
MPI Research (current)	70 biodiversity projects have been commissioned over the period 2000-14. A new 5 year programme is underway to address seven science objectives in the Biodiversity Programme: 1 characterisation and description; 2 ecosystem scale biodiversity; 3

	functional role of biodiversity; 4 genetics; 5 ocean climate effects; 6 indicators; 7 threats to biodiversity. MPI biodiversity research has strong synergies with marine research funded by MPI Aquatic and Environment Working Group (AEWG), Ministry of Business Innovation and Employment (MBIE), Department of Conservation (DOC), Land Information New Zealand (LINZ), other sections within the Ministry for Primary Industries (MPI), Ministry for the Environment (MfE),Statistics New Zealand (Stats NZ), Te Papa and Crown Research Institutes
NZ Biodiversity Research (current)	Research programmes and database initiatives on Marine Biodiversity are run at University of Auckland (World Register of Marine Species (WoRMS), marine reserves, rocky reef ecology, soft sediment functional ecology, Ross Sea meroplankton, genetics); Auckland University of Technology, University of Waikato (soft sediment functional ecology and biodiversity), Victoria University of Wellington (monitoring marine reserves, population genetics), University of Canterbury (intertidal and subtidal ecology, kelp forests and biodiversity), University of Otago (land-use effects, bryozoans, inshore ecology, ocean acidification), National Institute of Water and Atmospheric Research (NIWA) and Cawthron Institute. Relevant Core NIWA Coasts and Oceans Centre programmes include: Programme 1 - Marine physical processes and resources; Programme 2 - Marine biological resources; Programme 3 - Ocean flows and productivity; Programme 4 - Marine ecosystem structure and function; Programme 5 - Our changing ocean; Programme 6 - Marine biosecurity. The NIWA Fisheries Centre has 4 core-funded programmes: 1. Stock monitoring assessment and methodologies; 2.International fisheries; 3. Ecosystem approaches to fisheries management; 4.Enhance the value of wild fisheries. Bycatch mitigation and minimisation; DOC, MPI, NIWA and Landcare Research contribute to the NZ Organisms Register. . MBIE National Science Challenges “Deep South” and “Sustainable Seas” are hosted by NIWA, with research programmes to be initiated in early 2015. New 4 year programmes funded in the MBIE 2014 Environment Fund Round include Ocean Acidification (NIWA) and Marine Biosecurity (NIWA) and Estuaries (Massey).
Links to 2030 objectives	Fisheries 2030 Environmental Outcome Objective 1; environmental principles of Fisheries 2030 include: Ecosystem-based approach, Conserve biodiversity: Environmental bottom lines, Precautionary approach, Responsible international citizen, Inter-generational equity, Best available information, Respect rights and interests (MPI 2009). MPI’s Strategy “Our Strategy 2030”: two key stated focuses are to maximise export opportunities and improve sector productivity; increase sustainable resource use, and protect from biological risk.
Links across Government	The Biodiversity programme engages in Natural Resource Sector discussions (MfE, DOC, MBIE, LINZ, EPA, MOT, Maritime NZ, Antarctica NZ, NZ Statistics, MFAT) and whole of government projects such as Ocean Survey 20/20, International Polar Year, identification of strategic research needs in marine research, the National Science Challenges and the refresh of the NZ Biodiversity Strategy.
Related chapters/issues	Multiple use of marine resources, land-based effects, variability and change, marine monitoring, cumulative effects of use and extraction in the marine environment, protected areas; benthic impacts, ecosystem approaches to fisheries and marine resource management.

Note: This chapter was last updated for the AEBAR 2015.

16.1 INTRODUCTION

This chapter summarises the development and progress of the MPI Marine Biodiversity Research Programme 2000–2014 and reviews the work commissioned in the context of national and global concerns about biodiversity and the maintenance of the marine ecosystem in a healthy functioning state, as identified by the New Zealand Biodiversity Strategy (NZBS, Anon 2000).

16.1.1 HALTING THE DECLINE IN BIODIVERSITY

In June 2000, the 'New Zealand Biodiversity Strategy – Our Chance to Turn the Tide' (NZBS) with the over-arching objectives "to halt the decline of biodiversity in New Zealand and protect and enhance the environment" was launched as part of New Zealand's commitment to the international Convention on Biological Diversity 1993 (Anon 2000). To meet long-term goals of the NZBS, a comprehensive plan, with stated objectives and actions, was developed to address biodiversity issues in terrestrial, freshwater and marine systems. The Desired Outcomes by 2020 for the marine environment (Coasts and Oceans, Theme 3) in the NZBS were stated as:

- "New Zealand's natural marine habitats and ecosystems are maintained in a healthy functioning state and degraded marine habitats are recovering.
- A full range of marine habitats and ecosystems representative of New Zealand's indigenous marine biodiversity is protected.
- No human-induced extinctions of marine species within New Zealand's marine environment have occurred.
- Rare or threatened marine species are adequately protected from harvesting and other human threats, enabling them to recover.
- Marine biodiversity is appreciated, and any harvesting or marine development is done in an informed, controlled and ecologically sustainable manner."

In the marine environment, biodiversity decline is characterised not only by extinctions or reduction in species richness and abundance, but also by environmental degradation such as species invasion and hybridisations, habitats that have been diminished or removed, and the disruption of ecosystem structure and function, as well as ecological processes (e.g. biological cycling of water, nutrients and energy). Measuring the decline of marine biodiversity is complicated by the 'shifting baseline syndrome', a common obstacle to useful biodiversity assessment and monitoring[1]. Furthermore the size range of organisms sampled is often limited to macroscopic. Changes (declines) in biodiversity metrics at a macroscopic level may not detect potentially large changes in biodiversity in smaller sized organisms below our sampling threshold that may also be critical to marine ecosystem health and well-being.

Responsibility for implementing New Zealand's Biodiversity Strategy is led by the Department of Conservation (DOC), with significant input from the Ministry for Environment (MfE), and the Ministry of Fisheries (now part of MPI)[2] DOC is currently leading a process to refresh the Biodiversity Strategy to better meet the Aichi Agreement.

DEFINING BIODIVERSITY

New Zealand's Biodiversity Strategy defines biodiversity as:

"The variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part [as defined by the CBD]; this includes diversity within species, between species and of ecosystems [as further disaggregated for New Zealand purposes]. Components include:

- *Genetic diversity: the variability in the genetic make-up among individuals within a single species. In more technical terms, it is the genetic differences among populations of a single species and those among individuals within a population.*
- *Species diversity – the variety of species—whether wild or domesticated— within a particular geographic area.*
- *Ecological diversity – the variety of ecosystem types (such as forests, deserts, grasslands, streams, lakes wetlands and oceans) and their biological*

[1] A National Approach to Addressing Marine Biodiversity Decline (Australian Government-available on line at www.environment.gov.au/coasts/publications/marine-diversity-decline/index.html

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

communities that interact with one another and their non-living environments."

MPI's Biodiversity programme is concerned primarily with research to underpin NZBS Theme 3: Biodiversity in Coastal and Marine Ecosystems:

"Coastal and marine ecosystems include estuaries, inshore coastal areas and offshore areas, and all the resident and migratory marine species that live in them."

New Zealand's ocean territory (including territorial sea and the recent continental shelf extension[3]) is very large relative to the area of land[4] and includes some 15–18 000 kilometres of coastline extending from the subtropical 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 38% of all marine species (46% for Animalia) estimated as endemic (Gordon 2013) and comprising up to 8% of global marine biodiversity. [These statistics do not include estimated undiscovered species, which are likely to increase the proportion of endemics.]

About 18 000 known 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. A low estimate of undiscovered marine biodiversity suggests another 13 000 species. Several factors would suggest that this estimate of total marine species is conservative. Such factors include the region's size, the depth range, geomorphological and hydrological complexity, limited water column sampling and limited benthic sampling, especially below 1500 metres, and rates of new species descriptions, currently about 50 per year. Inflating estimates of undiscovered marine biodiversity is the potentially very large numbers of parasitic and commensal protists (especially microsporidia) and parasitic animals like myxozoans and nematodes, as well as free-living nematodes. If recent indications of massive oceanic microbial diversity are also taken into account (e.g. Sogin et al 2006) then the number above is certainly conservative, perhaps indeterminable.

New Zealand's marine biodiversity is affected by many uses of the marine environment, particularly fishing, aquaculture, shipping, petroleum and mineral extraction, renewable energy, tourism and recreation[5]. Impacts from changing land use, including agricultural, urban run-off and coastal development can also affect marine biodiversity (Morrison et al 2009). The potential loss of marine biodiversity and possible functionality caused by climate change and ocean acidification are of increasing concern worldwide (e.g., Guinotte et al 2006; Ramirez-Llodra et al 2011; as well as in New Zealand–see New Zealand Royal Society Workshop papers[6]). The growing arrival of non-indigenous (sometimes invasive) marine species is also a threat to local biodiversity (e.g., Coutts & Dodgshun 2007, Cranfield et al 2003, Gould & Ahyong 2008, Russell et al 2008, Williams et al 2008).

Understanding about New Zealand's coastal marine environment and its land-sea interactions has progressed, although knowledge about the state of the marine environment and marine biodiversity at a national scale remains limited (Lundquist et al. 2014). Current knowledge about New Zealand's and the Ross Sea's marine biodiversity suggests that it may generally be in better shape than that of many other countries (Costello et al 2010, Gordon et al 2010). However, New Zealand is less well placed when it comes to understanding the threats to marine biodiversity (Costello et al 2010, MacDiarmid et al 2012) and the nature of their impacts. Marine invasion and the effects of climate change and acidification of the ocean are key threats, and anthropogenic threats from increasing resource use, high levels of agricultural runoff and sedimentation as well as marine debris are causing localised degradation of marine habitats (Kingsford et al 2009, Lundquist et al 2011).

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

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

[5] http://www.royalsociety.org.nz/media/Future-Marine-Resource-Use-web.pdf
http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/fish.aspx

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

There are ongoing concerns about the decline of some key species (MfE 2007), localised impacts on habitats and conditions (Thrush & Dayton 2002, Cryer et al 2002, Clark et al 2010a, b, Gordon et al 2010,) and emerging threats to the marine environment (MacDiarmid et al 2012) despite the combined efforts of New Zealand's government and stakeholders to fill information gaps and reduce impacts on biodiversity. Global scale threats associated with the potential effects of ocean acidification on microbial diversity and their roles in biogeochemical processes have yet to be quantified but could have EEZ wide implications (Bostock et al 2012).

New Zealanders increasingly value environmental, economic and social aspects of marine biodiversity and the ecosystem services that a healthy marine environment provides. They also value the need to sustainably manage the use of coastal and marine environments and maintain biological diversity as reflected by recent policy statements by the New Zealand Government [7][8]. A broad range of legislation, regulations and policies are in place to manage and regulate uses of the marine environment, to protect marine biodiversity, to improve management of the coastal and marine environment and to meet world-wide consumer demands for improved sustainability.

The government's Business Growth Agenda acknowledges the lack of progress in halting the decline in biodiversity in New Zealand, and indicates that development of the marine economy requires a careful approach to the environment. However, despite many documents having been written about the lack of basic ecological characterisation throughout the Territorial sea and EEZ (Snelder et al 2006, Leathwick et al 2010, Bowden et al 2011a), no priority or action point has been included to rectify the shortfall.

The most recent introduction of new legislation is the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. However, progress on an integrated oceans policy and strategic direction for implementation of New Zealand's Biodiversity Strategy has not progressed as rapidly here compared with other countries such as Canada, the UK, the USA and Australia (Peart et al 2011).

IMPLEMENTATION OF NEW ZEALAND'S BIODIVERSITY STRATEGY

A number of initiatives have been supported by MPI to meet the goals of the NZBS. Commitments include the creation of NABIS (the National Aquatic Biodiversity Information System) [9], the administration of the MPI Biodiversity Research Programme, convening and chairing the Biodiversity Research Advisory Group[10], and developing a Marine Protected Area policy with DOC. DOC also surveys and monitors aspects of marine biodiversity, particularly in marine reserves[11]. New Zealand's no-take marine reserves have particular advantages over the other 94% of global marine-protected areas that allow fishing (Costello & Ballantine 2015) in that monitoring of any changes (including improvements) is not confounded by the effects of species extractions. MfE has encouraged Regional Councils to develop coastal monitoring programmes and with MPI and DOC, initiated an approach to Marine Environmental Classification [12]. Biodiversity related research has also been carried out through MPI's Biosecurity Science Strategy. One result includes mapping and valuation of marine biodiversity around New Zealand's coastline[13]. Periodic marine BioBlitzes around New Zealand yield surprising numbers of new species, even in presumed well-studied areas, have the advantage of engaging children, parents and teachers in discovery, and involve

[7] MfE Proposed National Policy Statement on Indigenous Biological Diversity (biodiversity) under the Resource Management Act 1991 www.mfe.govt.nz/publications/biodiversity/indigenous-biodiversity/proposed-national-policy-statement/statement.pdf

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

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

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

[11] www.doc.govt.nz

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

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

research scientists who go on to describe the new taxa (e.g. Harper et al 2009). More of these should be encouraged.

Marine biodiversity research is largely supported through public good funding and is conducted mainly by Universities and CRIs. Both have contributed to New Zealand's high profile for marine biodiversity on the international scientific network through participation in global initiatives such as the Census of Marine Life as well as to local programmes that have improved understanding of the role of biodiversity in the marine ecosystem. The Museums of Auckland, Canterbury, Otago and the Museum of New Zealand (Te Papa) also conduct biodiversity sampling expeditions and national collections of specimens have been set up within Museums and at NIWA. Regional Councils give effect to NZBS, Coastal Biodiversity Policy Statement 2011, protected areas and spatial planning.

CURRENT CHALLENGES AND AGENDAS

Since the launch of the Biodiversity Strategy, there have been substantial changes in Government goals for New Zealand. In July 2009, the Minister of Science set an overarching goal for research science and technology[14]:

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

This goal is reflected in the first progress report on "Building Natural Resources" as part of the Business Growth Agenda[15] released December 2012. The Business Growth Agenda sets an ambitious goal of increasing the ratio of exports to GDP to 40% by 2025. Meeting the target will require the value of our exports to double in real terms by 2025. The report states that one of the goals is to "Make the most of the considerable opportunities for New Zealand to gain much greater value from its extensive marine and aquaculture resources". More recently, the Business Growth Agenda states its goal for Natural Resources as "The quality of our natural resource base increases over time while sustaining the growth needed from key sectors while meeting our 40% export to GDP target"[16]

The economy of the sea is a significant part of the overall economy in New Zealand and has potential for growth, particularly in aquaculture, oil and gas, minerals (Business Growth Agenda 2014). It is important that the aquatic environment and biodiversity are not adversely affected by new or increasing activities, be they in the seafood sector or other natural resource industries (Fisheries Act 1996; Exclusive Economic Zone and Continental Shelf (Environment Effects) Act 2012).

Most of New Zealand's commercial fisheries are wild-caught, and continuity of their productivity is therefore dependent on the retention of a healthy functioning marine ecosystem. The "licence to operate" is mandated by the Fisheries Act 1996 that requires strict compliance with sustainable and environmentally responsible use of fishstocks. Compliance is also required with other legislation such as the Marine Mammals Protection Act 1978 and a range of international obligations such as the United Nations Convention on the Law of the Sea (UNCLOS). Under the Quota Management System, considerable monitoring of fishing activity and the environmental footprint of commercial operators is required.

The marketplace is continually evolving and as social awareness of commercial activity in the sea has increased across the globe, the "social licence" or "acceptance" of commercial fishing activities has come under higher scrutiny in New Zealand. Industry and government have gone beyond legislative requirements to maintain stocks at healthy levels and to demonstrate stewardship of the natural environment as well as the fishstocks; eco-labelling certification such as the Marine Stewardship Council (MSC) of some key fisheries is just one manifestation of this. It will become increasingly important to seek a social licence to

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

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

[16] http://www.mbie.govt.nz/pdf-library/what-we-do/business-growth-agenda/bga-reports/future-direction-2014.pdf

operate and to demonstrate responsible environmental stewardship in other industries as New Zealand stretches towards broader goals of growing the marine economy.

The large scale threats to the marine environment and biodiversity posed by increasing global impacts of stressors such as climate change and ocean acidification, increasing exploitation of resources (living or non-living) and the cumulative effect of multiple uses of the marine environment (e.g., renewable energy, commercial fisheries, recreational fisheries, aquaculture, hydrocarbon and mineral extraction) are increasingly being recognised in policy and government circles (e.g., Office of the Prime Minister's Science Advisory Committee 2013[17], NZ Royal Society 2012[18], Statistics New Zealand 2013, Statistics New Zealand 2012[19], see Royal Society 2009[20], Capson and Guinotte 2014; MBIE[21]). Progress on tackling the issues and investment in long-term monitoring of the marine environment and data access remains slow. Long-term monitoring and environmental reporting has however been recognised as a major gap by the government and a draft Environmental Reporting Bill is now available online[22].

Scientific research has provided information about the predicted distribution and abundance of marine biodiversity in some areas of New Zealand's coasts and oceans, but progress on validation in areas that remain unsampled has been slow. The structure and function of biodiversity of macrofauna within some marine ecosystems in the New Zealand and Ross Sea Region is well understood and the available information has been used to assess habitat types at greatest risk from disturbance, particularly fishing (Clark & Rowden 2009, Clark & Tittensor 2010, Hewitt et al 2011, Floerl & Hewitt 2012). Many ecosystems remain poorly sampled however, and the efficacy of current spatial protection measures for biodiversity in New Zealand is unknown. However, the proportion of different marine habitat types that should be or can be protected to maintain a healthy aquatic environment is also unknown (Lundquist et al 2015).

Progress has been made on evaluating threats and risks to the marine environment and components within it (e.g. Currey et al 2012, MacDiarmid et al 2011, 2012, 2014, http://www.fish.govt.nz/NR/rdonlyres/9516E99B-6F52-4BB9-9C2D-CC47C1939A07/0/2013NationalPlanofActionSeabirdsincludingcover.pdf, http://www.fish.govt.nz/NR/rdonlyres/94D86BF9-CF41-4BA5-9BCC-CA65DF7A7560/0/NZ_draft_NPOAsharks.pdf).

There is growing awareness of the likely importance of the diversity, biomass and species mix of micro-organisms, nano- and pico-plankton, and it is a fast developing field of research. The rate of change and the resilience of biodiversity to the cumulative effect of multiple stressors across large spatial scales (e.g. ocean acidification, temperature increase and oxygen depletion), particularly as utilisation of marine resources increases, remain semi-quantified (Ramirez-Llodra et al 2011). Understanding the dynamics of climate change and predicting the impacts on food webs and fisheries are only just being investigated (e.g., Fulton 2004, Brown et al 2010, Garcia & Rosenberg 2010).

16.2 GLOBAL UNDERSTANDING AND DEVELOPMENTS

Worldwide, there is concern about biodiversity and the current rate of decline. The current doctrine states that

- Greater species diversity ensures natural sustainability for all life forms
- Healthy ecosystems can better withstand and recover from impacts

[17] http://www.pmcsa.org.nz/wp-content/uploads/New-Zealands-Changing-Climate-and-Oceans-report.pdf
[18] http://assets.royalsociety.org.nz/media/Future-Marine-Resource-Use-web.pdf
[19] http://www.statisphere.govt.nz/tier1-statistics.aspx
[20] http://www.royalsociety.org.nz/expert-advice/information-papers/yr2009/ocean-acidification-workshop/
[21] http://www.msi.govt.nz/update-me/major-projects/national-science-challenges/
[22] http://www.legislation.govt.nz/bill/government/2014/0189/latest/whole.html

In addition, the premise that healthy biodiversity provides a number of natural services for everyone, such as ecosystem services, biological resources and social benefits, is slowly reaching to politicians and industry as people ask, "Why is biodiversity important? Does it really matter if there aren't so many species?[23]". It has now been shown that biodiversity boosts ecosystem productivity where each species, no matter how small, has an important role to play. It has also been shown that greater species diversity underpins system resilience and natural sustainability for all life forms; and healthy ecosystems can better withstand and recover from a variety of disasters (Hughes et al 2005, Thrush et al 2009).

In April 2002, the Parties to the Convention on Biological Diversity (CBD), including New Zealand, committed to achieve by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth. This target was subsequently endorsed by the World Summit on Sustainable Development and the United Nations General Assembly and was incorporated as a target under the Millennium Development Goals[24].

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[25]. 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[26].

The eleventh meeting of the Conference of the Parties to the Convention on Biological Diversity (held 8–19 Oct 2012)[27] generated some agreed outcomes of relevance for New Zealand, in particular:

- There was confirmation that the application of the scientific criteria for EBSAs and the selection of conservation and management measures is a matter for states and relevant inter-governmental bodies but that it is an open and evolving process that should continue to allow ongoing improvement and updating as new information comes to hand.
- It was recognised that there was a need to promote additional research and monitoring in accordance with national and international laws, to improve the ecological or biological information in each region with a view to facilitating the further description of the areas described.
- There is a tentative schedule of further regional workshops to facilitate the description of areas meeting the criteria for EBSAs.

New Zealand government agencies are currently updating the NZBS to better align with the Aichi Biodiversity targets.

THE DECADE OF BIODIVERSITY 2011–2020

At its 65th session, The United Nations General Assembly declared the period 2011–2020 to be "*the United Nations Decade on Biodiversity, with a view to contributing to the implementation of the Strategic Plan for Biodiversity for the period 2011–2020*" (Resolution 65/161). The decade will

[23] http://www.globalissues.org/article/170/why-is-biodiversity-important-who-cares

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

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

[26] 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/

[27] http://www.cbd.int/doc/?meeting=cop-11 UNEP/CBD/COP/11/23 Marine and Coastal Biodiversity: Revised Voluntary Guidelines for the Consideration of Biodiversity in Environmental Impact Assessments and Strategic Environmental Assessments in Marine and Coastal Areas.

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 of the Strategic Plan for Biodiversity. The five Strategic Goals are:

- Goal A - Address the underlying causes of biodiversity loss by mainstreaming biodiversity (NBSAPs) across government and society.
- Goal B - Reduce the direct pressures on biodiversity and promote sustainable use.
- Goal C - Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.
- Goal D - Enhance the benefits to all from biodiversity and ecosystem services.
- Goal E - Enhance implementation through participatory planning, knowledge management and capacity building.

Targets 6–11 specifically refer to fisheries and marine ecosystems and are provided in section 0 of this Chapter.

The CBD also calls for renewed efforts specifically on coastal and marine biodiversity: "The road ahead for coastal areas lies in better and more effective implementation of integrated marine and coastal area management in the context of the Convention's ecosystem approach. This includes putting in place marine and coastal protected areas to promote the recovery of biodiversity and fisheries resources and controlling land-based sources of pollution. For open ocean and deep sea areas, sustainability can only be achieved through increased international cooperation to protect vulnerable habitats and species."[28] The CBD held regional workshops during 2011 to identify information sources that might inform the location of Ecologically or Biologically Sensitive Areas (EBSAs). New Zealand participated in the SW Pacific workshop, and candidate EBSAs were identified[29]. The criteria used for identifying EBSAs and Vulnerable Marine Ecosystems were those recommended through UNGA and managed by Regional Fisheries Management Organisations[30]. The 2012 SPRFMO Science Working Group noted that there are differing approaches to identifying VMEs and EBSAs that may need to be resolved[31]

GLOBAL MARINE ASSESSMENT

The biological diversity of the marine environment is an important component of global resource security, ecosystem function and climate dynamics. The Marine Biodiversity Outlook Reports and Summaries prepared by UNEP's Regional Seas Programme for the 10th Conference of Parties of the Convention on Biological Diversity (CBD) held in 2010 provide the first systematic overview at a sub-global scale of the state of knowledge of marine biodiversity, the pressures it faces currently and the management frameworks in place for addressing those pressures[32].

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

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

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

[31] http://www.sprfmo.int/assets/Meetings/Meetings-before-2013/Scientific-Working-Group/SWG-11-2012/Report-DWSG-11-Meeting.pdf

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

The regional reports reflect a poor outlook for the continuing well-being of marine biodiversity, which faces increasing pressures in all regions from land sourced pollution, ship sourced pollution and the impacts of fishing. These pressures are serious and are generally increasing, despite measures in place to address them. They are amplified by predicted impacts of ocean warming, acidification and habitat change arising from climate and atmospheric change. Without significant management intervention marine biological diversity is likely to deteriorate substantially in the next 20 years with growing consequences for resource and physical security of coastal nations.

With respect to fisheries, the main findings of the reports are that in most regions fisheries peaked at some point between the mid-1980s and mid-2000s that catch expansion is not possible in many cases and that increased exploitation levels would lead to lower catch levels.

All regions report increases in shipping at levels which generally reflect annual economic growth. 3.4% of the global ocean area, 8.4% of all marine areas within national jurisdiction, and 10.9% of all coastal waters are covered by protected areas. Only 0.25% of marine areas beyond national jurisdiction are within protected areas. To meet the 10% target in areas within national jurisdiction, a further 2.2 million square kilometres of marine areas will need to be designated as marine protected areas. In addition, 21.5 million square kilometres in Areas Beyond National Jurisdiction (ABNJ) would need to be protected for the target of 10% to be attained (Juffe-Bignoli et al 2014).

It is likely to be many years before this target is reached. The figures do not include some managed fishery areas that have objectives consistent with multiple sustainable use and overall objectives for conservation but even if these are taken into account the proportion managed with objectives that explicitly address sustainability of biodiversity or ecosystem processes is inadequate.

After many years of international negotiations on the need to strengthen the science-policy interface on biodiversity and ecosystem services at all levels, more than 90 governments (including New Zealand) agreed in April 2012 to officially establish the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[33]. It will be a leading global body providing scientifically sound and relevant information to support more informed decisions on how biodiversity and ecosystem services are conserved and used around the world.

The United Nations Conference on Sustainable Development (UNCSD), also known as the Rio+20 Conference (June 2011)[34] had a strong sustainability focus and generated an outcome document entitled "*the future we want*" which had a section on oceans (para 158–177) including:

- Support for the Regular Process of Global Reporting and Assessment of the State of the Marine Environment established under the General Assembly and looked forward to the completion of the first global integrated assessment of the state of the marine environment by 2014[35].
- The ongoing work of the Ad Hoc Open-ended Informal Working Group on Study Issues Relating to the Conservation and Sustainable Use of Marine Biodiversity Beyond Areas of National Jurisdiction and the wish to, by the end of the 69th session (2014) make a decision about the development of an international instrument under UNCLOS.
- A concern about the health of oceans and marine biodiversity and the work of the IMO and relevant conventions including initiatives like the London Protocol on ocean fertilisation and the global programme of action for the protection of the marine environment from land based activities.
- The Rio+20 outcome also endorsed a process to develop sustainable development goals (to apply to all countries) which will include oceans issues. (This

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

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

[35] Integrated assessment of the state of the marine environment by 2014. http://www.un.org/depts/los/global_reporting/Santiago_Regular_Proceess_Workshop_Presentations/GRAME_Outline_of_the_First_Integrated_Assessment_Report.pdf

is still in its nascent stage and a clear work programme will be finalised by September 2013).

CLIMATE CHANGE MEANS OCEAN CHANGE

"*Rapidly rising greenhouse gas concentrations are driving ocean systems toward conditions not seen for millions of years, with an associated risk of fundamental and irreversible ecological transformation. Changes in biological function in the ocean caused by anthropogenic climate change go far beyond death, extinctions and habitat loss: fundamental processes are being altered, community assemblages are being reorganized and ecological surprises are likely*." (quote from http://www.globalissues.org/article/172/climate-change-affects-biodiversity).

Public discussion about the impacts of climate change tend to focus on changes to land and the planet's surface or atmosphere. However, most of the excess heat is going into the oceans and changes in water chemistry are underway (see Chapter 10 of the AEBAR).

Climate change can have an adverse impact on the spatial patterns of marine biodiversity and ecosystem function through changes in species distributions, species mix and habitat availability, particularly at critical stages of species life histories (Lundquist et al 2011, Poloczanska et al 2013). A study of the global patterns of climate change impacts on ocean biodiversity projected the distributional ranges of a sample of 1066 exploited marine fish and invertebrates for 2050 using a newly developed dynamic bioclimate envelope model which showed that climate change may lead to numerous local extinctions in the sub-polar regions, the tropics and semi-enclosed seas (Cheung et al 2009). Simultaneously, species invasion is projected to be most intense in the Arctic and the Southern Ocean. With these elements taken together, the model predicted dramatic species turnovers of over 60% of the present biodiversity, implying ecological disturbances that potentially disrupt ecosystem services (Cheung et al 2009).

The Intergovernmental Panel on Climate Change (IPCC) 5th Report [36] (2014) includes chapters to explicitly address ocean climate change issues for the first time. The Working Group I and Working Group II Contributions to the Fifth Assessment Report include chapters on the ocean (WG I) and Climate Change 2014: Impacts, Adaptation, and Vulnerability including Chapters on Coastal and Oceans ecosystems, and sections on biodiversity(WGII). Working Group I consider ocean biogeochemical changes, including ocean acidification in their Chapter 3 (Observations - Ocean), and in Chapter 6 on carbon and other biogeochemical cycles. Working Group II considered water property changes, including temperature and ocean acidification in Chapter 6, "*Ocean Systems*". In addition, "*Carbon Cycle including Ocean Acidification*" were identified as cross-cutting themes across (predominantly) WG1 and WG2.

The 5th IPCC report identifies that the effects of increasing greenhouse emissions — in particular carbon dioxide — on the oceans is likely to be significant. The basic chemistry of ocean acidification is well understood. These are the 3 main concepts:

1. More CO2 in the atmosphere means more CO2in the ocean;
2. Atmospheric CO2 is dissolved in the ocean, which becomes more acidic; and
3. The resulting changes in the chemistry of the ocean disrupts the ability of plants and animals in the sea to make shells and skeletons of calcium carbonate, while dissolving shells already formed.

The Summary for Policymakers (IPPC AR5, 2014) warns that ocean related climate change at the global scale overshadows the existing challenges of managing local impacts causing declines in marine biodiversity in the face of current levels of human use and impact. "*Due to projected climate change by the mid 21st century and beyond, global marine-species redistribution and marine-biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services (high confidence). Spatial shifts of marine species due to projected warming will cause high-latitude invasions and high local-extinction rates in the*

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

tropics and semi-enclosed seas (medium confidence)". (Quote from IPCC https://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf)

As the Global Biodiversity Outlook 3 report[37] summarizes, despite numerous successful conservations measures supporting biodiversity, none of the specific targets 2000 to 2010 were met, and biodiversity losses continue throughout most of the world.

In addition, "despite an increase in conservation efforts, the state of biodiversity continues to decline, according to most indicators, largely because the pressures on biodiversity continue to increase. There is no indication of a significant reduction in the rate of decline in biodiversity, nor of a significant reduction in pressures upon it."

The Outlook Report provides a reasonable understanding of the nature and extent of the problems facing marine biodiversity and marine resources. There are examples of effective actions to address some of these problems but management performance is generally insufficient and inadequately coordinated to address the growing problems of marine biodiversity decline and ecosystem change.

The World Bank, together with IUCN and Environmental Services Association released a brief for decision-makers entitled, "Capturing and Conserving Natural Coastal Carbon – Building Mitigation, Advancing Adaptation"[38]. This brief highlights the crucial importance of carbon sequestered in coastal wetlands and in submerged vegetated habitats such as seagrass beds, for climate change mitigation.

Hobday et al (2006) reported on the relative risks and likely impacts of ocean climate change and ocean acidification to marine life in Australian waters. 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

The Hub analysed patterns and dynamics of marine biodiversity through four research programmes to determine the appropriate units and models for effectively predicting Australia's marine biodiversity. These programmes were designed to develop and deliver tools needed to manage Australia's marine biodiversity in a changing ocean climate. The final report from three years intense research is available at the website[39]. 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[40].

In late June 2011, two science-based reports heightened concerns about the critical state of the world's oceans in response to ocean climate change. One focuses on the potential impacts of ocean acidification on fisheries and higher trophic level ecology and takes a modelling approach to scaling from physiology to ecology (Le Quesne & Pinnegar 2011) and the other assesses the critical state of the world's oceans in relation to climate change and other stressors (Rogers & Laffoley (2011). MacDiarmid et al (2012) undertook an expert assessment of the impact of sixty-five potentially hazardous human activities on sixty-two identifiable marine habitats in New Zealand's territorial seas and 200 nautical mile exclusive economic zone (EEZ). They found that many of the biggest threats stemmed from human activities outside the marine environment itself. The two biggest threats were ocean acidification and ocean warming. Seven other threats deriving from global climate change all ranked in the top 20 threats indicating the importance of global climate change to New Zealand's marine ecosystems.

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[37] http://www.cbd.int/doc/publications/gbo/gbo3-final-en.pdf

[38] 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?'

[39] www.marinehub.org/

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

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 16.1: Potential biological impacts of climate change on Australian marine life. The ratings in this table are based on the expected responses to predicted changes in Sea Surface Temperature (SST), slinity, 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. While generally accurate, new data is suggesting unanticipated or higher levels of threats for some taxa and habitats. Examples include that impacts of climate change on wind intensification on coastal upwelling systems is likely to be a strong driver of productivity, with implications for coastal and pelagic food webs (Sydeman et al 2014), that geographic limits to species range shifts are predicted to limit the ability of species to shift in response to temperature change (Burrows et al 2014), and that ocean acidification is receiving stronger attention in temperate coastal syst

CENSUS OF MARINE LIFE 2000–2010

In 2010, the international initiative to conduct a Census of Marine Life (CoML)[41] was concluded after ten years of accessing and databasing existing records, sampling and exploration around the globe. The Census was an unprecedented collaboration among researchers from more than 80 nations to assess and explain the diversity, distribution, and abundance of life in the oceans. During the last decade, the 2700 scientists involved in the Census have mounted 540 expeditions, identified more than 6000 potentially new species, catalogued upward of 31 million distribution records, and generated 2600 scientific publications. NIWA scientists were part of the team that led

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

CenSeam[42], the seamount component of the Census of Marine Life, and scientists from NIWA and the University of Auckland played significant roles in a number of other programmes. The New Zealand International Polar Year-Census of Antarctic Marine Life (IPY-CAML) voyage to the Ross Sea in 2008 was a major contribution to CoML.

The Census facilitated activities that led to better assessments of global marine biodiversity, resulting in an increase in the total number of known marine species by about 20 000, from 230 000 in 2000 to about 250 000 in 2010. Among the millions of specimens collected in both familiar and seldom-explored waters through new collecting, the Census found more than 6000 potentially new species and completed formal descriptions of more than 1200 of them. It also found that some species considered to be rare are commoner than previously thought (Ausubel et al 2010). The digital archive (the Ocean Biogeographic Information System OBIS (http://www.iobis.org/) has now grown to 31 million observations, and the Census compiled the first regional and global comparisons of marine species diversity. It helped to create the first comprehensive list of the known marine species, and also helped to compose web pages for more than 80 000 species in the Encyclopaedia of Life[43].

Applying genetic analysis on an unprecedented scale to a dataset of 35 000 species from widely differing major groupings of marine life, the Census graphed the proximity and distance of relations among distinct species, providing new insight into the genetic structure of marine diversity. With the genetic analysis often called barcoding, the Census sometimes decreased diversity but generally its analyses expanded the number of species, especially the number of different microbes, including bacteria and archaea.

The Census has overwhelmingly demonstrated that the total number of species in the ocean remain largely unknown. The Census also demonstrated that evidence of human impacts on the oceans extends to all depths and habitats and that we still have much to learn to integrate use of resources with stewardship of a healthy marine ecosystem. The Census results could logically extrapolate to at least a million kinds of eukaryotic marine life that earn the rank of species and to tens or even hundreds of millions of kinds of microbes. However, an expert assessment recently determined that only between one third and two thirds of marine eukaryotic species may be undescribed and previous estimates of there being more than one million such species appear highly unlikely (Appeltans et al 2012).

A summary of the overall state of knowledge about marine biodiversity after the Census by Costello et al (2010) places New Zealand sixth out of 18 national regions based on the collective knowledge assembled by the Census National and Regional Implementation Committees (NRIC) and comparing the Spearman rank correlation coefficients between known diversity (total species richness, alien species, and endemics) and available resources, such as numbers of taxonomic guides and experts. (Figure 16.2).

All NRICs reported what they considered the main threats to marine biodiversity in their region, citing published data and expert opinions. Although the reports were not standardised, the threats identified were grouped into several overarching issues. The data on biodiversity threats were integrated so as to rank each threat from 1 (very low) to 5 (very high threat) in each region. New Zealand was placed 12th out of 18 regions in terms of overall threat levels to biodiversity, overfishing and alien species invasion. Habitat loss and ocean acidification were identified as the biggest threats to marine biodiversity and marine habitats in New Zealand (Costello et al 2010, MacDiarmid et al 2012).

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

[43] www.eol.org/

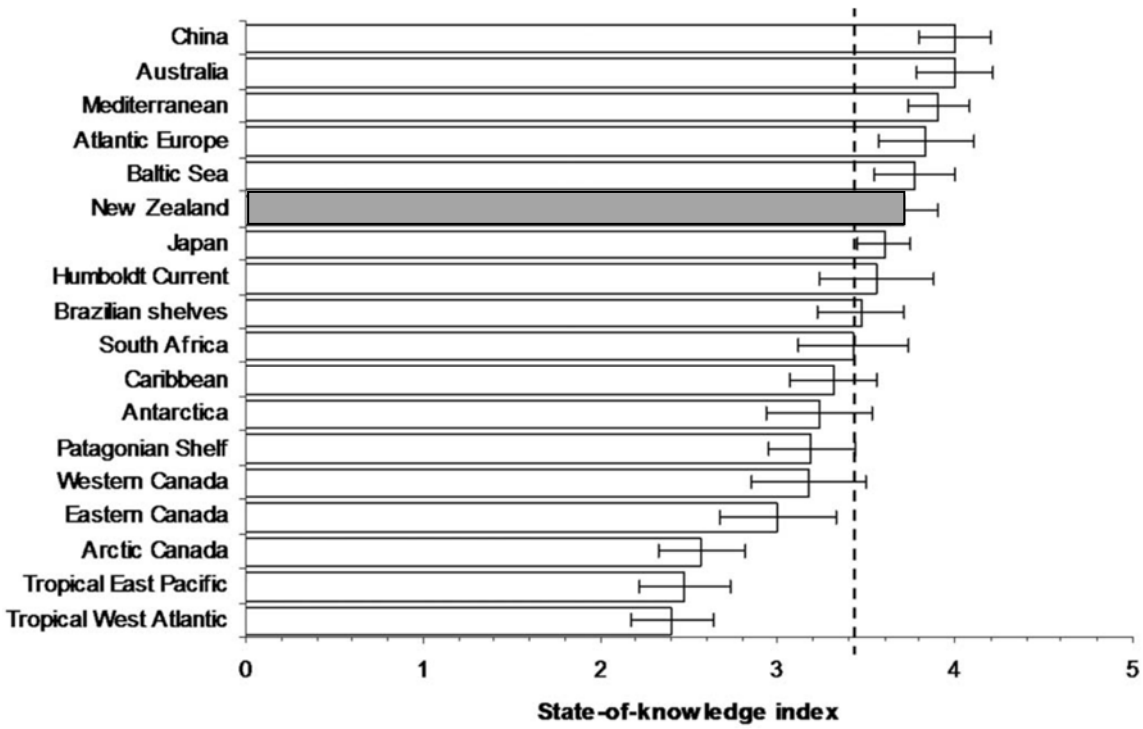


Figure 16.2: The regions are ranked by their state-of-knowledge index (mean ± standard error) across taxa. Dashed line represents the overall mean. (Image Source Costello et al 2010).

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[44]. 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[45]) which stimulates, encourages, coordinates and otherwise facilitates observations by national or international organizations. A Southern Ocean Observing System (SOOS[46]) is up and running. The SOOS International Project Office was officially opened in August 2011, hosted by the Institute for Marine and Antarctic Studies (IMAS) at the University of Tasmania, Australia[47].

Others include:

- ARGO, an international deepwater monitoring system of free floating buoys that are part of the integrated global observation strategy[48].
- The Ocean Observation Systems (OOS) in Canada have demonstrated many positive benefits.
- The Continuous Plankton Recorder (CPR) Surveys have been collecting data from the North Atlantic and the North Sea on the ecology and biogeography of plankton since 1931[49]. Sister CPR surveys around the globe include the SCAR SO-CPR

[44] http://jncc.defra.gov.uk/page-4233
[45] www.ioc-goos.org/index.php?option=com_content&view=article&id=12&Itemid=26&lang=en
[46] http://www.soos.aq/
[47] http://www.scar.org/soos/
[48] http://www.qc.dfo-mpo.gc.ca/publications/science/evaluation-assessment-eng.asp
[49] www.sahfos.ac.uk/

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[50].

- 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[51].
- 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[52]) which coordinates long-term marine biodiversity monitoring at a European level.
- New Zealand has now formed a partnership with Australia's Integrated Marine Observing System (IMOS[53]) which was established in 2007. IMOS is designed to be a fully integrated national array of observing equipment to monitor the open oceans and coastal marine environment around Australasia, covering physical, chemical and biological variables. All IMOS data is freely and openly available through the IMOS Ocean Portal for the benefit of Australian and New Zealand marine and climate science as a whole.
- Oceans 2025[54] is an initiative of the Natural Environment Research Council (NERC) funded Marine Research Centres. This addresses environmental issues that require sustained long-term observations.
- The Global Ocean Acidification Observing Network (GOA-ON) is an existing global ocean carbon observatory network of repeat hydrographic surveys, time-series stations, floats and glider observations, and volunteer observing ships. The interactive map below offers the best information available on the current inventory of global OA observing platforms. With participation from scientists from over 30 countries (http://www.goa-on.org/NetworkMembers.html), GOA-ON is a strong foundation of observations of the carbonate chemistry targeted to understand chemical and ecological changes resulting from ocean acidification from regions throughout the world.

New Zealand has now developed the NZ-AON (NZ Ocean Acidification monitoring Network) which was initiated in 2014 and now has 11 sampling sites around NZ. This is run by NIWA & the University of Otago.

A challenge for MPI and New Zealand is how to assimilate any or all of the above monitoring approaches as a means of measuring biodiversity baseline levels and the nature and extent of biodiversity changes, especially as a means of assessing the effectiveness of management measures to protect or enhance biodiversity or halt its decline.

VALUATION OF BIODIVERSITY AND ECOSYSTEM MATERIAL

The national and global responsibility for New Zealand to maintain a strong environmental record in fisheries and other marine-based industries is increasing. There is growing awareness of international treaties and agreements that New Zealand is party to. Global markets are becoming increasingly sensitive to our national environmental record. Fishing companies who meet rigorous standards receive Marine Stewardship Council Certification for certain fisheries (currently, hoki trawl, southern blue whiting pelagic trawl and albacore tuna troll fisheries). Proposals to exploit other living marine resources or extract non-living marine resources are increasingly under scrutiny to ensure that such activities do not adversely degrade the marine environment or impact on

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

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

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

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

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

marine living resource industries such as fishing and aquaculture.

The invisibility of biodiversity values has often encouraged inefficient use or even destruction of the natural capital that is the foundation of our economies. A recent international initiative "The Economics of Ecosystems and Biodiversity" (TEEB) [55] demonstrates the application of economic thinking to the use of biodiversity and ecosystem services. This can help clarify why prosperity and poverty reduction depend on maintaining the flow of benefits from ecosystems; and why successful environmental protection needs to be grounded in sound economics, including explicit recognition, efficient allocation, and fair distribution of the costs and benefits of conservation and sustainable use of natural resources. Valuation is seen as a tool to help recalibrate the faulty economic compass that has led to decisions about the environment (and biodiversity) that are prejudicial to both current well-being and that of future generations.

The idea of putting monetary values on natural capital is not without controversy; many underpinning life-supporting services such as nutrient recycling are difficult to quantify at scale, and assigning dollar values to many types of ecosystem services is fraught with difficulty.

A new United Nations platform, the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), was established in 2012, and provides a mechanism to assess the state of the planet's biodiversity, its ecosystems and the essential services they provide to society. This new international platform is similar in function to the IPCC in terms of bringing together international expertise, and will review information on the provisioning of biodiversity for ecosystem services, stimulate science and innovation on this research topic, and interact with national and international management agencies to integrate IPBES results into policy and management.

The past 750 years of human activity have impacted on marine environments. For example, depletion of fur seals and sea lions occurred from the earliest days of human settlement, not just with European arrival (Smith 2005, 2011). There was also a pulse of sedimentation coinciding with the initial clearance of 40% of New Zealand forests within 200 years of Polynesian settlement (McWethy et al 2010). Impacts have occurred near population centres, as well as in more remote areas and to depths in excess of 1000 metres (MacDiarmid et al 2012, Ministry for Primary Industries 2012). In some cases by looking back over historical records it becomes apparent how much biodiversity loss has occurred. Over long time spans incremental impacts can lead to major shifts in biodiversity composition. An analysis of marine biodiversity decline over a couple of decades could miss the major changes that can occur incrementally over long periods.

While New Zealand has reasonable archaeological, historical and contemporary data on the decline in abundance of individual marine species, in some cases over a period of 750 years (e.g., MacDiarmid et al in prep), current trends in the status of New Zealand's marine biodiversity are difficult to determine for several reasons. These include a lack of both pre-disturbance baseline and recent information, and a lack of a nationally coordinated approach to assessing and monitoring marine biodiversity.

A re-evaluation of the threat status of New Zealand's marine invertebrates was undertaken by the Department of Conservation in 2009, and identified no taxa that had improved in threat status as a result of past or ongoing conservation management action, nor any taxa that had worsened in threat status because of known changes in their distribution, abundance or rate of population decline (Freeman et al 2010). The authors cautioned however that only a small fraction of New Zealand's marine invertebrate fauna had been evaluated for their threat status and that many taxa remain 'data deficient' or unlisted. In June 2013, the Department of Conservation held an expert workshop to assess New Zealand's marine invertebrates using the New Zealand Threat Classification System (NZTCS) criteria, updating a previous listing process from 2009 (Freeman et al. 2009). A number of changes were made to the list, including those resulting from taxonomic name changes (Table 16.1) (Freeman et al. 2013). A total of 415 taxa were assessed, with a number of changes made to threat

[55] 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/

categories to reflect changes in certainty or knowledge around the distribution, abundance and population trends of some taxa, or to reflect a reinterpretation of the available data. All marine invertebrates assessed in 2009 were reassessed and an additional 108 taxa were also assessed. Most of the latter were assessed as either data deficient, or naturally uncommon. One taxon that was included in the list produced in 2009 was excluded from the current listing—*Cellana strigilis bollonsi* Powell, 1955, which is now considered to be a synonym of *C. oliveri*. While a number of changes were made to the threat categories assigned to the marine invertebrates we assessed, just one change was the result of an actual decline in abundance. The brachiopod *Pumilus antiquatus* (a monotypic, endemic genus) was listed as Nationally Endangered in 2009, but listed as Nationally Critical in 2013, to reflect an apparent decline in abundance at the sites it has previously been recorded from (Otago Harbour and Lyttleton). No taxa improved in status between 2009 and 2013 as a result of an actual change in distribution or abundance. Six taxa were listed as Nationally Critical and an additional five taxa were also included in the Threatened category. The majority of taxa we assessed were classified as At Risk, with most of these being taxa that are naturally uncommon, such as island endemics. A large number of marine invertebrates were assessed as Data Deficient. However, the majority of the New Zealand marine invertebrate fauna (over 95%) remains unassessed in the New Zealand Threat Classification System. While representatives of phyla not assessed in 2009 were included in the current assessment (e.g. sponges, phylum porifera), the full range of marine invertebrate phyla are not yet represented in the list.

A re-evaluation of marine mammal threat status found that relative to the previous listing, the threat status of two species worsened: the NZ sea lion (*Phocarctos hookeri*) was uplisted to Nationally Critical and the bottlenose dolphin (*Tursiops truncatus*) was uplisted to Nationally Endangered. No species was considered to have an improved status (See Chapter on marine mammals and also Baker et al 2010).

The most recent State of the Environment Report in New Zealand (MfE 2007) covers marine biodiversity in the Oceans section which states:

"Of the almost 16,000 known marine species in New Zealand, 444 are listed as threatened. Well-known species of particular concern include both subspecies of Hector's dolphin, New Zealand sea lion, southern right whale, Fiordland crested penguin, and New Zealand fairy tern. Land-based pressures on the inshore marine environment, as well as pressures on fisheries stocks, can be expected to persist and, therefore, continue to pose a challenge to the health of the marine environment. The increasing number of introduced species brought to New Zealand through marine-based trade and travel, and climate change may exacerbate existing pressures. Further information about our marine environment is needed if we are to help set priorities for future use and protection of our oceans".

Two major knowledge gaps identified by MfE 2007 that hinder resource management are sparse biodiversity baseline information; and the lack of a systematic national-scale approach to monitoring biodiversity trends (i.e. by comparing subsequent studies to the baseline information) in New Zealand.

The most recent summary of knowledge about marine biodiversity in New Zealand is provided by Gordon (2009, 2010, 2012) and Gordon et al (2010). Table 16.1 gives a tally of 17 987 living species in the EEZ, including 4320 known undescribed species in collections. More recent updates using all records available within OBIS, NIWA and Te Papa collections assessed the spatial distribution of biodiversity records and suggested metrics for reporting on the status of marine biodiversity (Lundquist et al 2014).

Species diversity for the most intensively studied animal phyla (Cnidaria, Mollusca, Brachiopoda, Bryozoa, Kinorhyncha, Echinodermata, Chordata) is more or less equivalent to that in the ERMS (European Register of Marine Species) region, an area 5.5 times larger than the New Zealand EEZ (Gordon et al 2010), suggesting that the New Zealand region biodiversity is proportionately richer than the ERMS region (Table 16.1).

In New Zealand, a number of new marine research projects were initiated in 2012 that contributed to the state of knowledge and management of marine biodiversity. The 'Marine Futures' programme (2012-2014) investigated decision-making frameworks for ocean management and developed new tools for enabling participation of all stakeholders (public, iwi, industry, government), to facilitate economic growth, improve marine stewardship and ensure that cumulative stresses placed on the environment do not degrade the ecosystem beyond its ecological adaptive capacity (MBIE project code C01X1227). The 'Ross Sea Climate & Ecosystem' (concluding in 2016) is modelling likely future changes in the physical environment

of the region and potential consequences of these changes on the ecosystem in terms of functional links between the environment and the marine food web (MBIE project code C01X1226). 'Management of offshore mining' (concluding in 2016) will develop a clear framework that will guide appropriate and robust environmental impact assessments and the development of integrated environmental management plans for the marine-mining sector, other resource users and resource management agencies (MBIE project code C01X1228).

One of the largest marine research developments in 2014 has been the launch of the National Science Challenge "Sustainable Seas"[56] The Challenge aims to enhance the utilisation of our marine resources within environmental and biological constraints.

To do this, the Sustainable Seas Challenge will:

- Assess the cultural, economic and environmental values of our oceans and coasts
- Investigate and describe the impacts of natural and human stresses on marine ecosystems
- Identify options for environmental mitigation or restoration; and
- Overcome impediments to enhanced resource use

Achieving this aim will require a new way of managing the many uses of our marine resources that combines the aspirations and experience of Māori, communities, and industry with the evidence of scientific research to transform New Zealand into a world-leader in sustainable marine ecosystem-based management.

Core purpose funding within the Coasts and Oceans Centre at NIWA include "Managing Marine Stressors: Quantifying and predicting the effects of natural variability, climate change and anthropogenic stressors to enable ecosystem-based approaches to the management of New Zealand's marine resources" and within the Fisheries Centre, "Ecosystem Approaches to Fisheries Management: Determine the impact of fisheries on the aquatic environment to inform an ecosystem-based approach to fisheries management and contribute to broader ecosystem-based management approaches in conjunction with the Coasts & Oceans Centre.

THE MPI BIODIVERSITY RESEARCH PROGRAMME

The recognition of increasing societal expectation to use fisheries management measures that will achieve biodiversity conservation was signalled by MPI through Fisheries 2030 [57] in its long-term commitment to– "ecosystem based fisheries management" and to ensuring that "biodiversity and the function of ecological systems, including trophic linkages, are conserved". While New Zealand's environmental performance with regard to fishing is perceived to be relatively high on an international scale, the Ministry is not complacent about the ongoing requirement to monitor and provide evidence that measures to achieve biodiversity conservation needs are being met. This is particularly true of the need to better understand and mitigate the effects of fishing in the areas impacted by fishing. The effects of fishing on the aquatic environment and risks to biodiversity and the aquatic environment are supported through MPI's 10 year 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" in New Zealand (see footnote 12). These include aesthetic and cultural values as well as other economic values such as tourism and marine recreation other than fishing[58]. To link socio-economic values of biodiversity to science supporting fisheries management will require a multi-disciplinary approach only just beginning in New Zealand.

MPI responded to the NZBS in 2000 with the establishment of the MPI Biodiversity Programme which has run successfully for more than 10 years with 64 research projects and a large number of published outputs,

[56] http://www.beehive.govt.nz/release/sustainable-seas-national-science-challenge-launched

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

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

presentations and contributions to NZ and CCAMLR management measures.

The Ministry is also one of several New Zealand government agencies with a strong interest and a statutory management mandate in the Ross Sea region of Antarctica through the Antarctic Marine Living Resources Act 1981. MPI Antarctic science contributes strongly to New Zealand's whole-of-government involvement in contributions to the Commission for the Convention on Antarctic Marine Living Resources (CCAMLR) and the Antarctic Treaty. Research conducted under the BioRoss component of the MPI Biodiversity Programme seeks to help New Zealand deliver on its international obligations to support an ecosystem-based approach to management in Antarctic waters. There are strong links with the MPI Antarctic Working Group research and with other Ross Sea ecosystems research carried out under NIWA core purpose Fisheries, and Coast and Oceans Centres (e.g., Sharp et al 2010).

Table 16.1: Diversity of marine species found in the New Zealand region (after Gordon 2010, 2012; Gordon et al 2010 and current unpublished NIWA data).

Taxonomic group	No. species[1]	State of knowledge (1 low, 5 high)	No. Alien species naturalised	No. experts	No. ID guides[2]
Superkingdom Prokaryota	**82**	**1-2**	**>1**	**3**	**1**
Cyanobacteria	40	3-4	1	2	1
All other Bacteria	42	1	?	1	0
Superkingdom Eukaryota	**17 905**	**3-4**	**185**	**59**	**77**
Kingdom Protozoa	**53**	**2**	**4**	**5**	**4**
Kingdom Chromista	**2 541**	**3-4**	**14**	**7**	**3**
Ochrophyta	858	3-4	11	1	2
Miozoa (incl. dinoflagellates)	249	3-4	0	2	0
Retaria (incl. foraminifera)	1 217	4-5	3	2	3
All other Chromista	217	2-3	0	1	0
Kingdom Plantae	**711**	**4-5**	**15**	**7**	**6**
Chlorophyta	156	3-4	0	2	2
Rhodophyta	550	4	12	2	2
Tracheophyta	5	5	3	3	2
Kingdom Fungi	**89**	**3**	**1**	**2**	**0**
Kingdom Animalia	**14 511**	**3-4**	**150**	**40**	**68**
Porifera	770	3	7	1	5
Cnidaria	1 114	4	24	0	7
Platyhelminthes	324	2	2	1	3
Mollusca	3 595	4	15	4	2
Annelida	793	3-4	33	1	2
Bryozoa	957	3-4	29	2	4
Arthropoda (esp. Crustacea)	2 979	4	27	11	17
Echinodermata	636	5	0	3	6
Tunicata	193	4	3	1	6
All other invertebrates	1 723	2-5	4	5	12
Fishes	1 254	4-5	6	6	8
All other vertebrates	173	5	0	4	4
TOTAL REGIONAL DIVERSITY[3]	**17 987**	**3-4**	**186**	**62**	**78**

[1]Sources of the tallies: scientific literature, books, field guides, technical reports, museum collections.

[2]Identification guides cited in Gordon et al (2010).

[3]Totals from Gordon (2009, 2010, 2012, 2013), Gordon et al (2010) and Nelson (2013) and unpublished NIWA data.

The biodiversity research programme is guided by a multi-stakeholder biodiversity research advisory group (BRAG), chaired by MPI. The research commissioned for the period 2001–2005 reflected goals set by the NZBS and the BRAG, while remaining compatible with the Ministry of Fisheries Statements of Intent (SOIs). During the first three years of this period, the Ministry of Fisheries also commissioned marine biosecurity research under NZBS, but this was transferred to Biosecurity New Zealand (MAFBNZ) in 2004. From 2006 to 2010, the programme evolved further with

the development of a 5-year work programme to address shortcomings identified in a review of the NZBS by Clark & Green (2006). An overview of the current Biodiversity Programme at a glance is given in Figure 16.3.

OVERALL PROGRESS IN MPI MARINE BIODIVERSITY RESEARCH

The MPI Marine Biodiversity Research programme has three overarching science goals:

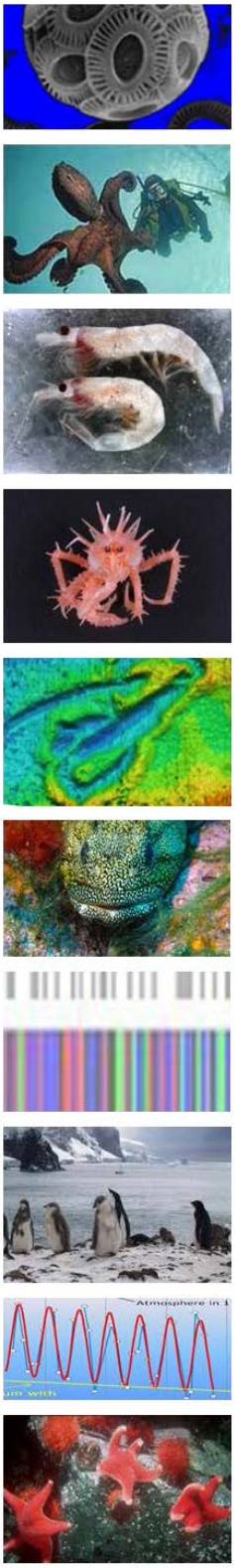
- To describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed.
- To determine the functional role of different organisms or groups of organisms in marine ecosystems, and assess the role of marine biodiversity in mitigating the impacts of anthropogenic disturbance on healthy ecosystem functioning.
- To identify which components of biodiversity are required to ensure the sustainability of healthy marine ecosystems as well as to meet societal values on biodiversity.

More specific Science Objectives developed below have been modified by BRAG over time and are used to focus the research commissioned:

1. To classify and characterise the biodiversity, including the description and documentation of biota, associated with nearshore and offshore marine habitats in New Zealand.
2. To develop ecosystem-scale understanding of biodiversity in the New Zealand marine environment.
3. To investigate the role of biodiversity in the functional ecology of nearshore and offshore marine communities.
4. To assess developments in all aspects of diversity, including genetic marine biodiversity and identify key topics for research.
5. To determine the effects of climate change and increased ocean acidification on marine biodiversity, as well as effects of incursions of non-indigenous species, and other threats and impacts.
6. To develop appropriate diversity metrics and other indicators of biodiversity that can be used to monitor change.
7. To identify threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation.

To date, 64 research projects have been commissioned. Early studies focused primarily on Objectives 1 and 2 and resulted in reviews, Identification Guides, habitat and community characterisations, and revised taxonomy for certain groups of organisms. These objectives have also resulted in large collaborative ship-based surveys that have contributed to improved seabed classification in New Zealand waters and the exploration of new habitats in the region and in Antarctic waters. Over time, the complexity and scale of studies has increased with projects on the functional ecology of marine ecosystems from localised experimental manipulation to broad-scale observations across hundreds of square kilometres under Objective 3. Such studies have also pursued the development of improved measures of biodiversity and indicators under Objectives 6 and 7. A study on changes in shelf ecosystems over the past 1000 years is yielding insights into the effects of long-term climate change, land-use effects and fishing on marine ecosystems while more recently, some studies have begun to address the effects of ocean acidification on marine biodiversity under Objective 5. A study underway has reviewed genetic variation in the New Zealand marine environment and is conducting field observations on several species to examine genetic variation across latitudinal gradients. Aspects of the seven Objectives have also been addressed through a range of biodiversity projects in the Ross Sea region including the International Polar Year Census of Antarctic Marine Life project (IPY-CAML). A key to study findings is consideration of biodiversity within the context of the carrying capacity of the system and the natural assemblages of biota supported by that system in the absence of human disturbance.

Progress in the MPI Biodiversity Programme is summarised in Table 16.2.



BIODIVERSITY THEMES	KEY QUESTIONS
BIODIVERSITY PATTERNS & DISTRIBUTION • Fauna and flora (taxonomy, biosystematics) • Distribution & abundance of major groups • Reviews of existing knowledge • Biogeography • Drivers of observed patterns	• What is the abundance and distribution of marine biodiversity in NZ? • What are the key drivers of observed patterns in biodiversity? • How much marine endemism is there in NZ waters? • What is the organism size distribution? • How do patterns in biodiversity change over time?
HABITAT DIVERSITY • Biogenic reefs • Rocky reefs • Rhodolith beds • Seamounts • Soft sediments • Habitat mapping EEZ • Deepsea habitats • Physical and biological characterisation	• What are the relative goods and services offered by each habitat to aquatic environment health? • Can the assemblages and biodiversity of marine habitats in the EEZ be predicted by modelling? • Which habitats are at greatest risk from extraction practices? • What proportion of a given habitat needs to remain intact for healthy ecosystem functioning?
FUNCTIONAL DIVERSITY • The role of different animal/plant groups in the ecosystem • Trophic processes • Bentho-pelagic processes	• How does biodiversity contribute to the resilience of ecosystems to perturbation? • Can we use ecosystem function to classify biodiversity? • Which key processes need to be retained?
GENETIC DIVERSITY • Barcode of Life • Connectivity (populations, areas)	• What are the barriers to connectivity within species? • What is the role of endemism in characterising the evolutionary history and taxonomy?
THREATS TO BIODIVERSITY • Climate change and variability • Invasive organisms; fishing • Land-use effects • Cumulative effects	• What are the key threats? • Does biodiversity increase resilience to climate change? • Which components of the ecosystem will be most at risk from climate change?
METHODS • Measuring biodiversity • Classification • Predictive modelling • Biodiversity indicators • Monitoring biodiversity • Ecosystem approaches	• How can we best measure and portray biodiversity? • How scalable are results from a local scale to an ecosystem scale? • What do we need to monitor to measure risks and change to ecosystem health? • How can we measure the economic value of biodiversity and ecosystem services?
BIOROSS/ & IPY RESEARCH • Bioross coastal biodiversity • Subtidal ice-sea interface • Census of Antarctic marine Life survey for IPY, Ross Sea • Trophic modelling Ross Sea • Balleny Islands survey for MPA • Functional habitats	• What is the connectivity between biodiversity in the Ross Sea and NZ? • How are biota adapted to polar conditions and what is their sensitivity to perturbation? • Are MPAs a useful protection tool for the Ross Sea? • Are climate change effects on the ocean already impacting on the Ross Sea biota?

Figure 16.3: Summary of MPI Biodiversity Research Programme 2000–2013. [Continued on next page]

ACHIEVEMENTS & KNOWLEDGE TO DATE	CURRENT WORK
• Taxonomy of coralline algae and bryozoans (2 ID Guides) • Coral and seapen ID Guides produced • Review of macroalgae distribution on soft sediments • Contribution to several books on marine biodiversity in NZ • EEZ surveys on Fjordland, Spirit's Bay, Kermadec seamounts, Farewell Spit, Norfolk Ridge, Chatham Rise and Challenger Plateau. • Links to MAFBNZ biodiversity mapping; MEC, MFish BOMEC • Extensive new data sets and specimen collections obtained	• Ongoing taxonomic work in relation to deep sea corals (VMEs) • Ongoing taxonomic work on specimens collected from the Chatham-Challenger project and from the IPY –CAML project.
• Ecological input to improve MEC (fish, benthic invertebrates) • Deep-sea habitats , biogenic habitat and soft-sediment reviewed • Ocean Survey 20/20 habitats mapped Chatham-Challenger • Biodiversity of Kermadec and Chatham Rise seamounts mapped • Foveaux Strait habitats mapped • Classification of seamounts and VMEs developed • Testing of MEC with Chatham Challenger data • Rhodolith beds as havens of biodiversity in NZ	• Mapping biogenic structures • Mapping deepsea fisheries habitats in relation to ocean acidification threats from changing saturation horizons • Modelling benthic impacts
• Rocky reef ecosystem function studied • Chatham Rise fish feeding study completed • Productivity in horse mussel and echinoderm benthic communities determined • Bioindicators in estuarine systems in Otago determined • Chatham-Challenger functional component analysis completed • Shellhash habitat function in the coastal zone	• Ocean acidification on shellfish • Response and recovery of seabed to disturbance-modelling project
• Molecular ID of certain fish and plankton determined • EEZ and Ross Seaspecies added to Barcode of Life Database, • Genetic assessment of ocean microbe diversity • Seamount connectivity reviewed	• Connectivity among coastal shellfish fish populations
• Threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation identified • Monitoring of plankton on transect NZ to Ross Sea annually • Changes in coccolithophore diversity and abundance in NZ waters and predicted change as temp and acidification increase asessed • Long-term effects of climate change on shelf ecosystems determined	• Experimental response of shellfish pH and temp. • CPR monitoring • Initial appraisal for MEMP • Acidification in deepwater fish habitat
• Diversity metrics and other indicators to monitor change developed • Large-scale sampling protocols for habitat mapping determined • Acoustic habitat mapping tools developed • Workshop held on qualitative modelling and marine environment monitoring • Development of "OFOP" and DTIS-visual analytical methods • Predictive modelling techniques progressed for biodiversity on different scales • Development of data to end-user portal interfaced with NABIS	• Development of functional biota model for habitat classification • Qualitative and quantitative modelling of rocky reef ecosystem • Predictive modelling VMEs • Measuring risk and resilience (Chat-Chall objective)
• Latitudinal gradient project and ICECUBE completed in Ross sea • Fish taxonomy and ID guide developed for the Ross Sea • Foodweb and role of silverfish vs krill studied • IPY-CAML 2008; Ross Sea 2006, BioRoss 2004 surveys done • Subtidal and offshore biodiversity sampled, Balleny Islands 2006 • Seaweed diversity determined at Balleny Islands • Bioregionalisation of the Ross Sea region completed	• Uptake of biodiversity results to CCAMLR trophic modelling and biomass estimation, VMEs • New spp logged for CAML • Review of squids, octopus

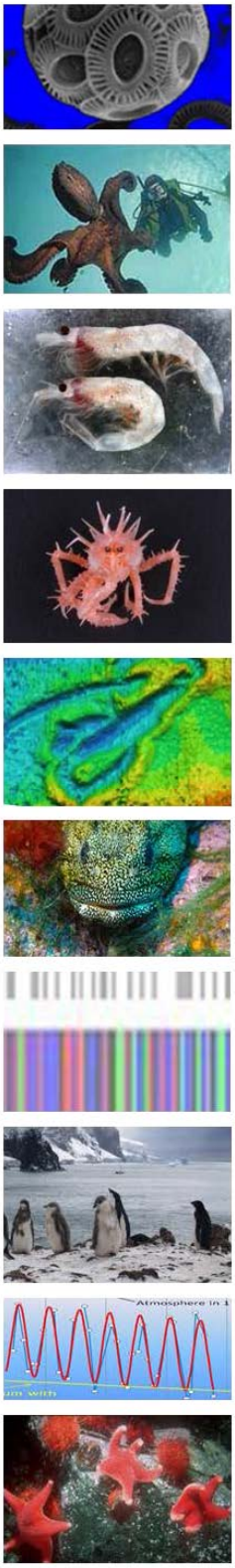


Figure 16.3 [Continued]: Summary of MPI Biodiversity Research Programme 2000–2013.

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

† Science objectives are- 1 characterisation and description; 2 ecosystem scale biodiversity; 3 functional role of biodiversity; 4 genetics; 5 ocean climate effects; 6 indicators; 7 threats to biodiversity. The objectives are detailed in MPI Biodiversity Programme: Part 2. Medium Term Research Plan 2011–2014.

Table 16.2: Progress on biodiversity research commissioned by MPI 2000–2014. Dark grey: Significant progress (several projects completed and results emerging from research underway). Light grey: Limited progress (some results emerging, more research needed). White: no substantive research. Diagonal-hatch: progress linked to large whole-of-government projects (e.g. Ocean Survey 2020) and/or other funding outside MPI (e.g. MBIE (MSI) funded projects, DOC Marine Coastal Services, MAFBNZ marine biosecurity research).

The chart depicts a logical flow down the page of increasing conceptual complexity from cataloguing of biodiversity to increasingly complex understanding of environmental drivers and functionality of biodiversity; and ultimately methods to develop standards and protection of biodiversity. Across the chart, the marine environment is graded from the coastline to offshore regions, and Antarctica. A full list of projects can be obtained from Appendix 17.9 at the back of this document.

Greatest progress has been made in the shallower inshore parts of the marine environment, not least because of cost and ease of access. However, by leveraging from existing offshore projects, significant progress has also been made to depths of 1500 m.

Biodiversity research based in Antarctica lags behind EEZ-based research, simply because of the difficulty in securing additional funding to access and work in such a remote and hostile marine environment. While the top left side of the figure shows the area of greatest progress, it would be a mistake to conclude that biodiversity work is completed in the Southern Ocean.

PROGRESS ON SCIENCE OBJECTIVE 1. CHARACTERISATION AND CLASSIFICATION OF BIODIVERSITY

The characterisation and classification of biodiversity requires an assessment of the abundance and distribution of marine life. Building on earlier research to map fish and squid species (Anderson et al 1998, Bagley et al 2000) and the biodiversity of the New Zealand ecoregion (Arnold 2004), literature reviews, taxonomic studies and habitat mapping surveys have been undertaken.

REVIEWS AND BOOKS

The following lists scientific reviews and books on biodiversity that were commissioned by the programme:

ZBD2000-01 A review of current knowledge describing the biodiversity of the Ross Sea region (Bradford-Grieve & Fenwick 2001, 2002; Fenwick & Bradford-Grieve 2002a, 2002b, Varian 2005).

ZBD2000-06 *"The Living Reef: The Ecology of New Zealand's Rocky Reefs"* (eds. Andrew & Francis 2003).

ZBD2000-08 A review of current knowledge describing New Zealand's Deepwater Benthic Biodiversity (Key 2002).

ZBD2000-09 Antarctic fish taxonomy (Roberts & Stewart 2001).

ZBD2001-02 Documentation of New Zealand Seaweed (Nelson et al 2002).

ZBD2001-04 "Deep New Zealand" (Batson 2003)

ZBD2001-05 Crustose coralline algae of New Zealand (Harvey et al 2005, Farr et al 2009, Broom et al 2008)

ZBD2001-06 Biodiversity of New Zealand's soft-sediment communities (Rowden et al 2012).

ZBD2003-09 Macquarie Ridge Complex Research Review (Grayling 2004).

ZBD2008-27 Scoping investigation into New Zealand abyss and trench biodiversity (Lörz et al 2012a).

In addition a major work which includes marine species – "The New Zealand Inventory of Biodiversity" (Gordon 2009, Gordon 2010, Gordon 2012), has been completed. Field identification guides have also been published by MPI on deepsea invertebrates (projects ENV2005-20 and ZBD2010-39, Tracey et al 2005, 2007, 2011b), bryozoans (project IPA2009/14 Smith & Gordon 2011) and on fish species (IDG2006-01 McMillan et al (2011 a, b, c) which further contribute to the accurate monitoring and identification of biodiversity in New Zealand waters.

PROJECTS

Several hundred new species of marine organisms have been discovered, and the known range of species extended, through exploratory surveys such as the NORFANZ project ZBD2002-16 (Clark & Roberts 2008); MSI's Seamount Programme, mainly commissioned through public-good science, supplemented by MPI projects ZBD2000-04, e.g., Rowden et al 2002, 2003, ZBD2001-10 (Rowden et al 2004), ZBD2004-01 (Rowden et al 2010) and MPI projects ENV2005-15, ENV2005-16 (Clark et al 2010a, Rowden et al 2008) and the Ocean Survey 20/20 programme (Clark et al 2009); inshore surveys of bryozoans at Tasman Bay ZBD2000-03 (Grange et al 2003); Farewell Spit, ZBD2002-18 (Battley et al 2005), Fiordland, ZBD2003-04 (Wing 2005); coralline algae ZBD2001-05, ZBD2004-07 (Harvey et al 2005, Farr et al 2009); soft sediment environments ZBD2003-08 (Neill et al 2012); rhodolith community study ZBD2009- 03 (Nelson et al 2012); offshore surveys of the Chatham Rise and Challenger Plateau funded through Ocean Survey 20/20 programme, ZBD2006-04 (Nodder 2008) and ZBD2007-01 (Nodder et al 2011; Hewitt et al 2011; Bowden 2011, Bowden & Hewitt 2012; Bowden et al 2011b; Bowden et al in press).

Research in the Ross Sea Region (BioRoss projects) have also generated records of new species including MPI projects ZBD2000-02 (Page et al 2001), ZBD2001-03

(Norkko et al 2002), ZBD2002-02 (Sewell et al 2006, Sewell 2005, 2006), ZBD2003-02 (Cummings et al 2003, 2006a), ZBD2003-03 (Rowden et al 2012a, 2013), ZBD2005-03 (MacDiarmid & Stewart 2012), ZBD2006-03 (Cummings et al 2003, 2006b;), ZBD2008-23 (Nelson et al 2010)and IPY2007-01 (Bowden et al 2011a, Clark et al 2010b, Eakin et al 2009, Hanchet, et al 2008a Hanchet et al 2008b, Hanchet et al 2008c, Hanchet et al 2008d. Hanchet 2009, Hanchet 2010, Koubbi et al 2011, Lörz & Coleman 2009, Lörz et al 2012, Mitchell 2008, O'Driscoll et al 2009. O'Driscoll 2009, O'Driscoll, et al 2010, O'Loughlin et al 2011).

HABITAT DIVERSITY, CLASSIFICATION AND CHARACTERISATION

The development of the Marine Environment Classification or "MEC" (Snelder et al 2006) was an important step in the delineation of areas with similar environmental attributes in the offshore environment. However, significant environmental drivers of variability in marine biodiversity, such as substrate type for seafloor organisms, were absent from the classification. In 2005, DOC and MPI jointly commissioned a project to optimise the MEC using fish distribution data. This project (ZBD2005-02) demonstrated a substantial improvement in the MEC classification for offshore habitats (Leathwick et al 2006a, b, c). In 2006, three projects to map coastal biodiversity were completed in the Coromandel scallop, Foveaux Strait oyster and southern blue whiting fisheries as part of fishery plan development for these fisheries (ZBD2005-04, ZBD2005-15, ZBD2005-16). These projects found that the biological distribution of organisms and their habitats were not well predicted by the MEC. MPI project (BEN2006-01) aimed to further optimise the MEC by producing a methodology for a Benthic Optimised MEC (Leathwick et al 2010). MPI Ecological studies to improve habitat classification and vulnerability indices have also been completed through MPI AEWG projects on seamounts (ENV2005-15, ENV2005-16) (e.g., Clark et al 2010c), and to supplement other studies funded by MPI, and MSI (e.g. ZBD2004-01, ZBD2001-10, ZBD2000-04, and CO1X0508).

Distribution maps providing indicative abundance and characterisation of biodiversity are now emerging and have been produced through projects using predictive modelling tools e.g., Compton et al 2012, ZBD2010-40 ; the fish optimised MEC in project ZBD2005-02 (Leathwick et al 2006a, 2006b, 2006c); the benthic optimised MEC (Leathwick et al 2009); Macroalgal diversity associated with soft sediment habitats ZBD2008-05; deep-sea benthic biodiversity in trench, canyon and abyssal habitats below 1500 m depth ZBD2008-27; distribution and associated biodiversity ZBD2009-03; and Chatham-Challenger project ZBD2007-01 (Hewitt et al in prep, Bowden et al 2012, Compton et al 2012).

Progress advanced considerably in recent years with the introduction of the whole-of-government Ocean Survey 20/20 Programme and Biosecurity New Zealand mapping projects (Beaumont et al 2008, 2010). In addition, MPI implemented spatial management tools (Benthic Protection Areas[59]) implemented on the basis of the Marine Environment Classification[60][61] to address broader statutory responsibilities on the environmental effects of fishing on biodiversity.

Current and recently started projects are as follows:

ZBD2012-03: Chatham Rise Benthos Ocean Survey 20/20

This project has two objectives: (1) to determine whether there are quantifiable effects on the benthos of gradients of fishing intensity, and (2) to document seabed habitats and fauna in previously unsampled areas of the central crest of Chatham Rise, particularly within the central Chatham Rise Benthic Protection Area (BPA). A single research voyage was undertaken in June 2013 (TAN1306) funded by OS 20/20, MPI, and NIWA, with additional funding from Chatham Rock Phosphate Ltd. (CRP) for research on the crest of the rise (Objective 2). For Objective 1, three towed-camera transects and three multicorer

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

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

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

samples were collected from each of six 10 x 10 km survey 'boxes' south of Mernoo Bank and five survey boxes on the southern flank of Chatham Rise along gradients of fishing intensity. For Objective 2, three camera transects were run in each of eight survey boxes within the Central Chatham Rise Benthic Protection Area (BPA).

Objective 1: effects on the benthos of gradients of bottom-contact fishing intensity.

This component of the research is still in progress, with all data sets planned to be ready for statistical analyses to start in early 2015. To date, 1,202 individual seabed photographs have been analysed to extract quantitative measures of benthic epifauna, bioturbation marks (burrows, tracks, etc.), and substratum type. Continuous video imagery is currently being analysed to capture quantitative data on larger, more sparsely-occurring benthic epifauna and bioturbation, and benthic and demersal fishes. Multicorer sediment samples have been analysed for sediment grain size and chemistry, and macro-infauna have been sorted from the sediments and are being identified and counted by taxonomists. Meiofauna samples were also collected from the sediment cores and these are being analysed by the University of Otago.

When complete, the multi-scale data from these analyses, ranging from cm^2 (meio- and macro-infauna, and sediments from multicorer samples), to m^2 (epifauna and substrata from still imagery), 100s m^2 (epifauna, substrata, and fishes from video imagery), and km^2 (multibeam echosounder data) will enable exploration of potential signatures of gradients in trawling disturbance on benthic habitats and communities.

Objective 2: benthic habitats and communities of the central crest region of Chatham Rise.

Work on this objective was completed in 2014, with detailed results and conclusions presented in NIWA Client Reports WLG2012-25 (Rowden et al. 2013) and WLG2014-9 (Rowden et al. 2014), and summarised in two progress reports to MPI.

Data on benthic epifaunal communities and physical substratum type extracted from the analysis of 937 seabed photographs from voyage TAN1306 were combined with comparable data from 3,908 photographs collected by CRP Ltd during a commercial survey of the area in 2012 (RV *Dorado Discovery*) and subsequently analysed by NIWA, to generate a comprehensive data set for the central Chatham Rise. Distribution maps of observed occurrences were generated for individual benthic taxa and for eight main benthic community types identified using multivariate statistical techniques. In addition to maps of observed point-occurrence, continuous coverage maps for individual taxa and communities were generated using the predictive species-environment modelling technique Boosted Regression Trees (BRT), which uses the relationships between observed point occurrences and gradients in physical environmental variables to predict probabilities of suitable habitat existing in unsampled areas.

Point-occurrence data showed that substrata across most of the crest of Chatham Rise, including the BPA, were primarily muddy soft sediments with sparse epifauna. The exception to this was in the central western part of the BPA, between approximately 179° 00' E and 179° 40' W, where areas of exposed hard substrata in the form of gravel-to-boulder sized phosphorite rock were widespread. These hard substrata supported patches of diverse epifaunal communities, often characterised by presence of the scleractinian stony coral *Goniocorella dumosa*. All such G. dumosa dominated habitats recorded were within the BPA and, with one exception, all were within the CRP Ltd, mining licence area (licence #50270). Predictive models, however, suggested that suitable environmental conditions for *G. dumosa* might also exist in an area to the northwest of the BPA that has not, to date, been surveyed. An important caveat for these predictions, however, is that the models do not include a detailed substratum-type layer. Because recruitment of *G. dumosa* and other sessile suspension-feeding taxa is dependent on the availability of exposed hard substrata at the seabed (i.e., rock), suitable oceanographic conditions are not sufficient in themselves to predict the occurrence of these taxa with any confidence.

ZBD2014-10 BPA Biodiversity

This is a new project that started in July 2015. It has 4 main objectives that will be addressed sequentially through to May 2017:

1) To update the inventory of benthic samples and biodiversity data available within BPA and Seamount Closure areas
2) To process and identify undescribed samples and material in selected BPAs and for selected taxonomic groups

3) To identify gaps in sample coverage, evaluate priority areas and design a sampling programme to collect appropriate data
4) To undertake an objective spatial management planning exercise to assess the effectiveness of the current BPAs to protect biodiversity

The project builds on initial work reported by Clark et al. (2014) that summarized NIWA data on benthic invertebrate samples from BPAs and seamount closure areas. Under Objective 1, a new extract of specimen data from the NIWA Invertebrate Collection has been completed, and is being combined with additional records from Auckland Museum and Te Papa Tongarewa collections. These data are in the process of being collated and analysed [October 2015].

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

Table 16.3.

Table 16.3: Other research linked to Objective 1 habitat classification and characterisation.

MPI	HAB2007-01 Biogenic habitats as areas of particular significance for fisheries management (complete) ZBD2006-02 NABIS (ongoing) Useful data related to defining potential VMEs are collected by MPI scientific fisheries observers working on NZ authorised fishing vessels that operate on the high seas in the South Pacific.
CRI core purpose or MBIE funding	NIWA Coasts & Oceans centre core-funded programmes: Programme 4 - Marine ecosystem structure and function: Programme 6 - Marine biosecurity C01X0907 Coastal Conservation Management (fish habitat classification) CO1X0906 Vulnerable deep-sea communities (mapping and sampling a range of deep-sea habitats (seamounts, slope, canyons, seeps, vents) (NIWA)
DOC	MEC development and application to MPAs, Regional surveys; refined habitat suitability modelling for protected coral species in the New Zealand EEZ has been undertaken along with the development of a pilot ecological risk assessment for protected corals. Both reports are currently in the final draft stage. Ongoing project that is developing a biophysical habitat classification system based on the JNCC classification system for the NZ coastal marine environment
OTHER	Victoria University of Wellington - ongoing projects involving marine biodiversity identification; marine protected areas
EMERGING ISSUES	
What portion of a given habitat type should remain intact to support sustainable ecosystems? What are the most effective predictive tools for predicting biodiversity in areas as yet unsampled?	

PROGRESS ON SCIENCE OBJECTIVE 2. ECOSYSTEM-SCALE RESEARCH

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

Recent theoretical and technical advances show great promise toward the goal of understanding the role of biodiversity in ecosystems. Technologies for remote sensing and deepwater surveying, combined with powerful integrative and interpretive tools such as GIS, climate modelling, qualitative ecosystem modelling, and trophic ecosystem modelling, will contribute to the development of an ecosystem-based approach to management (Thrush et al 1997, 2000), with potential benefits for marine conservation and management. Ecosystem modelling of species distribution (and habitats) with respect to known and projected environmental parameters will improve predictability for both broad and fine-scale biodiversity distribution. This has already resulted in improved

definition of environmental classifications addressing biodiversity assessment. It is also important to make progress in establishing the links between biodiversity and the long-term viability of fish stocks under various harvesting strategies. It is also important that modellers consider processes from all ecosystem function perspectives i.e., top-down effects such as predation (e.g. trophic modelling), bottom-up effects such as the environment (e.g., habitat classification based on environmental variable), and wasp-waisted systems where there are major effects in both directions.

PROJECTS

ZBD2008-01 Inshore biogenic habitats.

Existing knowledge on biogenic habitat-formers in the <5 – 200 m depth zone of New Zealand's continental shelf, from sources including structured fisher interviews ("Local Ecological Knowledge" LEK), primary and grey literature, and other sources have been integrated to generate maps of key biogenic habitats in New Zealand coastal waters.

Over 600 targets of interest were identified and marked on marine charts, with more than 200 of these targets being biogenic in nature. Fieldwork has been completed to verify and quantify biodiversity in biogenic habitats using Ocean Survey 20/20 vessel days on Tangaroa and a new MSI project to extend the survey potential of the project. New biogenic habitats have been identified, including extensive worm tube 'meadows' off the east coast of the South Island ("the Hay Paddock" and "Wire-weed"), with associated relatively high epi-faunal invertebrate diversity compared to adjacent bare sediments. Over 60 new species were also collected (dominated by sponges), along with range extensions of many other species. Analyses are underway for key selected areas included in the Tangaroa voyages, including offshore North Taranaki Bight, Ranfurly Bank, the polychaete meadows mentioned above, and the Otago Peninsula bryozoan fields.

ZBD2014-07 Southern Coralline algae habitat

Coralline algae are a structurally important component of coastal habitats, and play an important role in ecosystem processes. This project has the following objectives:

1. Document critical baseline information on the diversity of coralline algae in southern New Zealand using morphological and molecular identification.

2. Develop coralline reference collection from habitats and regions predicted to experience stress from ocean acidification 3. Prepare identification guide for coralline algae of southern New Zealand.

ZBD2014-06 Macroalgae mapping and utility as national indicators

Kelp and fucoid algae form large underwater forests, providing three dimensional structures for fish and invertebrate species and creating canopy for other algae. Because of their central role in a range of ecological processes on temperate reefs and adjacent habitats, loss of canopy-forming algae is likely to be associated with significant loss of associated species and ecological function. Loss of subtidal macroalgal forests is an increasingly common problem in temperate marine ecosystems, particularly on urbanised coasts. This project has the following objectives:

1. Summarise

a) the national and international literature on the use of macroalgae in monitoring programmes,

b) data available for laminarians and fucoid algae in New Zealand with respect to use in monitoring programmes, distributional data and response to environmental change

2. Establish the susceptibility of selected New Zealand laminarians and fucoids to selected environmental stressors

3. Establish the utility of selected macroalgae as monitoring tools for the assessment of ecosystem health and test methods for mapping distribution for baseline monitoring.

DOC-funded research on Ecological Integrity

This programme, undertaken through a partnership with Air New Zealand, has an objective to better understand the concept of ecological integrity in the New Zealand marine environment, and develop a suite of effective and comprehensive methods and tools for monitoring and reporting on species and ecosystems, processes, functioning and health in the marine environment. A key area of research and development work has been the identification and testing of indicators of ecological

integrity for New Zealand's marine protected areas, but the application of these indicators may extend beyond these conservation areas. The indicators are part of a broader Biodiversity Assessment Framework being developed by DOC. An example of one of the indicators being trialed is the use of functional traits (de Juan et al 2015).

Southeast Marine Protection Forum: DOC is supporting a stakeholder-led forum that is developing MPA proposals for the Otago coast, including provision of technical and scientific support (such as provision of SeaSketch as a conservation planning tool).

Review of citizen science programmes for marine monitoring: DOC is exploring mechanisms for better involving communities in marine monitoring and in turn increasing the capacity to undertake monitoring in the marine environment.

Estuaries: DOC is developing an internet-based estuaries resource hub. The first component connects current estuarine restoration and monitoring work around the country and provides restoration and citizen science resources (some are specifically for iwi, hapu and whanau). The second part will be a GIS portal with management relevant information layers designed for a wide range of users.

Marine ecosystem services: A review of ecosystem services in the marine environment has been completed [62]. Additional work is ongoing on developing an ecosystem services matrix. The objective of that work is to produce a methodology for characterizing the benefits provided by different ecosystem components within the coastal marine environment.

Cultural indicators programme: DOC is supporting the development of Marine Cultural Health Indicators with Te Rūnanga o Toa Rangatira (TRoTR) and Greater Wellington Regional Council (GWRC). This work will deliver a recommended monitoring programme that can be utilised by DOC, TRoTR & GWRC to monitor the marine environment from a Ngāti Toa perspective; a way in which TRoTR can build capability of staff and iwi members; a pathway to re-connecting the iwi back to the moana; and a holistic approach to monitoring.

Other research relevant or specifically linked to the projects above, is listed in Table 16.4.

Ecologically Significant Marine Areas: The objective of this research programme is to identify ecologically significant areas (ESMAs) within New Zealand's marine environment (including the territorial sea and EEZ). Work to date includes a 'think piece' report including a review of methodological approach for modelling ESMAs.

Other research relevant or specifically linked to the projects above, is listed in Table 16.4.

Near-shore ecosystems are complex and changes in diversity and community composition may be driven by multiple variables. Interactions between variables are likely to be non-linear, with disturbance thresholds and the potential for multiple stable states. As a consequence, it is often difficult to distinguish 'natural' from 'anthropogenic' impacts affecting ecosystem dynamics. MPI BioInfo research seeks to help disentangle this complexity, recognising that there will be contributions to this from both biodiversity research and Fisheries Services research.

Regional Councils and universities support some research projects and survey programmes in coastal and estuarine waters by investigating the effects of sedimentation, pollution, ocean outfalls, sand dredge spoils, sand mining and nutrient enrichment on the marine ecosystem [63]. Although this workstream applies to offshore areas as well as near-shore, research to date has focussed on the near-shore.

[62] http://www.doc.govt.nz/upload/documents/science-and-technical/sfc326entire.pdf

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

Table 16.4: Other research linked to ecosystem scale understanding of biodiversity in the marine environment.

MPI	ENV2006-04 Ecosystem indicators for New Zealand fisheries ENV2007-04 Climate and oceanographic trends relevant to New Zealand fisheries ENV2007-06 Trophic relationships of commercial middle depth species on the Chatham Rise ANT2012-01, ANT2013-01 – many objectives concerning ecosystem effects of fishing in the Ross Sea region, including research on spatial modelling of populations, multispecies minimum realistic modelling and biology/ecology of bycatch species DEE2010-05: Environmental Indicators for Deepwater Fisheries (Tuck et al., 2014) ZBD2005-05: Taking stock project ZBD2012-02: Tier 1 Statistic (Oceans) ZBD2008-15: Continuous Plankton Recorder – See Robinson et al. (2014). [and subsequent CPR project]
OTHER	AUT deepsea and subtidal food web dynamics; offshore & coastal biodiversity post graduate studies MBIE contestable: C01X1001 "Protecting Ross Sea Ecosystems" – ecosystem effects of fishing in the Ross Sea region Completed refer to MPI contract MBIE contestable: C01X1226 "Ross Sea Climate and Ecosystems" – effects of climate variability/change on the ecosystems of the Ross Sea region ongoing NZARI "Top predators of the Ross Sea" – Whales, seals and penguins in the Ross Sea region to understand fishery-predator interactions (http://nzari.aq/nzari-funded-projects#p2013-06) extended and ongoing..links to MPI project MBIE contestable: "Marine Futures" – ecosystem modelling and management in the Hauraki Gulf (http://www.niwa.co.nz/coasts-and-oceans/research-projects/marine-futures) complete, mapped into challenge MBIE contestable: "Climate change impacts and implications" – projected effects of climate change on New Zealand terrestrial, coastal and ocean environments and ecosystems (http://ccii.org.nz/) Waikato University: http://www.waikato.ac.nz/eri/research/coastal-and-marine-ecosystems Otago University: http://www.otago.ac.nz/marinescience Victoria University of Wellington - ongoing projects involving marine biodiversity identification; marine protected areas; fisheries, including stock assessment, in an EBM framework; work on global climate change, including OA; biosecurity; rock lobster connectivity University of Auckland : ongoing research on novel methods to measure marine biodiversity, coastal genetics studies, and marine mammal research Centre of Research Excellence: Te Pūnaha Matatini (Centre for Complex Systems and Networks) including a project on modelling biological and economic values of marine food resources (http://www.science.auckland.ac.nz/en/about/our-research/research-in-the-faculty-of-science/te-punaha-matatini.html) SeaChange: Hauraki Gulf Marine Spatial Plan, http://www.seachange.org.nz/ DOC research on marine ecological integrity? Ongoing, suite of recommended indicators

PROJECTS

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

project completed

ZBD2013-06 Shell generation

Earlier long term experiments on the functioning of key NZ mollusc species under low pH conditions have indicated that the mechanism behind the observed negative impact of ocean acidification may be due to shell dissolution and/or difficulty in shell generation and maintaining shell integrity. The shells of flat oysters, paua and (if time allows) cockles retained from these experiments will be examined in this project, to describe and assess the mineralogy of individuals from treated (low pH) and untreated (ambient pH) seawater. Data will be used to help identify potential causal mechanisms in the shell responses of these species, and interpreted in light of likely ocean acidification in their natural habitats in New Zealand.

ZBD2014-03 Sub-lethal effects of environment change on fish populations

This project (co-funded with MBIE) will investigate the potential effects of ocean acidification on New Zealand's fish and fisheries, with a focus on snapper. The project will begin with a workshop of key collaborators, followed by a review of existing information on ocean acidification effects

on fish and how these known effects are likely to play out in New Zealand's temperate setting. Tank experiments will be conducted to assess the response (e.g. mortality, morphology, energy utilisation, behaviour) of snapper larvae to different acidification scenarios. Finally, the findings of the review and tank experiments will be combined in a deterministic model to assess the effects of acidification at a broader population level.

DOC research on functional trait diversity

(see also DOC contract report, Hewitt et al. 2014)

As part of DOC's Ecological Integrity Programme, the use of a traits-based functional approach to the analysis of video imagery was explored. Functional traits that could be determined from video were derived from international literature and tested using video data collected by DOC. Six broad functional categories were used (living position, growth form, body flexibility, mobility, feeding mode, and size; these represent traits that are important for vulnerability, resilience, recovery as well as aspects of ecosystem functioning). A Biological Traits Analysis (BTA) supplemented by estimates of spatial heterogeneity (habitat transitions) and vertical habitat complexity was used to determine functional integrity. BTA fulfil most of the requirements of a good bio-monitoring tool, being well rooted in ecological theory, demonstrated to show responses to changes in environmental conditions and human disturbances and stability across regional species pools and time, and are directly and indirectly related to ecological functions and ecosystem goods and services. This project demonstrated the first step to an index of ecological integrity by successfully converting video data to functional traits data, in a way expected to be habitat independent.

Other research relevant or specifically linked to the projects above, are listed in Table 16.5.

Table 16.5: Other research linked to investigation of the role of biodiversity in the functional ecology of nearshore and offshore marine communities.

MPI	BEN2007-01 Assessing the effects of fishing on soft sediment habitat, fauna, and processes ongoing HAB2007-01 Biogenic habitats as areas of particular significance for fisheries management complete ZBD201202 Tier 1 Statistic Oceans, ZBD201302 VME – Genetic Connectivity ZBD201303 Continuous Plankton Recorder-2.
CRI Core purpose	C01X1005— Management Of Cumulative Effects Of Stressors On Aquatic Ecosystems ongoing; CO1X0907 Coastal Conservation Management, Freshwater and Estuaries and Coasts and Oceans
DOC	Conservancy surveys as part of EI project functional trait project
MPI Biosecurity	Biosecurity surveys- every 6 months marine high risk site surveillance
OTHER	Universities; National Science Challenge
EMERGING ISSUES	
Cumulative footprint of human activities; understanding cumulative impacts and risks; marine spatial planning	
Land-base effects on marine biodiversity and inshore/offshore habitats;	
Ecosystem-based management and integrative governance. Science challengehttp://www.sustainableseaschallenge.co.nz/	
Defining marine ecosystem services, linking them to ecosystem function and societal values	

PROGRESS ON SCIENCE OBJECTIVE 4. MARINE GENETIC BIODIVERSITY

Genetic biodiversity can be measured directly at the scale of genes and chromosomes or indirectly by measuring

physical features at the organism scale (assuming that they have a genetic basis).

Genetic diversity is fundamental to the long-term survival, stability and success of a species. Central to this is the "metapopulation" concept where populations are sufficiently genetically distinct from each other to be identifiable as individual units. A low level of recruitment between populations counters the effects of both random genetic drift and inbreeding depression of genetic diversity.

Human activities can profoundly affect genetic diversity both within populations and between populations. For example, shipping activity (movement across the globe) and aquaculture practices (transfer of organisms to different areas) can increase population connectivity such that genetic biodiversity may decrease between populations. In extreme cases, populations can become the same genetically (homogeneous) although considerable within population diversity may remain. In the event of increased genetic connectivity, a species may become more susceptible to extinction through biological or catastrophic stochasticity. That is, in the absence of between population diversity there is insufficient genetic variance to adapt to the effects of climate change, disease epidemics and so on.

In contrast, under the much more common scenario of habitat fragmentation caused by human activities (fishing, pollution), decreased connectivity between populations will result in greater between-population diversity, but a reduction of within-population diversity. This also results in a decrease in a species survival (fitness) because fragmented or isolated populations may become extinct through environmental and genetic stochasticity or localised depletion. Periodic fluctuations in annual temperature for example can lead to small scale population extinction, which in the absence of recruitment between populations will result, over time, in the demise of all populations.

To reduce the risk of species loss, information about the genetic diversity both within populations (population isolation) and between populations (population connectivity) is needed. Without such information, the effects of perturbation on a species persistence and survival cannot be predicted. Furthermore, the links between genetic diversity, the dispersal capacity (mode of reproduction and life history development) of a species and the minimum viable population (MVP) size required in the marine environment to ensure population persistence, are little understood. For example, the MVP size for a species with a large dispersal capacity is likely to be quite different from that of a species with a relatively restricted dispersal capacity. Examining the connectivity between populations in the marine environment is fundamental to resolving some of the central challenges in ecology and has almost been ignored in the management of New Zealand fisheries and protection of biodiversity.

Understanding marine genetic diversity is also being enhanced through phylogenetic investigations of the relationships of the New Zealand marine biota using molecular sequence data. With some groups of the flora and fauna, genetic data are essential to understanding relationships and species identities. The research undertaken to date has important applications in both the documentation of diversity and in the recognition of foreign taxa (e.g. central to investigations of diversity of coralline algae in New Zealand - ZBD2001-05, ZBD2004-07; recognition of diversity – D'Archino et al 2011; distinguishing native and foreign taxa – Heesch et al 2007, 2009).

PROJECTS

ZBD2002-12 Molecular identification of cryptogenic/invasive marine species – gobies.
Complete.
(Lavery et al 2006.)

ZBD2009-10 Multi-species analysis of coastal marine connectivity
Following the completion of an extensive literature review of published and unpublished information and the identification of gaps in knowledge about taxa, habitats and spatial coverage of sampling, research focussed on the development of a standardised collecting protocol and the development and application of microsatellite markers to quantify the population genetic structure and the coastal connectivity of these taxa (Gardner et al. 2010). Open sandy shores and estuarine environments were highlighted as needing attention. For this, two PhD students carried out field work, genetic analyses, and interpretation of patterns of genetic population structure and the identification of barriers to gene flow in two species of shellfish (tuatua and pipi) and two species of flatfish (yellow-bellied flounder and sand flounder). Both PhD theses are now complete (examined, revised and submitted to the VUW library). Work is currently underway, in conjunction with the scallop work described below, to complete the writing of an

Aquatic Environment and Biodiversity Report, and to compile an integrated library of references for submission to MPI. Further publications from the two PhD theses are also in preparation.

The coastal connectivity project has been extended to incorporate a new component of coastal connectivity, with work on the New Zealand scallop, *Pecten novaezelandiae*. This work focusses on population genetic structure and genetic connectivity at two different spatial scales and uses microsatellite markers (consistent with the study already concluded for the 4 species of the original

First, the extension work focusses on scallops across New Zealand (the full range of this species' distribution). Samples have been sourced from several regions including the fiords, the far north, and central New Zealand. Genetic analyses and writing up (in the form of a PhD thesis chapter) have been done and this study is now complete. Second, the extension work focusses on scallops in the Hauraki Gulf and Coromandel Peninsula region where an important fishery exists. Scallops have been collected from several populations in this region and genetic connectivity is being assessed to determine linkages among populations at small spatial and temporal scales. This information will be of particular relevance to support management of the Coromandel scallop fishery.

ZBD2013-02 Vulnerable marine ecosystems (VME) genetic connectivity

VMEs are ecosystems comprising species, communities and/or habitats that are highly vulnerable to disturbance, yet little is known about the distribution of biodiversity or genetic relationships within and between VMEs in the deep seas surrounding New Zealand. This project addresses the critical lack of data concerning deep sea genetic connectivity of VME indicator taxa, and will clarify the spatial relationships and distribution of biodiversity of several protected invertebrate VME species within New Zealand's EEZ and beyond.

One postdoctoral research fellow and one research assistant joined the project (April 2014). Following systematic examination of specimens preserved in the NIWA Invertebrate Collection (NIC), five species in two VME orders were identified as having sufficient representation over a wide geographic range within and beyond New Zealand's EEZ. These species are *Enallopsammia rostrata*, *Desmophyllum dianthus* (Order: Scleractinia, stony corals), *Leipoathes secunda*, *Bathypathes patula* and *Stichopathes variabilis* (Order: Antipatharia, black corals). Scleractinian specimens are by far the most numerous in the NIC, and the RV Tangaroa TAN1402 cruise to the Louisville Ridge (Jan - Mar2014) yielded prolific collections of *D. dianthus* in particular. The scleractinian species choice complements ongoing VME genetic connectivity work at Victoria University of Wellington, and data from both projects will provide the most comprehensive dataset on deep sea coral connectivity in New Zealand. Black corals are globally abundant yet poorly understood deep sea invertebrates, and are all protected in New Zealand. Several specimens of *Bathypathes patula* were collected in Antarctica, therefore connectivity between New Zealand and this area may also be inferred. Furthermore, *Enallopsammia rostrata*, *D. dianthus* and *B. patula* are cosmopolitan species and data from this research will be of interest to the wider deep sea community.

Genetic markers are currently being optimised for each species and include a combination of DNA sequences from various genes, microsatellites and single nucleotide polymorphisms (SNPs). Preliminary genetic analyses suggest a lack of concordant connectivity patterns between species, indicate potential genetic isolation in Louisville, and have identified potential cryptic speciation within *L. secunda*. Genetic analyses will continue into 2015, and data will be incorporated into a hydrodynamic modelling framework during the next stage of the South Pacific VME project. Octocorals are also omnipresent in deep sea communities and are well represented in the NIC, albeit with poor species-level identifications. In 2015, genetic connectivity analyses on octocorals will commence, providing much needed data for another abundant, poorly understood and highly vulnerable deep sea taxon.

Other research relevant or specifically linked to the projects above, are listed in Table 16.6.

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Table 16.6: Other research linked to marine genetic biodiversity.

MPI	ENH2007-01 Stock enhancement of blackfoot paua GEN2007-01 Genetic population profile of blackfoot paua ENH2007-02 Outbreeding depression in invertebrate populations IPY2007-01 Objective 11. Barcode of life
NIWA core funding	*Marine Biosecurity.* NIWA Coasts & Oceans core funded Programme 6: Identifying and evaluating biosecurity threats to marine ecosystems from non-indigenous species and developing tools and approaches to prevent entry, reduce establishment and mitigate impacts. Programme includes Cawthron development of molecular tools for identification of non-indigenous species.
OTHER	Universities
EMERGING ISSUES	
Can genetics combined with hydrographic models usefully contribute to the identification of biodiversity hot-spots and/or to source-sink relationships within ecosystems?	

PROGRESS ON SCIENCE OBJECTIVE 5. EFFECTS OF CLIMATE CHANGE AND VARIABILITY ON MARINE BIODIVERSITY

Cyclical changes or trends in climate and oceanography and associated effects (such as increased ocean acidification) and how they affect the marine ecosystem as a whole have long-term implications for trophic interactions and biodiversity, as well as functional aspects of the system e.g. biogeochemical processes. With significant improvement in remote sensing tools and global monitoring of climate change, new patterns are emerging indicating that there are long-term cycles. Examples include the Interdecadal Pacific Oscillation as well as shorter periods of change in relation to the El Niño Southern Oscillation that affect ocean ecosystems. Further, physical phenomena such as the deep subtropical gyre 'spin-up' in the South Pacific which resulted in a warmer ocean around New Zealand

from 1996–2002, can have flow-on effects on ecosystem functioning.

A new report was launched in 2010 by the United Nations on ocean acidification[64] Among other findings, the study shows that increasing ocean acidification will mean that by 2100 some 70% of cold water corals, (a key refuge and feeding ground for some commercial fish species), will be exposed to corrosive waters (see also Tracey et al 2011b). In addition, given the current greenhouse gas emission rates, it is predicted that the surface water of the highly productive Arctic Ocean will become under-saturated with respect to essential carbonate minerals by the year 2032, and the Southern Ocean by 2050 with disruptions to large components of the marine food source, in particular those calcifying species, such as foraminifera, pteropods, and coccolithophores, which rely on calcium carbonate.

Emerging research suggests that many of the effects of ocean acidification on marine organisms and ecosystems will be variable and complex and will affect different species in different ways. Evidence from naturally acidified locations confirms, however, that although some species may benefit, biological communities in acidified seawater conditions are less diverse and calcifying (calcium-reliant) species are absent whereas algae tend to dominate.

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[65] and has been identified as a gap in biodiversity research in New Zealand[66]. A refresh of the New Zealand Biodiversity Strategy is underway by DOC and will include a chapter on climate change.

PROJECTS

Completed

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

This 5-year project has provided new information on the potential impacts of ocean acidification and warming on future plankton abundance, distribution, and biodiversity. The study focussed primarily on two phytoplankton groups, the coccolithophores, which are present throughout New Zealand waters and form large blooms in productive frontal regions, and the nitrogen-fixing diazotrophs, which are important in nutrient-depleted (oligotrophic) Subtropical waters, north of New Zealand.

The project also considered two other potentially susceptible, carbonate-forming zooplankton groups, the Foraminifera and Pteropoda. The project has used observational data from research voyages, including time-series and remote-sensing data, to establish the species community composition and abundance for each group, and generate a present-day baseline against which future change can be assessed. In addition, comparison with environmental variables has identified the key drivers of coccolithophore and diazotroph distribution and abundance. Manipulation experiments conducted in the laboratory and at sea to assess the sensitivity of extant plankton species to future changes, have established the susceptibility of diazotrophs and coccolithophores to future reductions in pH, both alone and in combination with projected increases in temperature. Together the results provide novel insight into the current and potential future

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

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

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

status of important planktonic groups in New Zealand waters.

A regional survey provided a baseline dataset of coccolithophore diversity, abundance and biogeography for New Zealand surface waters, with 46 species identified, of which 31 were new or recently identified species, and one a previously undescribed species of *Syracosphaera*. The highest coccolithophore abundance occurred in the region of the Subtropical Front on the Chatham Rise, with coccolithophores accounting for 30% of carbonate and 26% of algal particulate organic carbon in surface waters during summer. Coccolithophore species diversity was greatest in the frontal regions on the Chatham Rise and in the southern Tasman Sea, but with significant variation in the dominant species observed over relatively small spatial scales. The globally ubiquitous coccolithophore, *Emiliania huxleyi*, was the dominant species in both bloom and non-bloom conditions, often exceeding cell abundances of 1 million cells per litre, one-two orders of magnitude greater than any other coccolithophore species. The observed restriction of elevated cell abundances of *E. huxleyi* to surface waters of low silicate concentration indicated that this species may be outcompeted by diatoms at higher silicate concentrations, and hence the growth and distribution of diatoms may restrict *E. huxleyi* blooms. *E. huxleyi* and the second-most dominant coccolithophore species, *Reticulofenestra parvula*, showed contrasting relationships with temperature and macronutrients, with *E. huxleyi* associated with warmer water of low silicate concentration and low N:P. Comparison with temperatures and nutrients projected for the Chatham Rise region by 2100 suggest that *E. huxleyi* may be the more successful of these two species in the future in this region. The inferred future increase in *E. huxleyi* blooms would influence both productivity and CO_2 uptake on the Chatham Rise, and so it is recommended that the role and contribution of coccolithophores in both the pelagic food web and vertical carbon export be established in this region.

The unique light-scattering properties of the coccoliths (carbonate plates) of *E. huxleyi* provides potential for quantifying this carbonate and the spatial distribution of this species in surface waters by satellite remote-sensing. An optical algorithm developed for other ocean regions was successfully tested and validated for New Zealand waters, by comparison of satellite-derived carbonate with *in situ* carbonate concentrations. The algorithm was then applied to ocean colour images, from the SeaWifs and MODIS satellites, for the period 1997-2014 to produce a Coccolithophore Atlas of seasonal climatologies and interannual trends in surface water carbonate associated with *E. huxleyi*. Blooms of *E. huxleyi* were identified around much of New Zealand, with the satellite data confirming shipboard observations that the Chatham Rise supported the highest carbonate concentrations and presence of *E. huxleyi*. The Atlas showed a southerly seasonal progression in bloom location, with a surface carbonate maximum in spring in Subtropical waters, in mid-summer in the Subtropical Front, and in late summer in Subantarctic waters. The time-series record also showed a low, but statistically significant, increase in carbonate between 42 and 47°S, suggestive of a minor increase in *E. huxleyi* abundance over the 15-year period in the Subtropical Front and northern Subantarctic waters. A second remote-sensing approach was developed for assessing *E. huxleyi* bloom frequency that also indicated an increase in the Chatham Rise region, but also identified an increase in bloom frequency in northern Subtropical waters, which was not apparent from the satellite carbonate algorithm. The absence of a temporal trend in satellite-derived carbonate in surface Subantarctic waters in the region of the Munida time-series off the Otago coast, where pH has been decreasing since 2000, suggests that ocean acidification is not currently a primary determinant of *E. huxleyi* abundance in these waters. Conversely, comparison of sea surface temperature and carbonate anomalies derived from satellite data indicated a positive relationship in Subantarctic waters and a negative relationship in Subtropical waters, suggesting that warming may be a more important determinant of *E. huxleyi* abundance. These opposing relationships with temperature may be attributable to the differing impacts of increased stratification and associated reductions in nutrient supply, and suggests contrasting future responses in coccolithophore abundance in the two main water masses around New Zealand. This study validated the application of remote-sensing for determining *E. huxleyi* distribution, and provided a baseline against which future changes in *E. huxleyi* distribution and biomass in New Zealand surface waters can be assessed. Application of this approach to monitor changes in *E. huxleyi* distribution and abundance would benefit from further surface sampling of carbonate and *E. huxleyi,* and validation, in different oceanic regions around New Zealand.

Manipulation experiments were carried out on unispecific cultures of *E. huxleyi* in the laboratory, and also on mixed natural populations containing coccolithophores at sea, to

determine the individual and combined impact of temperature and ocean acidification on coccolithophore abundance, morphology and carbon content. Unispecific cultures of *E. huxleyi* showed no sensitivity across a range of CO_2 concentrations in terms of growth rate and particulate organic carbon production over 16 days, although a significant decrease in calcification rate was observed. Comparison of these results with reported responses in different strains of *E. huxleyi*, including from New Zealand waters, showed considerable variability in the response of growth and particulate organic carbon to elevated CO_2, whereas a decline in the carbonate:particulate organic carbon ratio was a consistent response under high CO_2 conditions. The implications of this are currently unclear, but this may influence the survival of *E. huxleyi* in the future ocean, and also the transfer of organic carbon and carbonate into the deep ocean since carbonate acts as "ballast" and enhances particle export from the surface ocean. In the manipulation experiments at sea using natural mixed plankton communities, *E. huxleyi* abundance was not significantly altered when exposed to elevated CO_2 (750 ppmv) alone, and in combination with elevated temperature (+3-4°C). Overall, the laboratory and shipboard results suggest that *E. huxleyi* abundance may not change significantly in response to changes in CO_2 projected for 2100, despite an observed decline in particulate inorganic to organic carbon ratios under elevated CO_2 conditions. From a methodological viewpoint, the present study highlights the importance of considering the effects of interactions of climate-related stressors, and also in using complementary unispecific and mixed community experiments. Further natural community experiments are required to determine the net effects of future changes in temperature and CO_2 on the food quality of coccolithophores and other phytoplankton groups to zooplankton, to establish the potential impacts of climate change on food web dynamics and productivity. In particular, it would be valuable to determine how potential changes in the carbonate to particulate organic carbon ratio of *E. huxleyi* may influence grazing and the supply of carbon to the deep ocean.

A semi-continuous, 11-year record of the abundance of two carbonate-forming zooplankton groups, the foraminifera and pteropods, was obtained in the two major water masses to establish a biodiversity baseline in New Zealand waters, and determine whether significant changes in abundance occurred during the period 2000-12. The samples were obtained from sediment traps deployed at 1500 m depth on two time-series moorings, one in Subtropical water and one in Subantarctic water. In general, the foraminiferal fluxes showed a close association with calcium carbonate fluxes, with total fluxes in Subantarctic water exceeding those in Subtropical water, whereas the reverse was observed for organic carbon fluxes. Highest foraminiferal fluxes occurred in spring and autumn in Subantarctic waters, and in summer (or occasionally winter) in Subtropical water. Significant interannual variability was observed, and there was no significant interannual trend in foraminiferal abundance over the 11-year time-series in either water mass. However, there was evidence of a reduction in total foraminifera flux from 2008-2012, and an increase in more tropical species towards the end of the time-series. Pteropod flux also showed large interannual variability, with considerably higher abundances in Subtropical waters where abundance was dominated by a single species (*Limacina inflata*). Experiments on pteropods tests showed no evidence of carbonate dissolution at the undersaturated carbonate levels at 1500 m water depth. In contrast to trends reported in a Subantarctic water time-series south of Tasmania, there was no evidence of a decline in pteropod abundance in New Zealand Subantarctic waters. This suggests that there is currently no effect of ocean acidification on pteropods; however, projected future decreases in the saturation state of aragonite, the form of carbonate used by pteropods to form their shells, may result in a decline in pteropod abundance in these waters. Comparison of pteropod abundance with climatologies of environmental variables suggest that other factors, such as food supply, may be important determinants of pteropod abundance. Establishing the spatial distribution and the ecological role of pteropods and foraminifera in New Zealand waters in new surveys using the Continuous Plankton Recorder would be valuable, as would experimental determination of the sensitivity of the potentially more susceptible juvenile pteropod stages to ocean acidification.

The distribution of nitrogen fixation rate and the nitrogen-fixing diazotrophs were established in Subtropical waters north of New Zealand, by determining the presence of the *nifh* gene that encodes for the enzyme used in nitrogen fixation. Four different diazotroph phylotypes were identified in samples from three research voyages in the Tasman Sea, with the highest diversity and abundance coincident with highest nitrogen fixation rates both within, and north of, the Tasman Front. There was a corresponding decline in diazotroph abundance and nitrogen fixation in the southern Tasman Sea, coincident with decreasing surface seawater temperature. The different phylotypes were generally closely

associated, with higher abundances, particularly for the large colonial *Trichodesmium* sp., north of the Tasman Front. The smaller Unicellular Cyanobacteria A (UCYN A) phylotype was the dominant diazotroph in the Tasman Sea, and nitrogen fixation rate correlated with both total *nifH* abundance, and abundances of all the diazotroph phylotypes, except *Trichodesmium*. North of the Tasman Front, nitrogen fixation contributes less than 15% of total new nitrogen supply, although both the rate, and its proportional contribution to new nitrogen supply, may vary, as was observed during a tropical cyclone. Nitrogen fixation rates during winter in the ultra-oligotrophic surface waters of the South Pacific Gyre, north-east of New Zealand, were near analytical detection limits, and two orders of magnitude below that of the Tasman Sea. These low rates were accompanied by a corresponding absence of the main diazotroph phylotypes, with only gamma (γ) -proteobacteria present. Temperature and phosphate availability (N:P) were the primary environmental variables determining nitrogen fixation rate and diazotroph abundance in the Tasman Sea. Nitrogen fixation was detectable down to 14°C, with most of the diazotroph phylotypes recorded at lower temperatures than reported for the Atlantic; however nitrogen fixation rates were only significant (>1 nmol/l/d) at temperatures exceeding 19.5°C. As the Tasman Sea region is experiencing rates of warming that exceed the global average, this suggests that diazotroph abundance and nitrogen fixation may increase in the future. With projected further warming of surface waters and associated increases in stratification, nitrogen fixation may become a more significant source of nutrients for primary production in New Zealand waters, and so it is important to establish how nitrogen fixed by diazotrophs is transferred into the marine food web.

A number of studies have shown that the diazotroph species *Trichodesmium* may benefit from ocean acidification, as it increases carbon and nitrogen fixation under elevated CO_2. Manipulation experiments were carried out on natural mixed plankton communities containing nitrogen fixers from Subtropical waters north-east and north-west of New Zealand, under elevated CO_2 alone (750 ppmv), and in combination with elevated temperature (+3°C). Contrary to observations in other regions, nitrogen fixation was not stimulated by either elevated CO_2, or in combination with elevated temperature, at any of the four sampling sites. This most likely reflects that the diazotroph community was dominated by UCYN A and gamma-proteobacteria, and not the larger filamentous *Trichodesmium* species. As these smaller diazotrophs are heterotrophs they may gain little benefit from an increase in dissolved CO_2; however, the observed response may reflect other factors, such as the larger cell surface area:volume of small diazotrophs, the potential for iron limitation of the response to elevated CO_2, or that another component of the microbial community outcompeted the diazotrophs. Regardless, the results highlight the importance of studying endemic species and groups, and using natural mixed communities, to determine how climate change and ocean acidification will influence plankton biodiversity and productivity in New Zealand waters.

ZBD2014-01 Age and growth study of deepsea coral in aquaria.

Research funding has been provided to improve our understanding of the impacts of ocean acidification on deep-sea coral growth. An initial study was carried out to evaluate the feasibility of successfully collecting live specimens at sea and maintaining deepsea corals in the laboratory. Under Ministry for Primary Industries (MPI) Project SEA2013-01, a healthy colony of the deep-sea stony branching coral *Solenosmilia variabilis* was successfully maintained under laboratory conditions at NIWA for 14 months, demonstrating the possibility of carrying out future experimental work with this species. NIWA subsequently entered into an agreement with MPI to extend work on deep-sea corals (Project ZBD201401). New coral colonies, comprising several live polyps per colony, were collected in March 2014 during the High Seas *Tangaroa* Voyage to the Louisville Ridge, for the purpose of carrying out multiple stressor experiments in aquaria). With the limited funding available, the experiment is focussed on ocean acidification only. The project includes a collaboration between NIWA and Victoria University School of Biological Sciences post graduate programme with involvement of a Masters student in the in-aquaria experiments.

Ocean acidification manipulation is now underway to look at the physiological responses (e.g., growth) to future predicted environmental conditions. The experiment was initiated on the 29th of July 2014, when coral colonies were divided up and assigned to replicate control (pH 7.88) and treatment (pH 7.65) tanks. The corals are being held in the NIWA OA facility where small pieces from several coral colonies have been held in chambers in the dark, and in optimal temperature 3.5 degrees flow rate based on current velocity data for the region, (flow rate of, 120 mL/min and 240 mL/min.) turning over the volume of the

chambers every 15 minutes. The corals are fed twice a week with KorallFluid and sixteen months on the colonies are alive with tentacles extending from many of the individual calyces.

To date radial and linear extension and buoyant weight have been regularly measured to observe changes in morphology and measure growth. Some species of deepsea coral up-regulate their intracellular pH when exposed to acidified conditions. This serves as an adaptive response by increasing the internal carbonate saturation state, alleviating the affect that pH reduction has on the availability of carbonate and ease of calcification. Intracellular pH measurements on *S. variabilis* live polyps were made in January and September 2015 to determine whether this species of coral up-regulate intracellular pH when exposed to acidified conditions. Respiration rates have also been taken examined at 6 monthly intervals to determine what energetic costs may be associated with up-regulation and calcification under acidified conditions. The experiment is planned to run until 30 June, 2016.

The colonies have survived well in their laboratory environment. Tentacles continue to extend from the polyp mouth in several of the calyces. We note, however, that some small colonies appear stressed, there is a loss of external tissue material on some branch regions and some branches are very bleached. Nevertheless, we have now completed 6 intermediate sampling points and 2 major sampling point. As expected, to date we have not observed any linear growth of these very slow growing organisms.

ZBD2012-01 Development of a Tier 1 National Reporting Statistic for New Zealand's Marine Biodiversity project
Complete

ZBD2012-02 Tier 1 Statistic (Oceans)
(Pinkerton et al, 2014)
complete

ZBD2013-06: Impacts of environmental change on shell generation and maintenance of important aquaculture species
Ocean acidification is a real and imminent threat to calcifying organisms, including shellfish. A recent study of potential effects of near future conditions on NZ paua, flat oysters and cockles revealed effects on survival and condition, and suggested that effects on shell generation and/or integrity may have been a contributing factor. In this new project, involving collaboration between NIWA and University of Otago, shells of individuals of each species will undergo detailed analysis to determine how the decreased pH/increased temperature modified their shell (i) thickness, (ii) mineralogy and (iii) construction. A comparison of the responses of these species, which have different mineralogies and forms and occupy different habitats, to identical experimental conditions, will allow better predictions of their differential susceptibilities to future environmental conditions.

Other research relevant or specifically linked to the projects above, are listed in Table 16.7.

Table 16.7: Other research linked to effects of climate change and variability on marine biodiversity.

MPI	SAM2005-02 Effects of climate on commercial fish abundance ENV2007-04 Climate and oceanographic trends relevant to New Zealand fisheries
MBIE	C01X502 Coasts & Oceans Centre
DOC	Baseline surveys; protected deepsea corals (Tracey et al 2011b; Baird et al 2012)
OTHER	University of Otago-NIWA shelf carbonate geochemistry and bryozoans Geomarine Services-foraminiferal record of human impact Regional Council monitoring programmes NIWA Coast and Ocean core programme US-NZ Joint Commission Meeting for scientific and technological exchange. Ongoing ocean acidification work and deepsea coarl identification
EMERGING ISSUES (this objective)	
How does climate change influence marine microbial diversity, species mix and biogeochemical roles? How will harmful toxic algal blooms be affected by warming seas? (e.g. Chang & Mullan 2003, Chang et al 2003) How will climate change affect primary industries in the sea, and ecosystem services on which industry depends?	

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[67] 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[68]. A new international initiative launched in 2010 "Biodiversity Indicators Partnership"[69] provides guidelines and examples of biodiversity indicators developed around the globe, however, Oceania does not appear to have any partnership identified. The link between this initiative and OECD environmental indicators is unclear.

A serious gap identified by Green & Clarkson (2006) in their review of progress on implementation of the NZBS was the lack of development of an integrated national monitoring system (see Biodiversity Research Programme 2010: Part 4). Efforts to respond to this gap within the Biodiversity Programme resulted in the immediate initiation of a 5-year Continuous Plankton Recorder project, and a series of workshops to determine how best to approach monitoring on a national scale (ZBD2008-14). [One objective of monitoring would be to test the effectiveness of management measures.]

PROJECTS

ZBD2008-15 Continuous Plankton Recorder (CPR) Project: implementation and identification.
Complete.

ZBD2013-03 Continuous Plankton Recorder (CPR)-Phase 2

The overall objective of the Continuous Plankton Recorder (CPR)-Phase 2 project is to map changes in the quantitative distribution of epipelagic plankton, including phytoplankton, zooplankton and euphausiid (krill) life stages, in New Zealand's EEZ and transit to the Ross Sea, Antarctica.

The original project was established in 2008 for a five-year period with sampling carried out annually in the Austral summer. Sanford Limited continues to provide the FV *San Aotea II* and crew to take the samples, and sample analysis is carried out by the laboratory at NIWA Christchurch.

The current project, ZBD2013-03, continues this annual programme of CPR sampling and is funded for a further five years. This will enable a continuation of the data time series and provide a more robust dataset with which to make comparisons with the Southern Ocean CPR survey and potentially determine any trends in the plankton community.

To date, one summer sampling run has been completed (2013-14). Nine CPR runs were carried out between 30 November 2013 and 11 February 2014. The processing of the samples from these runs is well advanced and should be completed before the end of the second year of sampling, which is again due to commence from Nov/Dec 2014. At this stage, the new data is being collated and stored in the Southern Ocean CPR Survey meta-database.

ZBD2010-42 Marine Environmental Monitoring Programme.

Project complete

ZBD2014-09 Climate change risks and opportunities

The focus of this new, 4-year project is to identify how and when environmental change (climate, CO_2) might affect NZ

[67] 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

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

[69] www.bipnational.net/IndicatorInitiatives

fisheries. It will involve assessment of current state of knowledge of expected changes, how fin- and shell-fish might be affected, knowledge gaps, species risk assessments, and identification of adaptive management strategies.

ZBD2014-04 Isoscapes for trophic studies

The main objective of this project is to develop biochemical maps of the South Pacific that then can be used to understand the movements and migrations of marine animals. These maps are based on the spatial patterns of isotope values found at the base of the marine food web in different oceanic regions, driven mainly by the dominant biogeochemical provinces. This approach, based on both measured values from the open ocean and recently developed ocean models predicting these values (Somes et al 2012), is especially powerful in the South Pacific because of the large latitudinal variations. We see higher carbon isotope values in the tropics and consecutively more negative values as you move to higher latitudes, with the most negative ones found in the Southern Ocean. Physical factors (temperature and dissolved CO2) drive these large scale patterns, with some localized variations due to increases in primary production. After the baseline maps are established, samples can then be collected from migratory marine animals to determine if their values match those values observed in the region where they were sampled/captured, after correcting for relative trophic position. If the isotope values are different than what you would expect from the region, these individuals would be considered migratory or new immigrants to the region. For example, white sharks biopsied off of Steward Island in March of each year reflect an equatorial or tropical signal, demonstrating not only were the sharks travelling to these regions but they were foraging and fueling their migration back to Steward Island every year (Graham, Francis, et al. unpublished). Therefore, these chemical tracers can be used as tags to determine the movements of elusive marine animals or those that are difficult to employ other tracking techniques.

In addition to using isoscapes and the isotopes of marine animals to determine the movements of individuals in the open ocean, these techniques can also provide information on their diet and dietary changes in space and time. The information gained on movements and diet are not mutually exclusive. Therefore, when interpreting variations in an animals' isotope values requires careful consideration of both variables. For example, is the marine mammal or seabird's isotope value dissimilar to what we expect from the region of collection/capture or is that individual/group foraging differently than we expected. Incorporating information from other techniques and observations is critical to determine the factors driving the isotope values. In all most all isoscape and chemical tag studies, including those in this project, additional datasets (e.g., genetic, direct observations) and other constraints are required to distinguish the influences of movement and diet on the observed values. We also have another tool, compound-specific isotope analysis of specific amino acids isolated from the tissues of individuals that will indicate if the observed variations are due to diet, movements, or a combination of those two. For example, a recent study examining the diet of humpback whales foraging around the Balleny Islands in the Southern Ocean. Variations were observed in their (bulk) nitrogen isotope values, especially in male humpbacks, which could indicate a difference in diet (more fish) or in migratory pathways all while stopping to "snack" along the journey. The compound-specific isotope work indicates it is a combination of both – there is trophic position difference in these individuals and there is also an indication they have foraged in areas with different biogeochemical processes (Bury, Graham, et al. unpublished). Determining the migratory routes or changes in the diet of the Oceania group of humpbacks in the South Pacific is critical to their conservation, especially as their population growth is not increasing at the same rate as other humpback whale populations in the Pacific (findings from Constantine and colleagues).

Another excellent example of how isoscapes and the approach of this project can elucidate movements of elusive marine predators in the open ocean is examining the movements of tuna, sharks, and billfish in the Pacific. In the equatorial Pacific, we determined that tuna foraged in a region for a longer period of time than previously understood (traditionally it was assumed all tunas were highly migratory). We could conclude this important finding because the isotope values of the tuna were similar, after correcting for trophic position, to the base of the food web where they were captured by commercial fisheries (Graham et al. 2010; Lorrain, Graham et al. 2014). As this project allowed us to develop isoscapes beyond those that we produced for the equatorial Pacific, into the South Pacific, we were able to apply the same approach to examine the movements of tuna, sharks, and billfish around New Zealand. Results strongly indicate that these top predators are more transient (migratory) in NZ waters, as

very few reflect what we would expect for a NZ predator's values. Some species (e.g., mako and blue sharks, southern bluefin tuna), show more migration than other predators and these information is being generated for MPI's highly migratory working group (HMS2010405) and to be incorporated in future stock assessments and management strategies.

Our work continues on using these isoscapes and methods to determine the movements of marine mammals and seabirds in the South Pacific, especially those using the NZ EEZ for portions of their life cycle (e.g., rearing/rookeries, stop overs during migration, and mating). Currently emphasis has been placed on examining the movements of the Oceania population of humpback whales with the considerable effort recently expended on research voyages and biopsing these individuals (e.g., Constantine, Garrigue, Bury, et al.). It is important to note that the isoscapes and methods employed in this project are of very limited value to coastal ecosystems – the biogeochemistry and terrestrial inputs are too spatially and temporally dynamic to be able to model the coastal isoscapes. Much more detailed, and sampling intensive work is required in coastal systems, and is more likely project-by-project objective driven. However, even with that limitation, the open ocean isoscapes developed and established in this project can be used to examine movements in many marine animals and trophic guilds during current and future studies with reasonable project costs and timelines. This will be especially important to monitor in a changing ocean ecosystem(s).

The Ocean Acidification Modelling project seeks to determine how much the aragonite and calcite saturation horizons (ASH and CSH) have changed over the industrial era for the southwest Pacific, including New Zealand's Exclusive Economic Zone (EEZ.) The project team has collated a wealth of historical observations of temperature, salinity, oxygen, and carbonate parameters that have been made between the 1928 and the near present, assessed the data quality, and collated the data. In addition, we gathered output from ten ocean model simulations that have been optimised against ocean carbon data and used them to construct a time history of anthropogenic carbon storage in the Southwest Pacific. The range between models gives an estimate of uncertainty.

In the next phase of the project, the historical data and model simulations will be combined to estimate decadal changes in carbonate parameters, the ASH, and the CSH over the Southwest Pacific. This will give us insight into how much adaptation to ocean acidification may have already occurred in the waters around New Zealand. These data-based estimates of the ASH and CSH will then be compared with simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5) to explore the implications of these findings for future projections of the ASH and CSH in the southwest Pacific.

Other research relevant or specifically linked to the projects above, are listed in Table 16.8.

ZBD2014-05 Ocean acidification modelling

Table 16.8: Other research linked to biodiversity metrics and other indicators for monitoring change.

MPI	ENV2006-15: Database and fishing indicator on seamount habitats (Rowden et al 2008) BEN2009-02 (Tuck et al 2010) ENV2006-04: Fisheries indicators from trawl surveys (Tuck et al 2009) DEE2010-04 Development of a methodology for Ecological Risk Assessments for Deepwater Fisheries DEE2010-05 Development of a suite of ecosystem and environmental indicators for deepwater fisheries (completed) DEE2010-06 Design a programme to monitor trends in deepwater benthic communities
MBIE	Core funding for Coasts and Oceans Centre
DOC	Conservancy projects-Hawke's Bay
OTHER	Regional Councils, Universities Ministry of the Environment draft Environmental Reporting Bill and associated Technical support, Otago University development of the Ocean Acidification Monitoring Network (Kim Currie).
EMERGING ISSUES	
Monitoring coastal waters and New Zealand's oceans to report on a national scale remains a major gap that will be addressed in part by the proposed Tier 1 statistic on Oceans and the Environmental Reporting Bill.	

SCIENTIFIC OBJECTIVE 7. IDENTIFYING THREATS AND IMPACTS TO BIODIVERSITY AND ECOSYSTEM FUNCTIONING

Many marine ecosystems in New Zealand have been modified in some way through the harvesting of marine biota, the selective reduction of certain species and size/age classes, modification of food webs, including the detritus components and habitat destruction. Benthic communities including seamount communities, volcanic vent communities, bryozoans, corals, hydroids and sponges are vulnerable to human disturbance. The mechanical disturbance of marine habitats that occurs with some activities such as trawling, dredging, dumping, and oil, gas and mineral exploration and extraction; can substantially change the structure and composition of benthic communities. The invasion of alien species into New Zealand waters is also a real threat, with evidence of nuisance species already well established[70].

A number of inshore marine ecosystems (especially estuaries and other sheltered waters) have been modified by sediment, contaminants and nutrients derived from human land use activities (Morrison et al 2009). Coastal margin development has had a major impact on some inshore marine communities.

A recent project commissioned by the MPI Aquatic Environment Programme, which identifies key threats to the marine environment (BEN2007-05) is complete and has listed and ranked the top threats to New Zealand's marine environment, as perceived by expert opinion. Relevant findings are that the highest ranking threats are ocean acidification, increasing sea water temperatures and bottom trawling (across all habitats) and that the most threatened habitats are intertidal reef systems in harbours and estuaries (MacDiarmid et al 2012). Ecological risk assessment (ERA) methods have also been reviewed (under ENV2005-15, Rowden et al 2008), and a trial Level 2+ assessment completed on Chatham Rise seamounts to estimate the relative risk to seamount benthic habitat from bottom trawling (under ENV2005-16, Clark et al 2011). An MPI project (DEE2010-04) has resulted in a new ecological risk assessment being developed that is tailored for New Zealand deepwater fisheries.

PROJECTS

ZBD2009-25 Predicting impacts of increasing rates of disturbance on functional diversity in marine benthic ecosystems

This project expanded on a spatially explicit patch dynamic model as a framework to illustrate how increasing rates of disturbance to benthic marine ecosystems influence functional diversity, and ultimately, other elements of biodiversity and ecosystem function (such as the abundance of rare species, ecosystem productivity, and the provisioning of biogenic habitat structure). The aim of the model is to provide a heuristic tool that can be used when considering seafloor disturbance regimes in the context of spatial planning and other ecosystem-based management (Lundquist et al. 2013).

Eight functional groups were defined for the model, representing key aspects of the way organisms in seafloor communities modify their environment and interact with each other. These include: opportunistic early colonists with limited substrate disturbance; opportunistic early colonists with considerable substrate disturbance; substrate stabilisers (e.g., tube mat formers); substrate destabilisers; shell hash-creating species; emergent epifauna; burrowers; and predators and scavengers. While we did not define each functional group as having a sensitivity to disturbance, each functional group is allocated a selection of life history traits based on review of the scientific literature and expert knowledge (i.e., age of maturity, maximum lifespan, seasonality of reproduction, larval dispersal distance).

When disturbance is added, the model predicts changes in the occupancy of functional groups within the model seascape. Response to disturbance and recovery rates differ between the eight functional groups, reflecting the

[70] 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

different life history characteristics and dispersal characteristics simulated by the model. Some functional groups respond negatively to disturbance, including those known to be sensitive to, and recover slowly from, disturbance (e.g., emergent epifauna). Other groups (e.g., opportunistic taxa) respond favourably to disturbance in the model, as we would expect.

The model was run to compare with available inshore (Tasman and Golden Bays) and offshore (Chatham Rise and Challenger Plateau) empirical datasets. These datasets included video data with broad coverage of the seafloor, but relatively poor representation of small-bodied and infaunal groups, in combination with benthic sled, grabs, or cores that better sampled these groups. We used a fuzzy logic approach based on functional traits (e.g., feeding, motility, position in the sediment, size) to allocate 1056 individual taxonomic units (e.g., species) into one of eight functional groups, and compare relative abundance of functional groups from inshore and offshore surveys to model predictions.

Model predictions were consistent with changes in functional group abundance with increasing rates of disturbance in both the inshore and offshore datasets, with declines in functional group abundance occurring at the approximate disturbance rates predicted by the model. The strong similarity between model and observed community changes with disturbance showcases the value of this heuristic tool, based on fundamental biological parameters, for investigating disturbance and recovery dynamics in seafloor communities. Future research can build on this model framework, varying parameters and assumptions within model scenarios, to inform ecosystem-based management approaches for seafloor communities.

Other research relevant or specifically linked to the projects above, are listed in Table 16.9 (next page).

Table 16.9: Other research linked to threats to and impacts on biodiversity.

MPI	BEN2007-05 Assessment of anthropogenic threats to New Zealand marine habitats. MacDiarmid et al 2012 DEE2010-04
MBIE	CO1X0906 Vulnerable deep-sea communities (mapping and sampling a range of deep-sea habitats (seamounts, slope, canyons, seeps, vents), and determining relative risk to their benthic communities from human activities culminates in risk assessments; megafauna contestable?
MFE	MFE12301 Expert risk assessment of activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf. MacDiarmid et al 2011 MFE14301 Environmental risk assessment of discharges of sediment during prospecting and exploration for seabed minerals. MacDiarmid et al. 2014
EMERGING ISSUES	
The socio-economic valuation of biodiversity in NZ has not been adequately addressed. The cumulative footprint of anthropogenic activities on the NZ marine environment has not been assessed. Potential development of seabed mining makes this a priority in deepwater environments as well as coastal.	

BIODIVERSITY IN ANTARCTICA: BIOROSS PROJECT SUMMARIES AND PROGRESS

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

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

The MPI Antarctic Research and BioRoss Programmes are also directly involved in supporting the development of protection measures around the Balleny Islands. In 2005 MPI scientists and Ministry of Foreign Affairs and Trade

(MFAT) personnel prepared a paper for submission to CCAMLR justifying MPA designation around the islands to protect ecosystem processes occurring there that may be important for the stability and function of the wider Ross Sea regional ecosystem.

To collect data in support of the MPA proposal, MPI BioRoss funded a targeted research voyage to the Balleny Islands in February 2006 (ZBD2005-01), and also provided supplementary funding to carry out opportunistic biological sampling at the Balleny Islands on a voyage to the Ross Sea that was primarily funded by LINZ to do bathymetric mapping.

The field sampling of these projects were successful, both providing important data and specimens from the Balleny Islands area and supplementary information for the Antarctic Working Group Research Programme. The results will inform research planning for subsequent projects. Support for Ross Sea region biodiversity will remain a high priority for future research in the BioRoss Programme.

In addition, BioRoss funded a further ICECUBE project to sample the Antarctic coastline during the summer season of 2006/07 (ZBD2006-03). ICECUBE is a key part of the international Latitudinal Gradient Project to explore hypotheses about environmental drivers of structure and function in sub-tidal ecosystems along the western Ross Sea coastline (Cummings et al 2008). This project acquired funding for three seasons (2007/08, 08/09, 09/10) as part of the MBIE IPY contestable round (see also Cummings et al 2011 and Thrush & Cummings 2011). Published reports and papers from the MPI Ross Sea coastal projects include Cummings et al 2003, 2006b, 2008, 2010, 2011. De Domenico et al 2006, Grotti et al 2008, Guidetti et al 2006, Norkko et al 2002, 2004, 2005, 2007; Pinkerton et al 2006, Schwarz et al 2003, 2005, Sharp et al 2010, Sutherland 2008, Thrush et al 2006, 2010 and submitted.

The New Zealand Government provided one-off funding for a Census of Antarctic Marine Life (CAML) survey to the Ross Sea from R.V. Tangaroa as part of New Zealand's involvement in the 2007–08 International Polar Year activities. The CAML Voyage was a large cooperative research effort under the banner of Ocean Survey 20/20 with considerable international collaboration, simultaneously utilising a number of different vessels with different strengths and capabilities. Progress on the two projects IPY2007-01 and IPY2007-02, is detailed below.

PROJECTS

ZBD2003-03 Biodiversity of deepwater invertebrates and fish communities of the north western Ross Sea.
Completed.

ZBD2013-08 NZ Ross Sea connectivity, humpback whales
The main aims of this research are to determine the breeding ground origins, migratory path, Antarctic feeding grounds and prey of New Zealand's endangered humpback whales. We are using a multidisciplinary approach with satellite telemetry, DNA-based genetic markers, stable isotopes, isoscape modeling and photo-identification all being used to understand individual and population level linkages. The primary objectives are:

i) Deploy satellite tags on humpback whales at Raoul Island to determine the migration pathways and habitat use in Antarctica using spatial analysis tools.

ii) Determine the breeding and feeding ground linkages, site fidelity and levels of mixing through genotype and photo-identification analysis of individual whales.

iii) Determine the isotopic signatures of prey and model the values across the broader Ross Sea region to allow predictive models of humpback stock recovery.

We collected data at Raoul Island from 29th September to 11th October using small research boats deployed from the RV Braveheart. During this time we deployed 25 satellite tags, collected 85 tissue samples, recorded four hours of whale song and photo-identified 129 individuals.

A total of 17 satellite tags have transmitted location information throughout duty cycles of 10 hrs on and 2 hrs off. It is not unusual for tags to start transmitting a few weeks after deployment so we may receive signals from other tags over the next few weeks. In general, the whales have migrated in a southeasterly direction with only a few whales coming close to mainland New Zealand. The whales are on course for Antarctic feeding grounds spanning the Ross Sea across to the Amundsen/Bellingshausen Sea region and the first whale reached the ice-edge around the 19th November. The fluke photographs have all been quality controlled and entered into a matching database (Flukematcher). In total there are 133 whales in the Kermadec Islands catalogue; 3 prior to 2015 and 130 from 2015 (129 from our voyage and 1 from the land-based DOC

team at Raoul Island). Systematic matching to catalogues from Oceania, east Australia and Antarctica is underway and preliminary analysis found whales matched to the New Caledonia and Niue breeding grounds. We anticipate that other breeding ground origins will be identified once we have completed the systematic matching process. DNA from all 85 samples has been extracted and haplotype assignment to breeding grounds and sex PCR are underway. A sub-sample of tissue (equal numbers of males and females) will be analysed for patterns in isotope values allowing diet assessment.

Overall the early stages of this project are promising. We are on track to understand the importance of Antarctic feeding grounds for the endangered humpback whales passing through New Zealand's northernmost waters.

Other research relevant or specifically linked to the projects above, are listed in Table 16.10.

Table 16.10: Other research linked to MPI Ross Sea Antarctic biodiversity programme.

MPI	ANT2011-01 Stock modelling, fishery effects and ecosystems of the Ross Sea IPY2007-01 and 02 NZ IPY CAML projects are now complete
MBIE	C01X1001 Protecting Ross Sea Ecosystems. Comparative distribution and ecology of *Macrourus caml* and *M. whitsoni* in the Ross Sea region; feeding relationships of fish species in the Ross Sea region; Spatial processes, including spatial marine protection; Ecosystem modelling of the Ross Sea region).(Pinkerton et al 2012, Murphy et al 2012)
OTHER	Universities NIWA; Lincoln, Canterbury, Otago, Auckland, Waikato; Marsden, Cummings and Lohrer, effects of ocean acifidification and warming on under-ice algal productivity and nutrient uptake in coastal Ross Sea habitats
EMERGING ISSUES	
Coastal research and functional ecology-ongoing need Taxonomic issues for fish and invertebrates (from IPY)ANT 2005-02 Water samples from throughout water column to assess microbial content (from IPY)	

Given that the MPI Biodiversity programme has been running for more than 11 years, and that a number of new strategic documents and directions are emerging across government, it is time to look both back and forward and review the programme to ensure its alignment with more recent strategic documents.

In 2000, five strategic outcomes were built into the MPI (formerly MFish) Biodiversity Research Programme

That by 2010:

i. *the MPI Biodiversity programme will have become an integral part of the research effort devoted to understanding New Zealand's marine environment.*
ii. *research planning will benefit from close cooperative relationships within the Ministry of Fisheries, with other government agencies, and with external stakeholders.*
iii. *mutually beneficial collaborative research projects will be carried out alongside other New Zealand and international research providers, especially for vessel-based research.*
iv. *MPI Biodiversity projects will have contributed substantially to an improved understanding of New Zealand's marine biodiversity and its role in marine ecosystem function, yielding scientifically rigorous outputs for a national and international professional audience.*
v. *results generated by MPI Biodiversity projects will be incorporated into management policy, with clear benefits for the New Zealand marine environment.*

The Biodiversity Programme has been highly effective in delivering on the first four and part of the fifth of these five outcomes. A missing element is some measure of *"clear benefits for the New Zealand marine environment"*. In recent years, significant all-of-government projects have been administered through the programme, and one-off funding applications made jointly with other stakeholders have been successful. The Programme has made a significant contribution to increasing understanding about

biodiversity in the marine environment. Achievements in each outcome are addressed below.

i. Has the Biodiversity Research Programme become integrated with New Zealand's research effort to understand the marine environment?

Seven science objectives were developed by multiple stakeholders through the Biodiversity Research Advisory Group. The agreed objectives include ecosystem-scale studies in the New Zealand marine environment, the classification and characterisation of the biodiversity of nearshore and offshore marine habitats, the role of biodiversity in the functional ecology of marine communities, connectivity and genetic marine biodiversity, the assessment of the effects of climate change and increased ocean acidification, identification of indicators of biodiversity that can be used to monitor change, identification of key threats to biodiversity, identification of threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation.

Projects ranged from localised experiments on seabed communities of shellfish and echinoderms, to integrated studies of rocky reef systems and offshore fishery-scale trophic studies. The effects of ocean climate change (temperature, acidification) are being explored on shellfish, rhodolith communities, plankton productivity and the microbial productivity engines of polar waters. A major project to investigate shelf communities in relation to climate over the past 1000 years has resulted in the development of new methods and insights to past changes and human impact on New Zealand's marine environment.

A total of 64 projects were commissioned and managed within this 14 year period, yielding over 100 final research reports, most of which have been published through MPI Publications (Marine Biosecurity and Biodiversity Reports and Aquatic Environment and Biodiversity Reports), books, Identification Guides and mainstream scientific literature. A number of other publications are still in preparation. In addition, several workshops have been run through the Programme, including qualitative modelling techniques, how to set up a marine monitoring programme and predictive modelling. A large number of science providers, including NIWA, Cawthron Institute, University of Auckland, Auckland University of Technology, University of Waikato, Victoria University of Wellington, University of Otago, University of Canterbury and Massey University have been directly commissioned or sub-contracted to take part in or conduct research projects through the Programme during the 10-year period. For some, the projects have provided critical synergies with MBIE funded OBIs or projects, while others have provided one-off opportunities for marine biodiversity investigation or opportunistic leveraging for research voyages.

Research into the biodiversity of habitats such as seamounts has been completed and new methods to assess the vulnerability of seabed habitats have been developed. The land-sea interface is being investigated and projects have shown how land use in a given catchment can affect nutrient transfer and the living conditions and impact diversity and functioning of estuarine and coastal organisms. Publication and presentation of the results from these projects has resulted in widespread contribution to the development of Marine Science in New Zealand. Partnership with overseas researchers and presentations to international meetings and conferences has added to the growing global initiatives on marine biodiversity research questions.

Feedback from stakeholders has indicated that the move to a 5 year research planning horizon was welcomed by research providers, but some stakeholders felt that Requests for Proposals should be at a higher level than individual projects to safeguard intellectual property on new ideas and methods.

ii. Does research planning now benefit from close cooperative relationships within the Ministry of Fisheries, with other government agencies, and with external stakeholders?

The Biodiversity Programme is very co-operative. Of 38 projects underway in the last 5 years, 14 have formal collaborative components across government departments, with other stakeholders or multiple research providers and 10 have formal linkages to international research programmes. Within MPI and with other stakeholders (NGOs, industry, other government departments), the Biodiversity Projects have contributed to discussions about Marine Stewardship Council (MSC) certification, to decision papers on aspects of Antarctic management under CAMLR, fulfilling MPI commitments to the NZ Biodiversity Strategy, and to MPI progress towards recognising the role of the ecosystem in underpinning sustainable and healthy fisheries production. There are many other examples, e.g. the programme has contributed towards DOC and MPI decisions on marine protected areas.

The interaction at the research and policy advice stages of resource management feeds back into the BRAG planning for future research.

There are close links with the MPI Aquatic Environment research programme, the National Aquatic Biodiversity Information System (NABIS), an MPI web-based interactive data access and mapping tool, and the MPI Antarctic Research programme. These and other links have enabled contributions resulting from progress on land-sea interface research, habitats of significance to fisheries management, trophic studies (MSC Certification), climate change (effects on shellfish) and habitat classification (fish optimised MEC, testing of MEC and BOMEC). The successful involvement of the Biodiversity Programme in major all-of-government projects such as Ocean Survey 20/20 and IPY-CAML, has also raised the profile of MPI and the research it has commissioned both across New Zealand and internationally.

Datasets, voucher specimens and samples from all biodiversity research projects have resulted in a substantial amount of material that has been physically preserved and housed in the Te Papa Fish Collection and NIWA National Invertebrate Collection, and Herbarium (macroalgae). All data are held in databases either at MPI, NIWA or Te Papa, and accessibility is being improved. The recent Bay of Islands Ocean Survey 20/20 Portal was very well received and nominated for NZ Government Open Source awards. It will also incorporate data access from Chatham Challenger and IPY projects. Data from a number of MPI biodiversity projects have also been entered into international biodiversity databases such as OBIS and from there into the Global Biodiversity Information Facility (GBIF).

Biodiversity Research planning receives regular input from DOC, SeaFIC, MfE, Cawthron Institute, NIWA, GNS, LINZ, MAFBNZ, Te Papa, University of Auckland, AUT, University of Otago, MoRST, MFAT, Regional Councils and others. Research planning for 2013–14 and beyond will include a re-alignment of the current research programme to take account of new developments such as Fisheries 2030, MfE's environmental reporting programme, DOC's integrated coastal monitoring programme, Statistics New Zealand's Environmental Domain Plan [71], and international commitments such as the recent CBD COP10 Aichi-Nagoya Agreement.

Feedback and support for projects by external stakeholders has shown that the Programme has been effective in promoting inter-agency collaboration. The Programme has also had close links with Research Data Management and the Observer Programme for certain projects (e.g trophic studies on the Chatham Rise, ZBD2004-02). With the former restructure of the Ministry of Fisheries and the merger with MAF, and the move to Fisheries 2030 and Fisheries Plans, it important that the Programme develops strong relationships within MPI.

iii. Have mutually beneficial collaborative research projects been carried out alongside other New Zealand and international research providers, especially for vessel-based research?

As discussed above, collaborative research projects across government and among research providers have resulted in many mutually beneficial data and specimen collection, surveys of New Zealand marine biodiversity in NZ territorial seas, the EEZ and the Ross Sea, groundbreaking research into seamount biodiversity and the identification of VMEs, and research for international collaboration, particularly vessel based studies. Large scale vessel dependent oceanic research projects have made significant gains in baseline knowledge about the distribution and abundance of biodiversity in the EEZ/Ross Sea region. Vessel-based projects include: NORFANZ (Norfolk Island-Australia-New Zealand survey of biodiversity on Norfolk Ridge and Lord Howe Rise); BioRoss (MPI-LINZ, first NZ survey of biodiversity in the Ross Sea); Chatham-Challenger (LINZ-MPI-NIWA-DOC first Ocean Survey 20/20 project), NZ IPY-CAML (MPI-LINZ-NIWA (with international and NZ wide collaboration) survey of the Ross Sea as part of International Polar Year; Biodiversity of seamounts (MPI-NIWA-LINZ-MBIE voyages to the Kermadec Arc and on the Chatham Rise). These projects have generated huge geo-referenced datasets and thousands of specimens for Te

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

Papa and National Invertebrate Collections. They have also resulted in the identification of new species, new genera and new families, as well as new records extending the known distribution of species. These surveys have contributed to habitat classification, identified areas of high biodiversity and challenged paradigms on the environmental drivers that determine biodiversity. More recently they have provided new information on the effects of ocean acidification on the productivity of polar seas, and in New Zealand waters.

Vessel dependent coastal projects have also generated significant new understanding about the distribution of inshore biota, and the role they play in maintaining a healthy ecosystem. Experimental field work on the productivity of the seabed has been carried out in NZ waters (Fiordland, Otago, Bay of Islands, Hauraki Gulf, Kaipara and Manukau Harbours), and along the west coast of the Ross Sea. The impact of land practices on the land-sea interface has also highlighted real downstream effects on the productivity of the coastal environment. These projects have provided new insights into the connectivity between different species groups, and data are being used in a number of ways to assist with spatial planning by RMAs.

Feedback from stakeholders has indicated that the collaborative voyages administered through the Programme have successfully created synergy and opportunity for New Zealand scientists as well as facilitating new international collaborations.

iv. *Have MPI [MFish] Biodiversity projects contributed substantially to an improved understanding of New Zealand's marine biodiversity and its role in marine ecosystem function, yielding scientifically rigorous outputs for a national and international professional audience?*

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

v. *Have results generated by MPI [MFish] Biodiversity projects been incorporated into management policy, with clear benefits for the New Zealand marine environment?*

Examples of incorporation into management policy with clear benefits for the marine environment include the increased awareness of research topics initiated in the biodiversity programme by policy analysts to core Aquatic Environment research projects and Fishery Plans, (land-use effects, climate change in the ocean, habitat classification); links to the Antarctic research programme and uptake into CCAMLR (ecotrophic studies, ecosystem baselines, VME risk assessment, bioregionalisation), spatial management (seamount closures, BPAs, MPAs, RMAs), the need by MfE to report on the marine environment at a national scale (plankton recording programme, Marine Environmental Monitoring Programme). MPI biodiversity advice is frequently requested to contribute to cross-government initiatives including Ocean Survey 20/20, DOC Sub-Antarctic Islands Forum National Monitoring, Statistics New Zealand Tier 1 statistic review and Environmental Domain Stocktake, International Year of Biodiversity, OECD and CBD reports, International Oceans Issues, SPRFMO, NRS marine issues paper, the Antarctic Science Framework, Ocean Fertilisation and IPCC Finally, the programme has contributed to New Zealand's efforts in the international Census of Marine Life and an ongoing assessment of New Zealand's progress in Marine Biodiversity has been proposed as a new Tier 1 Environmental Statistic. However, the benefits to the marine environment are more inferred than demonstrated. There is substantially increased awareness within MPI and across government, that the health of fisheries and other valued uses of the sea depend on intact ecosystem services provided by the diversity of organisms, the diversity of habitats and the genetic diversity found in the marine environment. Statements of intent and long-term strategic documents such as Fisheries 2030 and Fish Plans have biodiversity protection and an ecosystem approach to fisheries management objectives explicitly stated. Future research questions will also need to address follow-up of management decisions to assess whether and to what extent the objectives have been achieved.

In 2000, the concept of research on marine biodiversity was hotly debated among stakeholders and the benefit of the research (other than to scientists) was not widely accepted. In 2010, it is clear that much of the research in this biodiversity programme has been about defining and mapping the biological diversity of the sea, its roles in marine ecosystem function, threats to these roles and how best biodiversity and its successful protection can be measured. Huge advances have been made in providing new identification tools for major groups (e.g. Coralline algae). Much progress has been made, and the programme has successfully raised the profile of biodiversity in coastal and ocean environmental management, in particular fisheries management, and biodiversity research uptake into policy and management decisions within MPI and across government.

16.3 CONCLUDING REMARKS

New Zealand is moving into an era of unprecedented and increasing interest in the utilisation of marine resources (Business Growth Agenda 2014). Mineral, petroleum and gas resources are estimated to be worth billions of dollars to the economy (Glasby & Wright 1990), and new environmental legislation has been enacted (the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012). Changes inshore are also taking effect with the Environmental Protection Authority Act passed by Parliament on 11 May 2011. This Act establishes a new Environmental Protection Authority (EPA) as a standalone crown agent from 1 July 2011 which has responsibility for regulating activities under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012.

The Government has also set national policy direction under the Resource Management Act 1991 to guide decisions affecting freshwater and coastal environments (National Policy Statement for Freshwater Management 2014; New Zealand Coastal Policy Statement 2010).

New Zealand is also a signatory to the CBD Aichi-Nagoya Agreement with a new International Decade for Biodiversity that runs 2011–2020 and New Zealand's contribution to the identification of EBSAs in the SW Pacific, and to GOBI. Progress in our knowledge of the marine biodiversity and ecosystem services provided by the marine environment has clearly been made over the last decade. However, we need a more co-ordinated approach across government to link science to policy needs. Essentially we need to know three things; what is out there in the marine environment to use, protect, or manage; how does the ecosystem function; and what are the impacts of natural and human induced changes, and what tools will allow for effective monitoring and management of environmental impacts? For example, there is a compelling need for large-scale projects such as mapping seafloor habitats and establishing long-term nationwide monitoring and reporting schemes to measure the effects of ocean climate change, regular assessment of the cumulative effects of anthropogenic activities and multiple stressors in the ocean and the effectiveness of their management. Without these, we face the risks that New Zealand's "green" branding will be increasingly challenged, and that tipping points in the health of the aquatic environment may be reached too soon for evasive action to be taken.

Consumer driven pressures and social awareness of human impacts on the environment, including marine biodiversity, has been increasing and New Zealand's newly launched science challenge, "Sustainable Seas" takes a conventional ecological approach integrated with a social science approach to ecosystem-based management.

CURRENT NZ/EU PARTNERSHIPS:

- BAYESIANMETAFLATS - Spatial organization of species distributions: hierarchical and scale-dependent patterns and processes in coastal seascapes http://www.kg.eurocean.org/proj.jsp?load=100553
- Chess - Biogeography of Deep-Water Chemosynthetic Ecosystems http://www.kg.eurocean.org/proj.jsp?load=103314
- INDEEP - International Network for Scientific Investigation of Deep-Sea Ecosystems http://www.kg.eurocean.org/proj.jsp?load=103321
- PHARMASEA - Increasing Value and Flow in the Marine Biodiscovery Pipeline - http://www.kg.eurocean.org/proj.jsp?load=100504
- MAREFRAME - Co-creating Ecosystem-based Fisheries Management Solutions - http://www.kg.eurocean.org/proj.jsp?load=500

- BENTHIS - studies the impacts of fishing on benthic ecosystems and will provide the science base to assess the impact of current fishing practices http://www.benthis.eu/en/benthis.htm

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16.5 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.

17 APPENDICES

17.1 TERMS OF REFERENCE FOR THE AQUATIC ENVIRONMENT WORKING GROUP FOR 2013 ONWARDS

OVERALL PURPOSE

For all New Zealand fisheries in the New Zealand TS and EEZ as well as other important fisheries in which New Zealand engages:

to assess, based on scientific information, the effects of (and risks posed by) fishing, aquaculture, and enhancement on the aquatic environment, including:

- bycatch and unobserved mortality of protected species (e.g. seabirds and marine mammals), fish, and other marine life, and consequent impacts on populations;
- effects of bottom fisheries on benthic biodiversity, species, and habitat;
- effects on biodiversity, including genetic diversity;
- changes to ecosystem structure and function from fishing, including trophic effects; and
- effects of aquaculture and fishery enhancement on the environment and on fishing.

Where appropriate and feasible, such assessments should explore the implications of the effect, including with respect to government standards, other agreed reference points, or other relevant indicators of population or environmental status. Where possible, projections of future status under alternative management scenarios should be made.

AEWG assesses the effects of fishing or environmental status, and may evaluate the consequences of alternative future management scenarios. AEWG does not make management recommendations or decisions (this responsibility lies with MPI fisheries managers and the Minister responsible for Fisheries).

MPI also convenes a Biodiversity Research Advisory Group (BRAG) which has a similar review function to the AEWG. Projects reviewed by BRAG and AEWG have some commonalities however, the key focus of projects considered by BRAG is on marine issues related to the functionality of the marine ecosystem and its productivity, whereas projects considered by AEWG are more commonly focused on the direct effects of fishing.

PREPARATORY TASKS

1. Prior to the beginning of AEWG meetings each year, MPI fisheries scientists will produce a list of issues for which new assessments or evaluations are likely to become available prior to the next scheduled sustainability round or decision process. AEWG Chairs will determine the final timetables and agendas.
2. The Ministry's research planning processes should identify most information needs well in advance but, if urgent issues arise, MPI-Fisheries or standards managers will alert MPI-Fisheries science managers and the Principal Advisor Fisheries Science, at least three months prior to the required AEWG meetings to other cases for which assessments or evaluations are urgently needed.

TECHNICAL OBJECTIVES

3. To review any new research information on fisheries impacts, including risks of impacts, and the relative or absolute sensitivity or susceptibility of potentially affected species, populations, habitats, and systems.
4. To estimate appropriate reference points for determining population, system, or environmental status, noting any draft or published Standards.
5. To conduct environmental assessments or evaluations for selected species, populations, habitats, or systems in order to determine their status relative to appropriate reference points and Standards, where such exist.
6. In addition to determining the status of the species, populations, habitats, and systems relative to reference points, and particularly where the status is unknown, AEWG should explore the potential for using existing data and analyses to draw conclusions about likely future trends in fishing effects or status if

current fishing methods, effort, catches, and catch limits are maintained, or if fishers or fisheries managers are considering modifying them in other ways.

7. Where appropriate and practical, to conduct or request projections of likely future status using alternative management actions, based on input from AEWG, fisheries plan advisers and fisheries and standards managers, noting any draft or published Standards.
8. For species or populations deemed to be depleted or endangered, to develop ideas for alternative rebuilding scenarios to levels that are likely to ensure long-term viability based on input from AEWG, fisheries managers, noting any draft or published Standards.
9. For species, populations, habitats, or systems for which new assessments are not conducted in the current year, to review and update any existing Fisheries Assessment Plenary report text in order to determine whether the latest reported status summary is still relevant; else to revise the evaluations based on new data or analyses, or other relevant information.

WORKING GROUP INPUT TO ANNUAL AQUATIC ENVIRONMENT AND BIODIVERSITY ANNUAL REVIEW

10. To include in contributions to the Aquatic Environment and Biodiversity Annual Review (AEBAR) summaries of information on selected issues that may relate to species, populations, habitats, or systems that may be affected by fishing. These contributions are analogous to Working Group reports from the Fisheries Assessment Working Groups.
11. To provide information and scientific advice on management considerations (e.g. area boundaries, by-catch issues, effects of fishing on habitat, other sources of mortality, and input controls such as mesh sizes and minimum legal sizes) that may be relevant for setting sustainability measures.
12. To summarise the assessment methods and results, along with estimates of relevant standards, references points, or other metrics that may be used as benchmarks or to identify risks to the aquatic environment.
13. It is desirable that full agreement among technical experts is achieved on the text of contributions to the AEBAR. If full agreement among technical experts cannot be reached, the Chair will determine how this will be depicted in the AEBAR, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.
14. To advise the Principal Advisor Fisheries Science, about issues of particular importance that may require review by a plenary meeting or summarising in the AEBAR, and issues that are not believed to warrant such review. The general criterion for determining which issues should be discussed by a wider group or summarised in the AEBAR is that new data or analyses have become available that alter the previous assessment of an issue, particularly assessments of population status or projection results. Such information could include:

    - New or revised estimates of environmental reference points, recent or current population status, trend, or projections;
    - The development of a major trend in bycatch rates or amount;
    - Any new studies or data that extend understanding of population, system, or environmental susceptibility to an effect or its recoverability, fishing patterns, or mitigation measures that have a substantial implications for a population, system, or environment or identify risks associated with fishing activity; and
    - Consistent performance outside accepted reference points or Standards.

MEMBERSHIP AND PROTOCOLS FOR ALL SCIENCE WORKING GROUPS (PARAGRAPH NUMBERS CONSISTENT WITH THOSE IN TERMS OF REFERENCE FOR FISHERIES ASSESSMENT WORKING GROUPS)

WORKING GROUP CHAIRS

17. The Ministry will select and appoint the Chairs for Working Groups. The Chair will be an MPI fisheries scientist who is an active participant

in the Working Group, providing technical input, rather than simply being a facilitator. Working Group Chairs will be responsible for:

- ensuring that Working Group participants are aware of the Terms of Reference for the Working Group, and that the Terms of Reference are adhered to by all participants;
- setting the rules of engagement, facilitating constructive questioning, and focussing on relevant issues;
- ensuring that all peer review processes are conducted in accordance with the Research and Science Information Standard for New Zealand Fisheries[1] (the Research Standard), and that research and science information is reviewed by the Working Group against the *P R I O R* principles for science information quality (page 6) and the criteria for peer review (pages 12-16) in the Standard;
- requesting and documenting the affiliations of participants at each Working Group meeting that have the potential to be, or to be perceived to be, a conflict of interest of relevance to the research under review (refer to page 15 of the Research Standard). Chairs are responsible for managing conflicts of interest, and ensuring that fisheries management implications do not jeopardise the objectivity of the review or result in biased interpretation of results;
- ensuring that the quality of information that is intended or likely to inform fisheries management decisions is ranked in accordance with the information ranking guidelines in the Research Standard (page 21-23), and that resulting information quality ranks are appropriately documented in Working Group reports and, where appropriate, in Status of Stock summary tables;
- striving for consensus while ensuring the transparency and integrity of research analyses, results, conclusions and final reports; and
- reporting on Working Group recommendations, conclusions and action items; and ensuring follow-up and communication with the MPI Principal Advisor Fisheries Science, relevant MPI fisheries management staff, and other key stakeholders.

WORKING GROUP MEMBERS

18. Working Groups will consist of the following participants:

- MPI fisheries science chair – required;
- Research providers – required (may be the primary researcher, or a designated substitute capable of presenting and discussing the agenda item);
- Other scientists not conducting analytical assessments to act in a peer review capacity;
- Representatives of relevant MPI fisheries management teams; and
- Any interested party who agrees to the standards of participation below.

19. Working Group participants must commit to:

- participating in the discussion;
- resolving issues;
- following up on agreements and tasks;
- maintaining confidentiality of Working Group discussions and deliberations (unless otherwise agreed in advance, and subject to the constraints of the Official Information Act);
- adopting a constructive approach;
- avoiding repetition of earlier deliberations, particularly where agreement has already been reached;

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

- facilitating an atmosphere of honesty, openness and trust;
- respecting the role of the Chair; and
- listening to the views of others, and treating them with respect.

20. Participants in Working Group meetings will be expected to declare their sector affiliations and contractual relationships to the research under review, and to declare any substantial conflicts of interest related to any particular issue or scientific conclusion.

21. Working Group participants are expected to adhere to the requirements of independence, impartiality and objectivity listed under the Peer Review Criteria in the Research Standard (pages 12-16). It is understood that Working Group participants will often be representing particular sectors and interest groups, and will be expressing the views of those groups. However, when reviewing the quality of science information, representatives are expected to step aside from their sector affiliations, and to ensure that individual and sector views do not result in bias in the science information and conclusions.

WORKING GROUP PAPERS

23. Working group papers will be posted on the MPI-Fisheries website prior to meetings if they are available. As a general guide, Powerpoint presentations and draft or discussion papers should be available at least 2 working days before a meeting, and near-final papers should be available at least 5 working days before a meeting if the Working Group is expected to agree to the paper. However, it is also likely that many papers will be tabled during the meeting due to time constraints. If a paper is not available for sufficient time before the meeting, the Chair may provide for additional time for written comments from Working Group members.

24. Working Group papers are "works in progress" whose role is to facilitate the discussion of the Working Groups. They often contain preliminary results that are receiving peer review for the first time and, as such, may contain errors or preliminary analyses that will be superseded by more rigorous work. For these reasons, no-one may release the papers or any information contained in these papers to external parties. In general, Working Group papers should never be cited. Exceptions may be made in rare instances by obtaining permission in writing from the Principal Advisor Fisheries Science, and the authors of the paper.

25. Participants who use Working Group papers inappropriately, or who do not adhere to the standards of participation, may be requested by the Chair to leave a particular meeting or, in more serious instances, to refrain from attending one or more future meetings.

WORKING GROUP MEETINGS

26. Meetings will take place as required, generally January-April and July-November for FAWGs and throughout the year for other working groups (AEWG, BRAG, Marine Amateur Fisheries and Antarctic Working Groups).

27. A quorum will be reached when the Chair, the designated presenter, and three or more other technical experts are present. In the absence of a quorum, the Chair may decide to proceed as a sub-group, with outcomes being taken forward to the next meeting at which a quorum is formed.

28. The Chair is responsible for deciding, with input from the entire Working Group, but focussing primarily on the technical discussion and the views of technical expert members:

- The quality and acceptability of the information and analyses under review;
- The way forward to address any deficiencies;
- The need for any additional analyses;
- Contents of Working Group reports;
- Choice of base case models and sensitivity analyses to be presented; and
- The status of the stocks, or the status/performance in relation to any relevant environmental standards or targets.

29. The Chair is responsible for facilitating a consultative and collaborative discussion.
30. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.
31. A record of recommendations, conclusions and action items will be posted on the MPI-Fisheries website after each meeting has taken place.
32. Data upon which analyses presented to the Working Groups are based must be provided to MPI in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MPI; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members).
33. The outcome of each Working Group round will be evaluated, with a view to identifying opportunities to improve the Working Group process. The Terms of Reference may be updated as part of this review.
34. MPI fisheries scientists and science officers will provide administrative support to the Working Groups.

Information Quality Ranking

22. Science Working Groups are required to rank the quality of research and science information that is intended or likely to inform fisheries management decisions, in accordance with the science information quality ranking guidelines in the Research Standard (pages 21-23). Information quality rankings should be documented in Working Group reports and, where appropriate, in Status of Stock summary tables.

- Working Groups are not required to rank all research projects and analyses, but key pieces of information that are expected or likely to inform fisheries management decisions should receive a quality ranking;
- Explanations substantiating the quality rankings will be included in Working Group reports. In particular, the quality shortcomings and concerns for moderate/mixed and low quality information must be documented; and
- The Chair, working with participants, will determine which pieces of information require a quality ranking. Not all information resulting from a particular research project would be expected to achieve the same quality rank, and different quality ranks may be assigned to different components, conclusions or pieces of information resulting from a particular piece of research.

RECORD-KEEPING

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

- keeping notes on recommendations, conclusions and follow-up actions for all Working Group meetings, and to ensure that these are available to all members of the Working Group and the Principal Advisor Fisheries Science in a timely manner. If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes; and
- compiling a list of generic assessment issues and specific research needs for each Fishstock or species or environmental issue under the purview of the Working Group, for use in subsequent research planning processes.

17.2 AEWG MEMBERSHIP 2014–15

CONVENORS: Rich Ford, Martin Cryer, Nathan Walker

MEMBERS: CONVENORS: Rich Ford, Nathan Walker

MEMBERS: Ed Abraham, Ian Angus, Karen Baird, Suze Baird, Sira Ballara, Michael Batson, Biz Bell, Michelle

Beritzhoff-Law, Katrin Berkenbusch, Jenny Black, Tiffany Bock, Laura Boren, Dave Bowden, Paul Breen, Niall Broekhuizen, Bruno Brosnan, Kelly Buckle, Malcolm Clark, Tom Clark, Katie Clemens-Seely, Deanna Clement, Graeme Coates, Chris Cornelisen, Paul Crozier, Rohan Currey, Igor Debski, Ian Doonan, Matt Dunn, Charlie Edwards, Jack Fenaughty, Giovanni Fesuiai, Barry Forrest, Dave Foster, Malcolm Francis, Dan Fu, Annie Galland, Alexia Garner, Hilke Giles, Mark Gillard, Katrina Goddard, Kim Goetz, Sharyn Goldstien, Oliver Gooday, Mark Hadfield, Judi Hewitt, Stephanie Hill, Julie Hills, Freydis Hjorvarsdottis, Tom Hollings, Rosie Hurst, Ben KnightMary Livingston, Greg Lydon, Darryl MacKenzie, Janice Malloy, Rob Mattlin, Kimberley Maxwell, Stefan Meyer, David Middleton, Jenny Oliver, Darren Parsons, Duncan Petrie, David Plew, Kris Ramm, Vicky Reeve, Amanda Richards, Yvan Richard, Jim Roberts, Bruce Robertson, Marie-Julie Roux, Max Schofield, Ben Sharp, Jennifer Siembieda, Liz Slooten, Vaughan Stagpoole, Rob Stewart, Graeme Taylor, Findlay Thompson, Rob Tilney, Ian Tuck, Steve Ulrich, Dominic Vallieres, Adam Watson, Barry Weeber, Richard Wells, Merv Whipp, Mike Williams, Neil Williams, Hamish Wilson, Oliver Wilson, Pete Wilson, Jana Wold.

17.3 TERMS OF REFERENCE FOR THE BIODIVERSITY RESEARCH ADVISORY GROUP (BRAG) 2013 ONWARDS

OVERALL PURPOSE

Since 2000, the objectives of the Biodiversity Research Programme have been drawn directly from MFish commitments to Theme 3 of the New Zealand Biodiversity Strategy. Within this framework, the Biodiversity Medium Term Research Plan has been adapted over time as new issues emerge, to build on synergies with other research programmes and work where biodiversity is under greatest threat from fishing or other anthropogenic activity.

Within the constraints of the overall purpose of the Programme,

> "To improve our understanding of New Zealand marine ecosystems in terms of species diversity, marine habitat diversity, and the processes that lead to healthy ecosystem functioning, and the role that biodiversity has for such key processes[2]"

and the NZBS definition of biodiversity (the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystem) the science currently commissioned broadly aims to:

- Describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed;
- determine the functional role of different organisms or groups of organisms in marine ecosystems, and assess the role of marine biodiversity in mitigating the impacts of anthropogenic disturbance on healthy ecosystem functioning;
- identify which components of biodiversity must be protected to ensure the sustainability of a healthy marine ecosystem as well as to meet societal values on biodiversity.

MPI also convenes an Aquatic Environment Working Group (AEWG) which has a similar review function to the BRAG. Projects reviewed by BRAG and AEWG have some commonalities in that they relate to aspects of the marine environment. However, the key focus of projects considered by BRAG is on marine issues related to the functionality of the marine ecosystem and its productivity, whereas projects considered by AEWG are more commonly focused on the direct effects of fishing.

BRAG may identify natural resource management issues that extend beyond fisheries management and make recommendations on priority areas of research that will inform MAF or other government departments of emerging science results that require the attention of managers, policymakers and decision-makers in the marine sector.

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

BRAG does not make management recommendations or decisions (this responsibility lies with the MAF Fisheries Management Group and the Minister of Primary Industry).

PREPARATORY TASKS

1. Prior to the beginning of BRAG meetings each year, MPI fisheries scientists will produce a list of issues for which new research projects are likely to required in the forthcoming financial year. The BRAG Chair will determine the final timetables and agendas.
2. The Ministry's research planning processes should identify most information needs well in advance but, if urgent issues arise, MPI fisheries managers will alert the Aquatic Environment and Biodiversity Science Manager and the Principal Advisor Fisheries Science at least three months prior to the required meetings where possible.

BRAG TECHNICAL OBJECTIVES

3. To review, discuss and convey views on the results of marine biodiversity research projects contracted by MPI (formerly Ministry of Fisheries).

It is the responsibility of the BRAG to review, discuss, and convey views on the results of marine biodiversity research projects contracted by MPI and the former Ministry of Fisheries. The review process is an evaluation of how existing research results can be built upon to address emerging research issues and needs. It is essentially an evaluation of "what we already know" and how this can be used to obtain "what we need to know". This information should be used by the BRAG to identify gaps in our knowledge and for developing research plans to address these gaps.

4. Discuss, evaluate, make recommendations and convey views on a 3 to 5 year Medium Term Research Plan.

It is the responsibility of BRAG participants to discuss, evaluate, make recommendations and convey views on a 3 to 5 year Medium Term Research Plan for its particular research area as required. Individual related projects on a species or fishery or research topic need to be integrated into Medium Term Research Plans. The Medium Term Research Plans should encompass research needs and directions for at least the next 3 to 5 years.

The Biodiversity Medium Term Research Plan is aligned to relevant strategic and policy directions such as the "MPI Statement of Intent" and any Strategic Research Plan (Fisheries 2030, Deepwater 10 year research plan) and fisheries plans developed for the appropriate species/fishery or research area, including biodiversity.

The recommendations on project proposals for the next financial year will be submitted via the Chair of BRAG to the Principal Science Advisor Fisheries (MAF).

5. The Biodiversity Research Programme includes research in New Zealand's TS, EEZ, Extended Continental Shelf, the South Pacific Region and the Ross Sea region and has seven scientific work streams as follows:
    1. To develop ecosystem-scale understanding of biodiversity in the New Zealand marine environment
    2. To classify and characterise the biodiversity, including the description and documentation of biota, associated with nearshore and offshore marine habitats in New Zealand
    3. To investigate the role of biodiversity in the functional ecology of nearshore and offshore marine communities.
    4. To assess developments in all aspects of biodiversity, including genetic marine biodiversity and identify key topics for research
    5. To determine the effects of climate change and increased ocean acidification on marine biodiversity, as well as effects of incursions of non-indigenous species, and other threats and impacts.
    6. To develop appropriate diversity metrics and other indicators of biodiversity that can be used to monitor change
    7. To identify threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation

BRAG INPUT TO MPI "AQUATIC ENVIRONMENT AND BIODIVERSITY ANNUAL REVIEW"

6. To contribute to and summarise progress on biodiversity research in the Aquatic Environment and Biodiversity Annual Review. This contribution is analogous to Working Group Reports from the Fishery Assessment Working Groups.
7. To summarise the assessment methods and results, along with estimates of relevant standards, references points, or other metrics that may be relevant to biodiversity objectives by MPI, the Biodiversity Strategy and international obligations.
8. It is desirable that full agreement among technical experts is achieved on the text of these contributions. If full agreement among technical experts cannot be reached, the Chair will determine how this will be depicted in the Aquatic Environment and Biodiversity Annual Review, will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.
9. To advise the Principal Science Advisor Fisheries (MPI), about issues of particular importance that may require review by a plenary meeting or summarising in the Aquatic Environment and Biodiversity Annual Review. The general criterion for determining which issues should be discussed by a wider group include:

    - Emerging issues, recent or current biodiversity status assessments, trends, or projections
    - The development of a major trend in the marine environment that will impact on marine productivity or ecosystem resilience to stressors
    - Any new studies or data that impact on international obligations

MEMBERSHIP AND PROTOCOLS FOR ALL SCIENCE WORKING GROUPS (NOTE: PARAGRAPH NUMBERS CONSISTENT WITH THOSE IN TERMS OF REFERENCE FOR FISHERIES ASSESSMENT WORKING GROUPS)

WORKING GROUP CHAIRS

17. The Ministry will select and appoint the Chairs for Working Groups. The Chair will be an MPI fisheries scientist who is an active participant in the Working Group, providing technical input, rather than simply being a facilitator. Working Group Chairs will be responsible for:

    - ensuring that Working Group participants are aware of the Terms of Reference for the Working Group, and that the Terms of Reference are adhered to by all participants;
    - setting the rules of engagement, facilitating constructive questioning, and focussing on relevant issues;
    - ensuring that all peer review processes are conducted in accordance with the Research and Science Information Standard for New Zealand Fisheries[3] (the Research Standard), and that research and science information is reviewed by the Working Group against the *P R I O R* principles for science information quality (page 6) and the criteria for peer review (pages 12-16) in the Standard;
    - requesting and documenting the affiliations of participants at each Working Group meeting that have the potential to be, or to be perceived to be, a conflict of interest of relevance to the research under review (refer to page 15 of the Research Standard). Chairs are responsible for managing conflicts of interest, and ensuring that fisheries management implications do not jeopardise the objectivity of the review or result in biased interpretation of results;
    - ensuring that the quality of information that is intended or likely to inform fisheries management decisions is

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

ranked in accordance with the information ranking guidelines in the Research Standard (page 21-23), and that resulting information quality ranks are appropriately documented in Working Group reports and, where appropriate, in Status of Stock summary tables;

- striving for consensus while ensuring the transparency and integrity of research analyses, results, conclusions and final reports; and
- reporting on Working Group recommendations, conclusions and action items; and ensuring follow-up and communication with the MPI Principal Advisor Fisheries Science, relevant MPI fisheries management staff, and other key stakeholders.

WORKING GROUP MEMBERS

18. Working Groups will consist of the following participants:

- MPI fisheries science chair – required;
- Research providers – required (may be the primary researcher, or a designated substitute capable of presenting and discussing the agenda item);
- Other scientists not conducting analytical assessments to act in a peer review capacity;
- Representatives of relevant MPI fisheries management teams; and
- Any interested party who agrees to the standards of participation below.

19. Working Group participants must commit to:

- participating in the discussion;
- resolving issues;
- following up on agreements and tasks;
- maintaining confidentiality of Working Group discussions and deliberations (unless otherwise agreed in advance, and subject to the constraints of the Official Information Act);
- adopting a constructive approach;
- avoiding repetition of earlier deliberations, particularly where agreement has already been reached;
- facilitating an atmosphere of honesty, openness and trust;
- respecting the role of the Chair; and
- listening to the views of others, and treating them with respect.

20. Participants in Working Group meetings will be expected to declare their sector affiliations and contractual relationships to the research under review, and to declare any substantial conflicts of interest related to any particular issue or scientific conclusion.

21. Working Group participants are expected to adhere to the requirements of independence, impartiality and objectivity listed under the Peer Review Criteria in the Research Standard (pages 12-16). It is understood that Working Group participants will often be representing particular sectors and interest groups, and will be expressing the views of those groups. However, when reviewing the quality of science information, representatives are expected to step aside from their sector affiliations, and to ensure that individual and sector views do not result in bias in the science information and conclusions.

WORKING GROUP PAPERS

23. Working group papers will be posted on the MPI-Fisheries website prior to meetings if they are available. As a general guide, Powerpoint presentations and draft or discussion papers should be available at least 2 working days before a meeting, and near-final papers should be available at least 5 working days before a meeting if the Working Group is expected to agree to the paper. However, it is also likely that many papers will be tabled during the meeting due to time constraints. If a paper is not available for sufficient time before the meeting, the Chair may provide for additional time for written comments from Working Group members.

24. Working Group papers are “works in progress” whose role is to facilitate the discussion of the Working Groups. They often

contain preliminary results that are receiving peer review for the first time and, as such, may contain errors or preliminary analyses that will be superseded by more rigorous work. For these reasons, no-one may release the papers or any information contained in these papers to external parties. In general, Working Group papers should never be cited. Exceptions may be made in rare instances by obtaining permission in writing from the Principal Advisor Fisheries Science, and the authors of the paper.

25. Participants who use Working Group papers inappropriately, or who do not adhere to the standards of participation, may be requested by the Chair to leave a particular meeting or, in more serious instances, to refrain from attending one or more future meetings.

WORKING GROUP MEETINGS

26. Meetings will take place as required, generally January-April and July-November for FAWGs and throughout the year for other working groups (AEWG, BRAG, Marine Amateur Fisheries and Antarctic Working Groups).
27. A quorum will be reached when the Chair, the designated presenter, and three or more other technical experts are present. In the absence of a quorum, the Chair may decide to proceed as a sub-group, with outcomes being taken forward to the next meeting at which a quorum is formed.
28. The Chair is responsible for deciding, with input from the entire Working Group, but focussing primarily on the technical discussion and the views of technical expert members:

    - The quality and acceptability of the information and analyses under review;
    - The way forward to address any deficiencies;
    - The need for any additional analyses;
    - Contents of Working Group reports;
    - Choice of base case models and sensitivity analyses to be presented; and
    - The status of the stocks, or the status/performance in relation to any relevant environmental standards or targets.

29. The Chair is responsible for facilitating a consultative and collaborative discussion.
30. Working Group meetings will be run formally, with agendas pre-circulated, and formal records kept of recommendations, conclusions and action items.
31. A record of recommendations, conclusions and action items will be posted on the MPI-Fisheries website after each meeting has taken place.
32. Data upon which analyses presented to the Working Groups are based must be provided to MPI in the appropriate format and level of detail in a timely manner (i.e. the data must be available and accessible to MPI; however, data confidentiality concerns mean that such data are not necessarily available to Working Group members).
33. The outcome of each Working Group round will be evaluated, with a view to identifying opportunities to improve the Working Group process. The Terms of Reference may be updated as part of this review.
34. MPI fisheries scientists and science officers will provide administrative support to the Working Groups.

RECORD-KEEPING

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

    - keeping notes on recommendations, conclusions and follow-up actions for all Working Group meetings, and to ensure that these are available to all members of the Working Group and the Principal Advisor Fisheries Science in a timely manner. If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes; and

- compiling a list of generic assessment issues and specific research needs for each Fishstock or species or environmental issue under the purview of the Working Group, for use in subsequent research planning processes.

17.4 BRAG ATTENDANCE 2015

CONVENOR: Mary Livingston (MPI chair),

MEMBERS: Malcolm Clark, Mark Morrison, Anne-Nina Loerz, Dennis Gordon, Wendy Nelson, Cliff Law, Di Tracey, David Bowden, Matt Pinkerton, Ashley Rowden, Carolyn Lundquist, Malcolm Francis, Darren Parsons, Judi Hewitt, Drew Lohrer, Alison MacDiarmid, Julie Hall, Karen Robinson, Wendy Nelson, Emma Jones, Vonda Cummings, Di Tracey, Alistair Dunn, Barb Hayden, Scott Nodder, Sara Mikaloff-Fletcher (all NIWA); David Middleton (Trident Services NZ); Martin Cryer, Rob Tinkler, Rich Ford, Rohan Currey (MPI); Mark Costello, Shane Lavery (Auckland University); Lyndsey Holland, Jo Hamilton, Jonathan Gardner (Victoria University of Wellington); Paul Breen (RLIC); William Arlidge, Shane Geange (DOC); Aaron Irving (Deepwater Group)

17.5 GENERIC TERMS OF REFERENCE FOR RESEARCH ADVISORY GROUPS (SEPT 2010)

OVERALL PURPOSE

1. The purpose of the Research Advisory Groups (RAGs) is to develop research proposals to meet management information needs and support standards development.

CONTEXT

2. To assist RAG members with their work this section outlines the wider process that RAGs will operate within.

Fisheries Plans will guide the management of fisheries

3. From 1 July 2011 the Ministry of Fisheries (MFish) will be using Fisheries Plans in the following five areas to guide the management of fisheries:

- Deepwater
- Highly Migratory Species
- Inshore – Finfish
- Inshore – Freshwater
- Inshore – Shellfish

4. In each of those five areas there will be:

- A Fisheries Plan that sets out management objectives over a 5 year period.
- An Annual Operational Plan that sets out what will be done in a financial year to help meet those objectives, including in the areas of science research, compliance and observer coverage (i.e., the Annual Operational Plan will be where priorities are set each year). Note that external stakeholders will have an opportunity to provide comment on prioritisation through draft Annual Operational Plans.
- An Annual Review Report that will assess progress made against the management objectives, and help identify gaps to be considered in setting the next set of priorities.

RAGs will largely be aligned to the Fisheries Plan areas

5. There will be a RAG for each of the five Fisheries Plan areas above.
6. In addition there will be a RAG for Aquatic Environment (Standards), for research needed to support standards development, and another for Antarctic research. (Note that biodiversity research is dealt with through a separate process that has more of a cross-agency focus.)

RAGs will develop research proposals to be considered as part of a subsequent prioritisation process

7. As part of the process for developing the Annual Operational Plans, the identification and prioritisation of science research will broadly occur as follows:
   i. MFish fisheries managers will identify the fisheries management objectives and information needs that they want the relevant RAG to consider. This will be done

in conjunction with MFish scientists, and will draw on the following:

- The relevant Annual Review Report discussed above
- Existing research plans
- Science Assessment Working Groups' feedback arising from research that has been evaluated previously
- Ad-hoc issues as they arise
- Initial indications of the available budget

ii. The RAGs will then develop proposals for scientific research to meet those management and information needs.

iii. MFish fisheries managers will then run a process for prioritising the research proposals that have been developed and updating multi-year research plans, in conjunction with MFish scientists. This will be part of the wider process for developing Annual Operational Plans.

8. In the Aquatic Environment (Standards) and Antarctic areas a similar process will be followed to that above, involving relevant MFish managers.

9. In practice, these processes are likely to iterate between the above steps, e.g., when prioritising research proposals fisheries managers may identify additional questions that they want a RAG to consider.

10. RAGs will only be convened when necessary. If, for example, all of the research for the coming year under review has previously been approved as part of a multi-year funding package for an area, and no additional management needs have emerged, the relevant RAG will not be convened.

11. During 2010-11 RAGs will be used, as required, in all areas except Inshore, given that the three Inshore Fisheries Plans are still being developed through the year. For the Inshore areas a transitional process will be used, with RAGs commencing during 2011-12.

RESEARCH PROPOSALS

12. RAGs will provide recommendations to fisheries managers on research to meet management needs. This section provides more detail on the research proposals that the RAGs will produce.

13. The RAGs will produce an initial set of project proposals to meet the management and information needs provided to the RAG, for consideration in the subsequent prioritisation process.

14. The proposals may be in the form of multi-year projects where appropriate.

15. While the prioritisation of research is outside the scope of the work of the RAGs, the proposals will include information on potential cost and feasibility to guide decisions on prioritisation. Cost estimates should be specified as ranges so as to not unduly influence subsequent research provider costings.

16. Where the RAG identifies more than one desirable option for scientific research to meet management and information needs, the RAG's proposals will cover those options, their relative pros and cons, their respective potential costs, and the RAG's recommendation as to the preferred option.

17. Once prioritisation decisions have been made on the initial set of research proposals, the RAG may be asked to produce more fully developed project proposals for inclusion in the relevant Annual Operational Plan, and for the purposes of cost recovery consultation and tendering.

MEMBERSHIP

18. Membership of RAGs is expertise-based.

19. Membership will be by invitation from MFish only.

20. A RAG will consist of a core group of one MFish scientist and one manager from the relevant Fisheries Plan or Standards team, with the option to "call in" relevant technical expertise (internal and/or external) as needed.

21. External participants will be paid for their time. This will include preparing for and attending RAG meetings, and any time spent writing proposals.

PROTOCOLS

22. All RAG members will commit to:

- participating in the discussion in an objective and unbiased manner;
- resolving issues;
- following up on agreements and tasks;
- adopting a constructive approach;
- facilitating an atmosphere of honesty, openness and trust;
- having respect for the role of the Chair; and
- listening to the views of others, and treating them with respect.

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

24. Participants who do not adhere to the standards of participation may be requested by the Chair to leave a particular meeting or, in more serious instances, will be excluded from the RAG.

Chairpersons

25. The Chair of each RAG will be a MFish scientist with appropriate expertise.

26. The Chair commits to undertaking the following roles:

- The Chair is an active participant in RAGs, who also provides technical input, rather than simply being a facilitator.
- The Chair is responsible for: setting the rules of engagement; promoting full participation by all members; facilitating constructive questioning; focussing on relevant issues; reporting on RAG recommendations, conclusions and action items, and ensuring follow-up; and communicating with relevant MFish managers.

27. The Chair is responsible for facilitating consultative and collaborative discussions.

Decision-making

28. The Chair is responsible for working towards an agreed view of the RAG members on their recommendations to the fisheries manager, but where that proves not to be possible then the Chair is responsible for determining the final recommendation. Minority views should be clearly represented in proposals in those cases.

29. A record of recommendations, conclusions and action items will be circulated by e-mail after each meeting by the Chair.

30. Each RAG round will be evaluated by MFish, with a view to identifying opportunities to improve the process. The Terms of Reference may be updated as part of this review.

Non-disclosure agreements

31. Participants may be asked to sign a Non-Disclosure Agreement relating to documents that disclose cost details.

Conflicts of Interest

32. New Zealand is a small country and fisheries research is a relatively limited market, even internationally. People with the necessary skills and knowledge to participate in this advisory process may also have close working relationships with industry, research providers and other stakeholders. This will apply to nearly all external members of a RAG.

33. Participants will be asked to declare any "actual, perceived or likely conflicts of interest" before involvement in a RAG is approved, and any new conflicts that arise during the process should be declared immediately. These will be clearly documented by the Chair.

34. Management of conflicts of interest will be determined by the Chair in consultation with Fisheries Managers, and approved by the Deputy Chief Executive, Fisheries Management prior to meetings commencing.

Frequency of Meetings

35. Relevant MFish managers, in consultation with the Chair of the RAG, will decide on the frequency and timing of RAG meetings.

Documents and record-keeping

36. Unless signalled by the Chair, all RAG documents (papers, agendas, formal records of recommendations, conclusions and action items) will be available to all interested parties through the Ministry of fisheries website (www.fish.govt.nz), except where confidentiality is required for reasons of commercial sensitivity (e.g. cost estimates).
37. RAG documents will be distributed securely.
38. Participants who use RAG papers inappropriately may not be invited to subsequent RAG meetings.
39. The overall responsibility for record-keeping rests with the Chair and includes:

    - Records of recommendations, conclusions and follow-up actions for all RAG meetings and to ensure that these are available in a timely manner.
    - If full agreement on the recommendations or conclusions cannot readily be reached amongst technical experts, then the Chair will document the extent to which agreement or consensus was achieved, and record and attribute any residual disagreement in the meeting notes.

17.6 FISHERIES 2030

USE OUTCOME – Fisheries resources are used in a manner that provides the greatest overall economic, social, and cultural benefit. This means having:

- An internationally competitive and profitable seafood industry that makes a significant contribution to our economy
- High-quality amateur fisheries that contribute to the social, cultural, and economic well-being of all New Zealanders
- Thriving customary fisheries, managed in accordance with kaitiakitanga, supporting the cultural well-being of iwi and hapū
- Healthy fisheries resources in their aquatic environment that reflect and provide for intrinsic and amenity value.

GOVERNANCE CONDITIONS – Fundamental to achieving our goal is the recognition that our approach must be based on sound governance. This means having arrangements that lead to:

- The Treaty partnership being realised through the Crown and Māori clearly defining their respective rights and responsibilities in terms of governance and management of fisheries resources
- The public having confidence and trust in the effectiveness and integrity of the fisheries and aquaculture management regimes
- All stakeholders having rights and responsibilities related to the use and management of fisheries resources that are understood and for which people can be held individually and collectively accountable
- Having an enabling framework that allows stakeholders to create optimal economic, social, and cultural value from their rights and interests
- An accountable, responsive, dynamic, and transparent system of management.

Fisheries 2030 draws on a number of values and principles. These seek to outline the behaviour and approach that should be used to undertake the actions, make decisions, and achieve the goal for New Zealand fisheries.

VALUES

- Tikanga: the Mäori way of doing things; correct procedure, custom, habit, lore, method, manner, rule, way, code, meaning, reason, plan, practice, convention. It is derived from the word tika meaning 'right' or 'correct'.
- Kaitiakitanga: The root word in kaitiakitanga is tiaki, which includes aspects of guardianship, care, and wise management. Kaitiakitanga is the broad notion applied in different situations.
- Kotahitanga: Collective action and unity.
- Manaakitanga: Manaakitanga implies a duty to care for others, in the knowledge that at some time others will care for you. This can also be translated in modern Treaty terms as "create no further grievances in the settlement of current claims".
- Integrity: Be honest and straightforward in our dealings with one another. If we agree to do something we will carry it out.

- Respect: Treat each other with courtesy. We will respect each other's right to have different values and hold different opinions.
- Constructive relationship: Strive to build and maintain constructive ways of working with each other, which can endure.
- Achieving results: Focus on producing a solution rather than just discussing the problem.

PRINCIPLES

- Ecosystem-based approach: We apply an ecosystem-based approach to fisheries management decision-making.
- Conserve biodiversity: Use should not compromise the existence of the full range of genetic diversity within and between species.
- Environmental bottom lines: Biological standards define the limits of extraction and impact on the aquatic environment.
- Precautionary approach: Particular care will be taken to ensure environmental sustainability where information is uncertain, unreliable, or inadequate.
- Address externalities: Those accessing resources and space should address the impacts their activities have on the environment and other users.
- Meet Settlement obligations: Act in ways that are consistent with the Treaty of Waitangi principles and deliver settlement obligations.
- Responsible international citizen: Manage in the context of international rights, obligations, and our strategic interests.
- Inter-generational equity: Current use is achieved in a manner that does not unduly compromise the opportunities for future generations.
- Best available information: Decisions need to be based on the best available and credible biological, economic, social, and cultural information from a range of sources.
- Respect rights and interests: Policies should be formulated and implemented to respect established rights and interests.
- Effective management and services: Use least-cost policy tools to achieve objectives where intervention is necessary and ensure services are delivered efficiently.
- Recover management costs for the reasonable expenses of efficiently provided management and services, from those who benefit from use, and those who cause the risk or adverse effect.
- Dynamic efficiency: Frameworks should be established to allow resources to be allocated to those who value them most.

Fisheries 2030 includes a "plan of action" for the five years from 2009, including: improving the management framework; supporting aquaculture and international objectives; ensuring sustainability of fish stocks; improving fisheries information; building sector leadership and capacity; meeting obligations to Māori; and enabling collective management responsibility. The key components guiding this document are ensuring sustainability of fish stocks and improving fisheries information:

ENSURING SUSTAINABILITY OF FISH STOCKS

- Setting and implementing fisheries harvest strategy standards
- Setting and monitoring environmental standards, including for threatened and protected species and seabed impacts
- Enhancing the framework for fisheries management planning, including the use of decision rules to adjust harvest levels over time

IMPROVING FISHERIES INFORMATION

- Determining best options for information collection on catch from amateur fisheries, including the implementation of charter boat reporting
- Improving our knowledge of fish stocks and the environmental impacts of fishing through long-term research plans
- Gaining access to increased research and development funding

17.7 OUR STRATEGY 2030: GROWING AND PROTECTING NEW ZEALAND

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

OUR STRATEGY 2030
Growing and protecting New Zealand

WHY THIS STRATEGY?

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

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

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

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

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

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

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

OUR FOCUS

MAXIMISE EXPORT OPPORTUNITIES AND IMPROVE SECTOR PRODUCTIVITY

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

INCREASE SUSTAINABLE USE AND PROTECTION OF NATURAL RESOURCES

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

WE WILL ACHIEVE THIS BY:

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

WE WILL ACHIEVE THIS BY:

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

OUR APPROACH

ENABLING

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

WE WILL ACHIEVE THIS BY:

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

PARTNERING

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

WE WILL ACHIEVE THIS BY:

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

OUR ORGANISATION

FOCUS ON RELATIONSHIPS

WE WILL ACHIEVE THIS BY:

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

DEVELOP OUR PEOPLE

WE WILL ACHIEVE THIS BY:

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

MAKE INFORMED DECISIONS

WE WILL ACHIEVE THIS BY:

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

BE INNOVATIVE

WE WILL ACHIEVE THIS BY:

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

OUR CULTURE

CONNECTED | **FOCUSED ON RESULTS** | **DELIVERING ON OUR OBLIGATIONS TO MĀORI** | **LEAN AND AGILE** | **TAKING INFORMED RISKS**

SUCCESS

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

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

AND WHEN THE MINISTRY ACHIEVES:

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

THURSDAY 16 JUNE, 12:27AM

17.8 OTHER STRATEGIC POLICY DOCUMENTS

17.8.1 BIODIVERSITY STRATEGY

New Zealand's Biodiversity Strategy was launched in 2000 in response to the decline of New Zealand's indigenous biodiversity — described in the State of New Zealand's Environment report as our "most pervasive environmental issue". It can be found on the government's biodiversity website at:

(http://www.biodiversity.govt.nz/picture/doing/nzbs/contents.html)

The Strategy also reflects New Zealand's commitment, through ratification of the international Convention on Biological Diversity, to help stem the loss of biodiversity worldwide. Strategic Priority 7 of the strategy was "To manage the marine environment to sustain biodiversity". Fishing practices, the effects of activities on land, and biosecurity threats are identified as constituting the areas of greatest risk to marine biodiversity. Pertinent objectives and summarised actions from the strategy are as follows:

Objective 3.1: Improving our knowledge of coastal and marine ecosystems (Substantially increase our knowledge of coastal and marine ecosystems and the effects of human activities on them, especially assessing the importance of, and threats facing, marine biodiversity, and establishing environmental monitoring capabilities to assess the effectiveness of measures to avoid, remedy or mitigate impacts on marine biodiversity).

Objective 3.4: Sustainable marine resource use practices (Protect biodiversity in coastal and marine waters from the adverse effects of fishing and other coastal and marine resource uses, especially maintaining harvested species at sustainable levels, integrating marine biodiversity protection into an ecosystem approach, applying a precautionary approach, identifying marine species and habitats most sensitive to disturbance, and integrating environmental impact assessments into fisheries management decision making.)

Objective 3.6: Protecting marine habitats and ecosystems (Protect a full range of natural marine habitats and ecosystems to effectively conserve marine biodiversity, using a range of appropriate mechanisms, including legal protection, especially establishing a network of areas that protect marine biodiversity.)

Objective 3.7: Threatened marine and coastal species management (Protect and enhance populations of marine and coastal species threatened with extinction, and prevent additional species and ecological communities from becoming threatened.)

In addition to its annual reviews (http://www.biodiversity.govt.nz/news/publications/index.html), the Biodiversity Strategy was reviewed by Green and Clarkson at the end of its 5-year term. This review was published in 2006 (http://www.biodiversity.govt.nz/pdfs/nzbs-5-year-review-synthesis-report.pdf). Most relevant to this synopsis were their findings on Objective 3.4 (Sustainable marine resource use) where they cited "Moderate progress". *"The policy move towards adopting a more ecosystem approach to fisheries management should be encouraged and strengthened. We acknowledge, however, the difficulties associated with obtaining the necessary information to make this approach effective. There are links to Objective 3.1 and the need for a more coordinated approach to identifying priority areas for marine research."*

17.8.2 BIOSECURITY STRATEGY

In its 2003 Biosecurity Strategy, The Ministry of Agriculture and Forestry's Biosecurity NZ defined biosecurity as "the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health". New Zealand is highly dependent on effective biosecurity measures because our indigenous flora, fauna, biodiversity, and, consequently, our primary production industries, including fisheries are uniquely at risk from invasive species. Information can be found on the Biosecurity New Zealand website at: (http://www.biosecurity.govt.nz/biosec/sys/strategy/biostrategy/biostrategynz (noting that MAF-BNZ is part of the Ministry of Agriculture and Forestry and will be merged with the Ministry of Fisheries in 2011 so this URL may change). A complementary Biosecurity Science Strategy for New Zealand was developed in 2007 to address the science expectations of the Biosecurity Strategy. The science strategy identified the need to:

- prioritise science needs;

- minimise biosecurity risks at the earliest stage possible by increasing focus on research that is strategic and proactive;
- improve planning, integration and communication in the delivery of science;
- ensure research outputs can be used effectively to improve biosecurity operations and decision making.

17.8.3 MARINE PROTECTED AREAS POLICY

The Marine Protected Areas (MPA) Policy and Implementation Plan was released for consultation in December 2005 jointly by the Ministry of Fisheries and Department of Conservation. It confirmed Government's commitment to ensuring that New Zealand's marine biodiversity was protected, and established MPA Policy as a key component of that commitment. The MPA Policy objective is to protect marine biodiversity by establishing a network of Marine Protected Areas that is comprehensive and representative of New Zealand's marine habitats and ecosystems. The Policy involved a four-stage approach to implementation:

Stage 1: Development of the approach to classification, formulation of a standard of protection, and mapping of existing protected areas and/or mechanisms. Scientific workshops will be used to assist with the process, and the results will be put on the website for comment

Stage 2: Development of the MPA inventory, identification of gaps in the MPA network, and prioritisation of new MPAs

Stage 3: Establishment of new MPAs to meet gaps in the network. This will be undertaken at a regional level and a national process will be followed for offshore MPAs

Stage 4: Evaluation and monitoring.

Stage 1 and the inventory specified for Stage 2 are complete and regional forums were established for the Subantarctic and West Coast bioregions.

The link for the stage 2 report is at:

http://www.doc.govt.nz/publications/conservation/marine-and-coastal/marine-protected-areas/coastal-marine-habitats-and-marine-protected-areas-in-the-new-zealand-territorial-sea-a-broad-scale-gap-analysis/

In June 2009, these planning forums released consultation documents on implementation of the MPA Policy in their bioregions:

Consultation Document - Implementation of the Marine Protected Areas Policy in the Territorial Seas of the Subantarctic Biogeographic Region of New Zealand:

http://www.biodiversity.govt.nz/pdfs/seas/subantarctics-mpa-policy-consultation-document.pdf

Proposed Marine Protected Areas for the South Island's West Coast Te Tai o Poutini: A public consultation document:

http://www.westmarine.org.nz/documents/ProposedMPAsWestCoastSubmissiondocumentwebresv2.pdf

The MPA Classification, Protection Standard, Implementation Guidelines, together with a summary of subsequent consultation processes around implementing the policy can be found on the Government Biodiversity website at:

http://www.biodiversity.govt.nz/seas/biodiversity/protected/mpa_consultation.html

17.8.4 REVISED COASTAL POLICY STATEMENT

The revised New Zealand Coastal Policy Statement (NZCPS) came into force in December 2010, replacing the original 1994 NZCPS. The statement is to be applied, as required by the Resource Management Act 1991 (RMA), by persons exercising functions and powers under that Act. The documentation can be read on the Department of Conservation's website at:

http://www.doc.govt.nz/publications/conservation/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/

The NZCPS does not directly apply to fisheries management decision-making, although the Minister of Fisheries is required to have regard to the Statement when making decisions on sustainability measures under section 11 of the Fisheries Act. In addition, this synopsis include chapters on land use issues and habitats of particular significance for fisheries management for which the main threats are

managed under the RMA (e.g., land use practices could increase sedimentation and affect the estuarine nursery grounds of important fishstocks). In other areas, management of effects under the RMA can complement management of the effects of fishing (e.g., complementary management of the habitat and bycatch of a protected species). The following objectives and policies are considered relevant (numbering as per NZCPS, text in parentheses summarises subheadings in the Statement of most relevance to fisheries values):

Objective 1: To safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries, dunes and land (especially by maintaining or enhancing natural biological and physical processes in the coastal environment).

Objective 6: To enable people and communities to provide for their social, economic, and cultural wellbeing and their health and safety, through subdivision, use, and development (especially by recognising that the protection of habitats of living marine resources contributes to social, economic and cultural wellbeing and that the potential to utilise coastal marine natural resources should not be compromised by activities on land).

Policy 5: Land or waters managed or held under other Acts (especially to consider effects on coastal areas held or managed under other Acts with conservation or protection purposes and to avoid, remedy or mitigate adverse effects of activities in relation to those purposes).

Policy 8: Aquaculture: Recognise the significant existing and potential contribution of aquaculture to the social, economic and cultural well-being of people and communities (especially by taking account of the social and economic benefits of aquaculture, recognising the need for high water quality, and including provision for aquaculture in the coastal environment).

Policy 11: Indigenous biodiversity: To protect indigenous biological diversity in the coastal environment (especially by avoiding, remedying or mitigating adverse effects on: habitats that are important during the vulnerable life stages of indigenous species; ecosystems and habitats that are particularly vulnerable to modification; and habitats of indigenous species that are important for recreational, commercial, traditional or cultural purposes).

Policy: 21 Enhancement of water quality: Where the quality of water in the coastal environment has deteriorated so that it is having a significant adverse effect on ecosystems, natural habitats, or water based recreational activities, or is restricting existing uses, such as aquaculture, shellfish gathering, and cultural activities, give priority to improving that quality.

Policy 22: Sedimentation (especially with respect to impacts on the coastal environment).

Policy 23: Discharge of contaminants (especially with respect to impacts on ecosystems and habitats).

17.8.5 MANAGEMENT OF ACTIVITIES IN THE EEZ

Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. The Act manages the environmental effects of activities in New Zealand's oceans. The legislation aims to protect our oceans from the potential environmental risks of activities like petroleum exploration activities, seabed mining, marine energy generation and carbon capture developments.

The Resource Management Act regulates natural resource management activities on land and in the territorial sea out to 12 nautical miles. Fishing and shipping are also regulated by other Acts. The EEZ Act does not override these other controls that already exist in the EEZ. Beyond 12 nautical miles New Zealand has historically had no means to assess and regulate the environmental effects of many other activities. The EEZ Act fills that regulatory gap and manages the previously unregulated adverse environmental effects of activities in the EEZ and continental shelf. Before the EEZ Act was passed there was a gap in our domestic legislation.

The EEZ Act sets up a framework for managing the effects of activities in the EEZ and continental shelf. The text of the Act can be found on the New Zealand Legislation website.

The EEZ legislation to manage effects other than those caused by fishing do not directly apply to fisheries management decision-making under the Fisheries Act. However, there are issues around the management of cumulative effects (e.g., of more than one activity on benthic communities) and around effects of any proposed new activities in the EEZ on fishing activity already occurring. Some projects already completed or currently underway are likely to be useful for these processes (e.g.,

detailed maps of fishing effort produced under ENV2001/07 and BEN2006/01 and enhancements of the Marine Environment Classification produced under ZBD2005-02 for demersal fishes and BEN2006/01A for benthic invertebrates).

17.8.6 NATIONAL PLAN OF ACTION TO REDUCE THE INCIDENTAL CATCH OF SEABIRDS IN NEW ZEALAND FISHERIES

New Zealand released its first National Plan of Action (NPOA) to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries in April 2004. That document is available online at:

http://www.doc.govt.nz/documents/conservation/native-animals/birds/npoa.pdf

or

http://www.fish.govt.nz/NR/rdonlyres/5618E7BB-CE01-4865-9E99-1B891F95FB2A/0/NZNPOASeabirds2004.pdf

A completely revised and refreshed NPOA-Seabirds was released in March 2013. A resources page was added to the MPI (Fisheries) website to provide access to this plan, its supporting risk assessment documents, a web-based reporting system for protected species captures, and information on MPI's fisheries planning processes that will be the vehicle for implementation:

http://www.fish.govt.nz/en-nz/Environmental/Seabirds/default.htm

The 2013 NPOA-Seabirds can be found at:

http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1760

The 2013 NPOA covers all New Zealand fisheries and has a long-term objective that *"New Zealand seabirds thrive without pressure from fishing related mortalities, New Zealand fishers avoid or mitigate against seabird captures and New Zealand fisheries are globally recognised as seabird friendly."*

There are high-level subsidiary objectives related to practical aspects, biological risk, research and development, and international issues.

i. Practical objective: All New Zealand fishers implement current best practice mitigation measures relevant to their fishery and aim through continuous improvement to reduce and where practicable eliminate the incidental mortality of seabirds.
ii. Biological risk objective: Incidental mortality of seabirds in New Zealand fisheries is at or below a level that allows for the maintenance at a favourable conservation status or recovery to a more favourable conservation status for all New Zealand seabird populations.
iii. Research and Development objectives:
    a. the testing and refinement of existing mitigation measures and the development of new mitigation measures results in more practical and effective mitigation options that fishers readily employ;
    b. research and development of new observation and monitoring methods results in improved cost effective assurance that mitigation methods are being deployed effectively; and
    c. research outputs relating to seabird biology, demography and ecology provide a robust basis for understanding and mitigating seabird incidental mortality.
iv. International objective: In areas beyond the waters under New Zealand jurisdiction, fishing fleets that overlap with New Zealand breeding seabirds use internationally accepted current best practice mitigation measures relevant to their fishery.

17.8.7 NEW ZEALAND NATIONAL PLAN OF ACTION FOR THE CONSERVATION AND MANAGEMENT OF SHARKS

The New Zealand National Plan of Action (NPOA) for the Conservation and Management of Sharks (2013) was approved by the Minister of Fisheries on 9 January 2014. The purpose of the NPOA-Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. It also contains a set of actions in order to meet this purpose. The document is available online at:

http://www.fish.govt.nz/en-nz/Environmental/Sharks/default.htm.

17.8.8 NATIONAL SCIENCE CHALLENGES

The National Science Challenges were conceived to tackle some of the biggest science-based issues and opportunities facing New Zealand. They were designed to take a more strategic approach to the government's science investment by targeting a series of goals, which, if achieved, would have major and enduring benefits for New Zealand. The Challenges provide an opportunity to align and focus New Zealand's research on large and complex issues by drawing scientists together from different institutions and across disciplines to achieve a common goal through collaboration.

Many of the issues facing New Zealand require new knowledge obtained through science and research. The Government has launched the Challenges to provide a means to address the most pressing of these complex issues. The Challenges will seek answers to questions of national significance to New Zealand by focusing effort and providing additional focus on key areas. The Challenges provide an opportunity to identify which issues are most important to New Zealand and will allow Government to take a targeted, cross-government approach to addressing them.

Each Challenge includes both new funding and funds that will become available as current MBIE research contracts mature. Relevant CRI core funding will also be invested in Challenges, where CRIs are part of a Challenge collaboration. The new Challenge money comprises $73.5 million over four years in Budget 2013, in addition to the $60 million allocated in Budget 2012, and $30.5 million per year thereafter.

The eleven research areas identified for National Science Challenge funding (asterisks mark those Challenges potentially relevant to fisheries and the marine environment) were:

1. High Value Nutrition
2. The Deep South *
3. New Zealand's Biological Heritage *
4. Sustainable Seas *
5. A Better Start
6. Resilience to Nature's Challenges *
7. Science for Technological Innovation
8. Ageing Well
9. Healthier Lives
10. Our Land and Water *
11. Building Better Homes, Towns and Cities

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

The Ministry for Business, Innovation and Employment administers the Challenges and issued Requests for Proposals for four of the Challenges in October 2013 and for the remainder in February 2014. Given that the Challenges represent a radically different approach to research in New Zealand, and required substantial collaboration between science organisations, it is perhaps not surprising that designing and contracting the work has taken some time. The following Challenges of relevance to fisheries and marine systems have been launched (as at December 2014, listed in order of their launch):

The Deep South — Te Kōmata o Te Tonga — was launched on 5 August 2014 with a headline of *Understanding the role of the Antarctic and the Southern Ocean in determining our climate and our future environment*. The mission of this Challenge is to transform the way New Zealanders adapt, manage risk, and thrive in a changing climate. Working with communities and industry we will bring together new research approaches to determine the impacts of a changing climate on our climate-sensitive economic sectors, infrastructure and natural resources to guide planning and policy. This will be underpinned by improved knowledge and observations of climate processes in the Southern Ocean and Antarctica - our Deep South - and will include development of a world-class earth systems model to predict Aotearoa/New Zealand's climate. Further information can be found at: http://www.deepsouthchallenge.co.nz/.

New Zealand's Biological Heritage — Ngā Koiora Tuku Iho — was launched on 29 August 2014 with a headline of *Protecting and managing our biodiversity, improving our biosecurity, and enhancing our resilience to harmful organisms*. This Challenge does not consider marine systems as such, but includes estuarine systems and close liaison between this Challenge and Sustainable Seas will be necessary to ensure important biological systems and processes are covered. Further information can be found at: http://www.biologicalheritage.org.nz/.

Sustainable Seas — Ko ngā moana whakauka — was launched on 4 September 2014 with a headline of *Enhance utlilisation of our marine resources within environmental and biological constraints*. The aim of this Challenge is to enhance use of New Zealand's vast marine resources, while ensuring that our marine environment is understood, cared for, and used wisely for the benefit of all, now and in the future. This requires a new way of managing the many uses of our marine resources that combines the aspirations and experience of Māori, communities, and industry with the evidence of scientific research to transform New Zealand into a world-leader in sustainable marine economic development. Thus, this is the Challenge most closely associated with fisheries management. Further information can be found at: http://sustainableseaschallenge.co.nz/.

17.9 APPENDIX OF AQUATIC ENVIRONMENT AND BIODIVERSITY FUNDED AND RELATED PROJECTS

The following listing of projects are those relevant to aquatic environment research that have been through research planning and subsequently been funded by the Ministry of Fisheries (MFish), the Ministry for Primary Industries (MPI) or the fishing industry. These projects have been ordered by the research themes:

1. Protected species (PRO)
2. Non-protected bycatch (NPB)
3. Benthic impacts (BEN)
4. Ecosystem effects (ECO)
5. Biodiversity (ZBD)

Within these themes projects are ordered chronologically (from the most recent to the oldest). A list of references cited within the table is included at the end of this appendix.

Each project or row of the table is described by a project number (used by MFish/MPI), a project title, specific objectives (where there are many objectives and some are clearly not relevant to aquatic environment research they may not be listed), project status and any relevant citations from the project.

Citations listed below can be accessed differently depending upon the type of output. Finalised FARs (Fisheries Assessment Reports) and AEBRs (Aquatic Environment and Biodiversity Reports), historical FARDs (Fisheries Assessment Research Documents) and MMBRs (Marine Biodiversity and Biosecurity Reports), and some FRRs (final Research Reports) can be found at: http://fs.fish.govt.nz/Page.aspx?pk=61&tk=209. Increasingly, reports will be available from the MPI website at: http://www.mpi.govt.nz/news-resources/publications. For unpublished documents or those not available on either of these websites please contact Science.Officer@mpi.govt.nz. Every attempt has been made to make this table comprehensive and correct, but if any errors are found please send suggested corrections or additions through to Science.Officer@mpi.govt.nz

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	DAE2015-01	Characterisation of seabird capture data	To collate and characterise the seabird capture information from deepwater trawl fisheries to improve understanding of potential risk factors for captures of seabirds, with a focus on net captures.	Approved, but not contracted.	
PRO	DAE2015-03	Exploring the influence of changes in sea lion diet on pup survival using fatty acid signatures	Determine whether changes in survival of sea lion pups at the Auckland Islands are associated with changes in sea lion diet that could be influenced by fisheries.	Approved, but not contracted.	
PRO	PRO2015-01	Improving estimates of cryptic mortality for use in seabird risk assessments	1. To develop guidelines for the production of estimates of total seabird captures from observer data, with methods varying based on the level and quality of data. 2. To increase the capability of other countries to produce robust estimates of seabird captures.	Approved, but not contracted.	
PRO	PRO2015-03	Improving information on out-of-zone bycatch of New Zealand seabirds	1. To develop guidelines for the production of estimates of total seabird captures from observer data, with methods varying based on the level and quality of data. 2. To increase the capability of other countries to produce robust estimates of seabird captures.	Approved, but not contracted.	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2015-04	Addressing key information gaps for Māui dolphins	1. To collect information on spatial distribution and overlap with fisheries to decrease uncertainty in our understanding and estimates of risk to Māui dolphins	Approved, but not contracted.	
PRO	SEA2015-06	Additional aerial survey effort for Hector's dolphins on the West Coast South Island	Following increased Hectors dolphins sightings over the summer survey this project allows for extra effort in the Grey (0-4nm), Hector (4-12nm) and Okarito (4-12nm) strata (Plan A). If time and weather permits this will also allow for extra effort in the 4-12nm strata off Whanganui, Jackson Bay and Milford.	Completed as part of PRO2013-06	
PRO	SEA2015-10	Sea lion prey survey	1. Undertake a demersal trawl survey of the Auckland Islands and Stewart/Snares shelf to determine the spatial and bathymetric distribution and abundance of the main prey species of NZ sea lions in the areas used by benthic and pelagic foraging lactating females; 2. Conduct a potting feasibility study to determine the distribution, abundance and biology of yellow octopus (Enteroctopus zealandicus); 3. Conduct a benthic habitat characterisation based on acoustic swath mapping of the seafloor in the area immediately surrounding demersal trawl stations; 4. Deploy underwater cameras to visually survey seafloor habitat and sea lion prey species at a representative subsample of habitat types, identified from the acoustic swath habitat characterisation; 5. Make oceanographic observations to quantify physical characteristics of sea lion foraging habitat.	Ongoing	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	SEA2015-12	Potential impacts of fisheries restrictions for the NZ sea lion TMP	1. To estimate the likely impact on catch rates and total catches of squid, scampi, and hoki of a range of specified potential fishing restrictions. 2. To estimate the likely impact on sea lion interactions and captures of the specified fishing restrictions.	Ongoing	
PRO	SEA2015-15	Stewart Island sea lion survey	To determine the feasibility of monitoring pup production in January, concurrent with the monitoring of other colonies, While testing the feasibility of using thermal technology in finding sea lion pupping locations, To screen for Klebsiella pnuemonia, and Determine common causes of death for Stewart Island pups.	Ongoing	
PRO	PRO2014-06	Update of level-2 seabird risk assessment	1. To update the level-2 seabird risk assessment using all new information on bird population size, productivity, and distribution, and all relevant fishing effort and observer data for the 2009/10 to 2013/14 fishing years. 2. To identify key drivers of uncertainty and opportunities to reduce uncertainty in the risk ratios for species at high or very high risk. 3. To participate in, and provide data for, a workshop to review the findings relative to other available data and results. 4. To update the level-2 seabird risk assessment using all new information on bird population size, productivity, and distribution, and all relevant fishing effort and observer data for the 2010/11 to 2014/15 fishing years.	Ongoing	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			5. To identify key drivers of uncertainty and opportunities to reduce uncertainty in the risk ratios for species at high or very high risk.		
PRO	PRO2014-03	Research in response to advice from the Maui's dolphin research advisory group	1. To be developed through the MRAG process: agreed project was genetic mark recapture estimation of Maui dolphin abundance with field effort in 2014/15 and 2015/16.	Ongoing fieldwork and analysis	
PRO	PRO2014-02	Risk assessment modelling for fishing-related mortality of sea lions to underpin the TMP	1. To review existing models of New Zealand sea lions that have been used to estimate key demographic rates and their variability 2. Based on the results of Objective 1, develop an operating model of the Auckland Island population of New Zealand sea lions suitable for use in management strategy evaluation 3. To use a management strategy evaluation to assess the risk posed by commercial fishing to New Zealand sea lions, including assessing the likely performance of candidate management approaches against current or agreed performance criteria 4. To extend the modelling to other populations and risks as information permits	Almost complete. Publication undergoing review.	
PRO	PRO2014-05	Reducing uncertainty in biological components of the risk assessments for at-risk seabird species	1. Species, population, and information requirements to be determined based on the prioritisation procedures in the NPOA-seabirds and the table of priorities from the outputs of the review workshop	Ongoing, MPI partially funded black petrel research	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2014-01	Improving information on the distribution of key protected species	1. To produce an agreed list of seabird and marine mammal species for inclusion and compile all available spatial data for these species. 2. To model and map the distribution of the species identified in objective 1 from available spatial data, reflecting any temporal changes (seasonality or trends). 3. To refine the results of the mapping for priority species by developing and implementing predictive habitat distribution models.	Approved, but not contracted.	
PRO	SEA2014-12	NZ sea lion stable isotope analysis	1. Locate the ideal NZ sea lion teeth for stable isotope analysis from that will provide the best temporal coverage. 2. Prepare and micro-drill the NZ sea lion teeth within the annual bands to document changes in their foraging and changes in ocean conditions through time using stable isotope analysis. 3. Assess the stable isotope datasets in combination with existing diet studies, prey abundance estimates and climate indices to best examine temporal patterns.	Ongoing	
PRO	SEA2014-15	Sensitivity of the Seabird Risk Assessment to selected scenarios	1. Assess the sensitivity of the Seabird Risk Assessment to assumptions about Buller's albatrosses 2. Assess the ability of the Seabird Risk Assessment to detect changes in the capture rates 3. Assess the sensitivity of the risk assessment to live captures	Almost complete. Publication undergoing the review process.	Yvan & Richards *In press*
PRO	SEA2014-16	Observer coverage power analysis for NPOA	1. Assess the level of observer coverage required to detect a change in the estimated risk of fisheries to New Zealand seabirds, for varying levels	Ongoing	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			of decrease in fishing-related fatalities, for selected seabird species and fisheries.		
PRO	SEA2014-19	Development and production of smaller hook pods for trial in NZ	To modify the current Hook Pod to New Zealand version without the LED incorporated. This will result in a smaller and more robust Hook Pod that will be equally effective at reducing seabird bycatch in New Zealand's surface longline fisheries.	Ongoing	
PRO	SEA2014-21	Additional analyses to support the New Zealand sea lion risk assessment	1. The effect of past mortality resulting from key threats for which data are available (such as disease and fishing mortality), or for which plausible estimates are available (such as cryptic mortality), will be explored by fitting the historical demographic model including data on mortality arising from known threats to estimate starting (1960) and current population structure. Threat-derived mortality will then be excluded from the model and re-run from the estimated starting population to predict population structure in the absence of such mortality. 2. Questions were raised about the most appropriate way to deal with animals of unknown pupping status in the model. At present, decision rules are used to determine pupping status from observations (observed suckling, at least 3 sightings with a pup or 3 sightings without a pup) to determine pupping status, with the remaining animals classified as unknown and divided in the proportion of known pupping / non-pupping. Exclusion of animals of unknown status results in increased estimates of pupping rate. Alternative approaches should be considered and the sensitivity of pupping rate to relaxing the decision rules should be explored, such as relaxing the decision rules used to determine pupping status to 2 or 1 observations with or without a pup, or use of other information such as females calling to pups. (Linked to the following item)	Almost complete. Publication undergoing review. This project will be reported alongside any Work in Progress reporting from PRO2014-02.	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			3. Similar questions were raised about determining pupping status before an animal that has moved between colonies is used to estimate migration (translocation) rates. As an alternative, this requirements could be relaxed to include animals simply observed (but not confirmed to be pupping) at another colony to be included in migration rate estimation. 4. The assumption of a CV of 0.06 for pup census indices, as the only way of specifying a relative weighting between census and tag-recapture data, was questioned. Alternative CVs and weighting approaches should be determined using something like standard deviations of Pearson residuals. 5. Incorporation of time-varying re-sighting probability was noted to improve model fits, indicating that that re-sighting probabilities did vary over time. One could explore whether the number of days on which re-sightings were conducted each year are correlated with effort days, in which case effort days could be used to estimate re-sight probabilities for recent years that have not been back-corrected. 6. It was recommended that the effect of incorporation of 'phantom tags' on parameters such as re-sighting probability should be explored. An alternative approach would be to simply multiply the survival rate from tagging to age 1 yr by the directly estimated proportion of pups that die prior to tagging. The latter is, after all, the basis for how many phantom tags are added.		
PRO	SEA2014-23	An assessment of thermal aerial survey techniques on fur seals	1.Undertake field work component 2.Submit draft report and present to the Aquatic Environment Working Group	Ongoing Analysis	
PRO	SEA2014-24	Level-2 seabird risk assessment – revised methodology	1. Design and test changes to the risk assessment method	Ongoing	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			1		
PRO	SEA2014-25	Black petrel distribution and fisheries overlap	1. Geographical Information Systems (GIS) data, giving the distribution of black petrel. 2. GIS data giving the overlap of black petrel with bottom longline, surface longline, set net, and trawl fisheries	Ongoing	
PRO	SEA2013-06	Black Petrel Distribution Modelling	1. To use the best available information to develop a spatial and seasonal distribution of black petrel, in New Zealand waters.	Completed	Abraham *et al.* 2015
PRO	SEA2013-14	Re-Run of Level-2 Seabird Risk Assessment 2014	1. To provide an update of the Seabird Risk Assessment, including observer and fisheries data to the end of the 2012/13 fishing year.	Completed	Richard & Abraham 2015
PRO	SEA2013-08	Data preparation for protected species bycatch estimation	1. Groom catch effort, observer, and protected species capture data 2. Provide web-based interface to allow exploration, display, and reporting on the data	Completed: preparation for PRO2013-01	
PRO	PRO2013-01	Protected species capture estimation	1. To estimate capture rates and total captures of seabirds, marine mammals, turtles, and protected fish species by method, area, and target fishery, and where possible, by species for the fishing years 2012/13, 2013/14 and 2014/15. 2. To estimate factors associated with the capture of seabirds and marine mammals.	Ongoing analysis	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			3. To estimate, where possible, the nature and rate of warp strike incidents and total number of seabirds affected.		
PRO	PRO2013-06	Abundance and distribution of WCSI Hector's dolphins	1. To develop and refine designs and methods for summer and winter aerial surveys for Hector's dolphins along the WCSI consistent with the recent ECSI surveys. 2. To estimate the abundance of Hector's dolphins along the WCSI in summer 2013/14 applying an agreed aerial survey methodology. 3. To estimate the distribution of Hector's dolphins along the WCSI in summer 2013/14 applying an agreed aerial survey methodology. 4. To estimate the abundance of Hector's dolphins along the WCSI in winter 2014 applying an agreed aerial survey methodology. 5. To estimate the distribution of Hector's dolphins along the WCSI in winter 2014 applying an agreed aerial survey methodology.	Ongoing analysis	
PRO	PRO2013-08	Reanalysis of Hector's dolphin line transect aerial survey data	1. To collate sightings and effort data for all Hector's dolphin aerial surveys that applied different approaches to estimating the detection function. 2. To assess the impact of different approaches to estimating the detection function on estimates of abundance and distribution and develop correction factors. 3. To reanalyse all relevant survey data to estimate Hector's dolphin abundance and distribution applying the agreed approach to estimating the detection function	Included in PRO2013-06	
PRO	PRO2013-13	Global seabird risk assessment (for New Zealand species)	1. Evaluate relative exposure to commercial fisheries at a global scale for New Zealand seabird populations applying a seasonally-disaggregated spatial overlap approach (i.e. accessing global seabird spatio-temporal distribution data and compiling comprehensive global fisheries effort databases) for different categories of fishing effort. 2. Apply estimates of population PBR (from the updated NZ-EEZ seabird	Contracted	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			risk assessment, including uncertainty) and species- or guild-specific estimates of seabird Vulnerability (i.e. as estimated in the updated NZ-EEZ seabird risk assessment, modified to the extent possible by data indicative of relative seabird bycatch rates in comparable fishing effort inside vs. outside the New Zealand EEZ, including uncertainty) to estimate global fisheries risk for New Zealand seabird populations. 3. For each New Zealand seabird population estimate what proportion of global fisheries risk is attributable to mortalities occurring inside vs. outside the NZ-EEZ, and what proportion is likely to be unaccounted for in the analysis (e.g. due to incomplete global fisheries data or risk from IUU fishing). 4. For that portion of species risk outside the NZ-EEZ, summarize the source of that risk to the extent possible, for example by RFMO (or other relevant management agency), and by fishery group, geographic area, season, vessel size, and other relevant categories.		
PRO	PRO2013-17	Repeat quantitative modelling of southern Buller's albatross	1. To update the fully quantitative population model of southern Buller's albatross to assess population trend and key demographic rates for this population. 2. To use the model to predict future trends assuming recent average demographic rates.	Almost complete, publication is undergoing revision.	Fu and Sagar. *In Press*
PRO	PRO2013-18	Authoritative Sea Lion Capture List	To produce a definitive data set of New Zealand sea lion captures and to reconcile data from the different sources, and resolve any discrepancies.	Completed	Thompson *et al.* 2015
PRO	SEA2013-08	Data preparation for protected species bycatch estimation	1. Groom catch effort, observer, and protected species capture data 2. Provide web-based interface to allow exploration, display, and reporting on the data	Completed: preparation for PRO2013-01	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	No project number	A risk assessment of threats to Maui's dolphins	To evaluate of the risks posed to Maui's dolphin to support the review of the TMP.	Completed	Currey *et al.* 2012
PRO	PRO2012-02	Assessment of the risk to marine mammal populations from New Zealand commercial fisheries	1. To scope the risk assessment, including producing an agreed list of marine mammal populations (in concert with MAF and DOC). 2. To review the literature, compile the required information and evaluate the appropriate level of risk assessment for the marine mammal populations identified in objective 1. 3. To conduct a risk assessment for the marine mammal populations identified in objective 1 using, where possible, a risk index reflecting the ratio of fisheries-related mortality to the level of potential biological removal. 4. To refine the results of the risk assessment for priority marine mammal populations by incorporating spatially and temporally-explicit abundance, distribution and capture information.	Ongoing analysis	Berkenbusch *et al.* 2013
PRO	PRO2012-07	Cryptic mortality of seabirds in trawl and longline fisheries	1. To review available information from international literature and unpublished sources to characterize and inform estimation of cryptic mortality and live releases for at-risk seabirds in New Zealand trawl and longline fisheries 2. To review the extent to which fisheries observer data informing current estimates of seabird captures may be used to also estimate cryptic mortalities in different fishery groups in the seabird risk assessment, and identify key assumptions and associated uncertainty in the estimation of cryptic mortalities. 3. To identify those species and/or fishery groups for which current uncertainty regarding cryptic mortality contributes most strongly to high risk scores for at-risk seabird species, and recommend options to	Complete	Pierre et al. 2015

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			improve estimation of cryptic mortality for those species / fishery group combinations.		
PRO	PRO2012-10	Level 3 risk assessment for Antipodean albatross	1. Develop an Antipodean albatross population model 2. Assess the effect of fisheries mortality on population viability 3. As information permits, assess the effect of alternative management strategies	Ongoing analysis	
PRO	ENV2011-01	NPOA-sharks science review	1. To collate and summarise information in support of a review of the National Plan of Action for the Conservation and Management of Sharks (NPOA-sharks). 2. To identify research gaps from objective 1 and suggest cost-effective ways these could be addressed.	Completed	Francis & Lyon 2012; Francis & Lyon 2013
PRO	SEA2011-14	CCSBT Seabird risk assessment	To undertake an Ecological Risk Assessment for seabird interactions in surface longline fisheries managed under the Convention for the Conservation of Southern Bluefin Tuna	Completed	Waugh et al. 2012
PRO	SRP2011-03	Probabilistic modelling of sea lion interactions	1. Estimate the probability that a sea lion suffers mild head trauma following a collision with a SLED grid	Completed	Abraham 2011
PRO	SRP2011-04	HSL Modelling	1. Revise Breen-Fu-Gilbert sea lion model	Completed	Breen *et al.* 2010
PRO	DEE2010-03	Development of a methodology to estimate cryptic mortalities to ETP	1. To conduct a review of existing national and international techniques to estimate cryptic mortality of endangered, threatened and protected species caused by deepwater fishing activities 2. To develop one or more approaches to estimating cryptic mortality of endangered, threatened and protected species caused by deepwater	Ongoing analysis	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		species from DW fishing activity	fishing activities 3. To field test one or more approaches to estimating cryptic mortality of endangered, threatened and protected species caused by deepwater fishing activities		
PRO	PRO2010-01	Estimating the nature and extent of incidental captures of seabirds, marine mammals and turtles in New Zealand commercial fisheries	1. To estimate the nature and extent of captures of seabirds, marine mammals and turtles, and the warp strikes of seabirds in New Zealand fisheries for the fishing years 2009/10, 2010/11 and 2011/12.	Ongoing analysis	Thompson *et al.* 2012; 2013; Submitted; Richard & Abraham 2015
PRO	PRO2010-02	Research into key areas of uncertainty or development of mitigation techniques for the revised NPOA-seabirds	1. To provide the information necessary to underpin the revised NPOA-seabirds or develop mitigation techniques to reduce risk identified via the revised NPOA-seabirds.	Completed	Richard & Abraham 2013a, b, c, Berkenbusch *et al.* 2013
PRO	No project number	A risk assessment framework for incidental seabird mortality associated with New Zealand	To describe the conceptual and methodological framework of this risk assessment approach to guide the completion of similar risk assessments elsewhere.	Completed	Sharp *et al.* 2011

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		fishing in the New Zealand EEZ			
PRO	SRP2010-03	Fur Seal interactions with a SED excluder device	1. Fur seal interactions with SED excluder device (Dr J Lyle)	Completed	Lyle 2011
PRO	SRP2010-05	Fur seal interaction with an SLED excluder device	1 Using a series of 10-15 impact tests at a maximum collision speed of 5 or 6 ms-1, develop a "HIC map" for the SLED grid to enable the consequences of collisions with different parts of the grid by sea lions of different head masses to be predicted (scaling values (for eq 3) will include -1/3, -2/3, and -3/4) 2 Using a small number of collision tests, verify that the HIC for a glancing blow can be predicted with sufficient accuracy by resolving vectors 3 Calculate the maximum possible sensitivity to different boundary conditions using the relative masses of the SLED grid and sea lion heads 4 Clarify in the final research report that undertaking tests in air (as opposed to underwater) should not affect the results	Completed	Ponte et al. 2011
PRO	IPA2009-09	Sea Lion bioenergetics modelling	1. To review and collate data on growth, metabolism, diet and reproductive parameters of NZ sea lions or, if data are inexistent, of other sea lions species 2. To analyse the energy density of various NZ sea lion prey items 3. To incorporate the data acquired in objectives 1. and 2. into a bioenergetics model to estimate the energy and food requirements of NZ sea lions	Completed	Meynier 2010

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	IPA2009-16	Preliminary impact assessment of NZ sea lion interaction with SLEDS	1. Preliminary impact assessment of New Zealand sea lion interactions with SLEDs	Completed	Ponte *et al.* 2010
PRO	IPA2009-19/20	Level 2 seabird risk assessment rerun	1. To examine the risk of incidental mortality from commercial fishing for 64 seabird species in New Zealand trawl and longline fisheries	Completed	Richard *et al.* 2011
PRO	No project number	External review of NZ sea lion bycatch necropsy data and methods	The primary purposes of this review were to determine whether, in the opinion of a group of independent experts: - the interpretation of necropsy findings and trauma classification system used by Dr Wendi Roe are valid - sea lions recovered from trawl nets have sustained clinically significant trauma - some or all of the sea lions exiting through SLEDs are likely to survive	Completed	Roe 2010a
PRO	PRO2009-01A	Abundance & distribution of Hector's & Maui's dolphins (5 year project)	1. To estimate the distribution of the South Coast South Island Hector's dolphin sub-population in both winter and summer. 2. The work for this sub-project was subsequently extended to include data collection necessary to estimate abundance.	Completed	Clement & Mattlin 2010

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2009-01B	Abundance, distribution, and productivity of Hector's (and Maui's) dolphins	1. To estimate the likely precision of abundance estimates from summer aerial surveys for Hector's dolphins along the East Coast South Island (ECSI; from Farewell Spit to Nugget Point) under different levels of sampling intensity and stratification. 2. To estimate the likely precision of abundance estimates and the likely quality of distribution information from winter aerial surveys for Hector's dolphins along the ECSI under different levels of sampling intensity and stratification. 3. To identify and quantify trade-offs between the precision of abundance estimates and the quality of distribution information as well as between overall precision and likely cost (e.g., based on the number of flying hours required). 4. To identify key areas and times for which it would be particularly useful to have information on Hector's dolphin distribution (e.g., where risk may come from overlap with particular fisheries) and quantify trade-offs between the precision of ECSI-wide surveys and collecting such fine-scale information. 5. Assess the extent to which two-phase or adaptive approaches would be useful to improve the surveys' utility for assessing dolphin distribution, particularly the seaward limit.	Completed	MacKenzie *et al.* 2013
PRO	PRO2009-01C	Abundance, distribution and productivity of Hector's (and Maui's) Dolphins	1. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the abundance of Hector's dolphins along the ECSI in summer 2012/13 applying an agreed aerial survey methodology. 2. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the distribution	Completed	MacKenzie & Clement 2014

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			of Hector's dolphins along the ECSI in summer 2012/13 applying an agreed aerial survey methodology. 3. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the abundance of Hector's dolphins along the ECSI in winter 2013 applying an agreed aerial survey methodology. 4. To estimate critical aspects of the biology, abundance and distribution of Hector's and Maui's dolphin populations to assess the effects of fishing-related mortality on these populations including the distribution of Hector's dolphins along the ECSI in winter 2013 applying an agreed aerial survey methodology.		
PRO	PRO2009-04	Development and efficacy of seabird mitigation measures	1. To test the efficacy of a variety of configurations of mitigation techniques at reducing seabird mortality (or appropriate proxies for mortality) in longline fisheries	Completed	No reports specified as required output
PRO	ENV2008-03	Bycatch of basking sharks in New Zealand fisheries	1. To review the productivity of basking sharks 2. To describe the nature and extent of fishery-induced mortality of basking sharks in New Zealand waters and recommend methods of reducing the overall catch.	Completed	Francis & Smith 2010
PRO	PRO2008-01	Risk assessment of protected species bycatch in NZ fisheries	1. To provide an assessment of the risk posed by different fisheries to the viability of New Zealand protected species, and to assign a risk category to all New Zealand fishing operations.	Completed	Waugh *et al.* 2009

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	PRO2008-03	Necropsy of marine mammals captured in New Zealand	1. To necropsy marine mammals captured incidentally to New Zealand fishing operations in the SQU6T fishery during the 2008/09 fishing year to determine life-history characteristics such as sex- reproductive status and the likely cause of mortality- and to determine the species- and sex of captured animals returned for necropsy. 2. To determine- through examination of returned carcasses- the species- sex- reproductive status- and age-class of sea lions and fur seals captured in the SQU6T New Zealand fishery. 3. To detail any injuries and- where possible- the cause of mortality of sea lions and fur seals returned from New Zealand fisheries- and examine relationships between injuries and body condition- breeding status- and other associated demographic characteristics. 4. To review and collate data from previous NZ sea lion autopsy programmes.	Completed	Roe 2010b; Roe & Meynier 2012
PRO	SAP2008-14	Sea lion population modelling, additional	1. To assess the likely performance of different bycatch control rules for the SQU6T fishery. 2. To correct and update the Breen-Fu-Gilbert (2008) sea lion model- including assessment of the performance of 200-series and 300-series management control rules. 3. To document the development of the model- including all four objectives of project IPA2006/09 and objective 1 of this project- in a single report suitable for an international review.	Completed	Breen *et al.* 2010
PRO	Deepwater Group	Necropsy of marine mammals captured in New Zealand fisheries in the 2007-08 fishing year	Necropsy of marine mammals captured in New Zealand fisheries in the 2007-08 fishing year	Completed	Roe 2009a

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	IPA2007-09	Protected species risk assessment	To provide an assessment of the risk posed by different fisheries to the viability of NZ protected species- and to assign a risk category to all NZ fishing operations	Completed	Waugh *et al.* 2008
PRO	PRO2007-01	Estimating the nature and extent of incidental captures of seabirds in New Zealand commercial fisheries	1. Estimate capture rates per unit effort and total captures of seabirds for the New Zealand EEZ and in selected fisheries by method, area, target fishery, in relation to mitigation methods in use, and, where possible, by seabird species for the fishing year 2006/07, 2007/08 and 2008/09. 2. Examine the incidence of seabird warp strike in trawl fisheries where these data are available from fisheries observers, and estimate the rate of incidents (birds affected per hour) and total number of seabirds affected by fishery, area and method. Examine the factors (fishery, environmental, seasonal, mitigation, area) that influence the probability of warp-strike occurring.	Completed	Abraham 2010; Abraham & Thompson 2009a; 2010; 2011a; b; Thompson & Abraham 2009a; Abraham et al. 2010b
PRO	PRO2007-02	Estimating the nature and extent of incidental captures of seabirds in New Zealand commercial fisheries	1. Estimate capture rates per unit effort and total captures of seabirds for the New Zealand EEZ and in selected fisheries by method, area, target fishery, in relation to mitigation methods in use, and, where possible, by seabird species for the fishing year 2006/07, 2007/08 and 2008/09. 2. Examine the incidence of seabird warp strike in trawl fisheries where these data are available from fisheries observers, and estimate the rate of incidents (birds affected per hour) and total number of seabirds affected by fishery, area and method. Examine the factors (fishery, environmental, seasonal, mitigation, area) that influence the probability of warp-strike occurring.	Completed	Abraham et al. 2010a; Thompson & Abraham 2009a; 2009b; 2009c; 2010; 2011; Thompson *et al.* 2010a; 2010b
PRO	ENV2006-05	The use of electronic monitoring technology in New	1. Trial the deployment of electronic monitoring systems in selected longline fisheries, monitoring incidental take of protected species. 2. Evaluate the efficacy of electronic monitoring in allowing enumeration and identification of protected species captures.	Completed	McElderry *et al.* 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		Zealand longline fisheries	3. Recommend options for data management and information transfer arising from the deployment of electronic monitoring in selected fisheries.		
PRO	IPA2006-02	The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery	1. Groom the mitigation trial data and produce a summary of the data 2. Examine strike rates and capture rates on warps and mitigation devices 3. Determine the relative efficacy of mitigation devices tested in the trial 4. Make recommendations regarding future trials 5. Compare seabird warp strike data for 2005 and 2006 6. Work with SeaFIC and the mitigation trials TAG to produce analyses and outputs	Completed	Middleton & Abraham 2007
PRO	IPA2006-09	Modelling interactions between trawl fisheries and New Zealand Sea lion interactions	1. Model the New Zealand sea lion population and explore alternative management procedures for controlling New Zealand sea lion bycatch in the SQU 6T fishery 2. Collate and review all available sea lion biological data- fisheries data- and sea lion bycatch data relevant to a population model and management strategy evaluation for the Auckland Islands sea lion population 3. Update and improve the existing Breen and Kim sea lion population model (2003) to incorporate all relevant data and address model uncertainties including but not necessarily limited to those identified by the AEWG 4. Fit the revised model to all available data and test sensitivity including but not necessarily limited to runs identified by the AEWG 5. Test a range of management procedures (rules) with the model to determine if they meet agreed management criteria	Completed	Breen 2008
PRO	IPA2006-13	Identification of Marine Mammals	1. To determine, through examination of returned marine mammal carcasses, the species, sex, reproductive status, and age-class of marine mammals returned from New Zealand fisheries.	Completed	Roe 2009b

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		Captured in New Zealand Fisheries	2. To detail any injuries and, where possible, the cause of mortality of marine mammals returned from New Zealand fisheries, and examine relationships between injuries and body condition, breeding status, and other associated demographic characteristics.		
PRO	PRO2006-01	Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability	1 To gather demographic, distributional and dietary information on selected seabird species to allow assessment of effects of fishing on population viability.	Completed	Sagar & Thompson 2008; Sagar et al. 2009a; b; 2010a; b; c; Baker *et al.* 2008; 2009, 2010
PRO	PRO2006-02	Modelling of the effects of fishing on the population viability of selected seabirds	1. Model the effects of fisheries mortalities on population viability compared with other sources of mortality or trophic effects of fishing 2. Examine the overlap of fishing activity with species distribution at sea for different stages of the breeding and life-cycle and for different sexes, and assess the likely risk to species or populations from fisheries (by target species fisheries, fishing methods, area and season) in the New Zealand EEZ	Completed	Francis & Bell 2010, Francis 2012, Francis *et al.* 2015
PRO	PRO2006-04	Estimation of the nature and extent of incidental captures of seabirds in New Zealand	1. To estimate the nature and extent of captures and warp-strikes of seabirds in New Zealand fisheries for the fishing year 2005/06.	Completed	Baird & Smith 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		commercial fisheries			
PRO	PRO2006-05	Estimating the nature and extent of marine mammal captures in New Zealand commercial fisheries	1. To estimate and report the total numbers, releases and deaths of marine mammals where possible by species, fishery and fishing method, caught in commercial fisheries for the years 1990 to the end of the fishing year 2005/06. 2. To analyse factors affecting the probability of fur seal captures for the years 1990 to the end of the fishing year 2005/06. 3. To classify fishing areas, seasons and fishing methods into different risk categories in relation to the probability of marine mammal incidental captures for the years from 1990 through to the end of the fishing year 2005/06.	Completed	Mormede *et al.* 2008; Baird 2008a; 2008b; Smith & Baird 2009; Smith & Baird 2011; Baird 2011.
PRO	PRO2006-07	Characterise non-commercial fisheries interactions	1. To characterise non-commercial fisheries interactions with seabirds and marine mammals 2. Characterise non-commercial fisheries risk to seabirds and marine mammals by area and method Recommend mitigation measures appropriate for uptake in non-commercial fisheries in which seabird or marine mammal captures occur	Completed	Abraham et al. 2010a; Thompson & Abraham 2009a; 2009b; 2009c; 2010; 2011; Thompson et al. 2010a; b; c
PRO	ENV2005-01	Estimation of the nature and extent of incidental captures of seabirds in New Zealand fisheries	1. To estimate the nature and extent of captures of seabirds in selected New Zealand fisheries for the fishing year 2004/05.	Completed	Baird & Smith 2007a; Baird & Gibbert 2010

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	ENV2005-02	Estimation of the nature and extent of marine mammal captures in New Zealand fisheries	To examine the nature and extent of the captures of marine mammals in New Zealand fisheries, for the whole New Zealand EEZ, by Fishery Management Area and fishing season, and by smaller metric as appropriate for the fishing year 2004/05. 2. Examine alternative methods for estimating sea lion captures and recommend one or more alternative standardised methods for describing and estimating sea lion captures in the SQU 6T fishery.	Completed	Abraham 2008; Baird 2007; Smith & Baird 2007b; Baird & Smith 2007b
PRO	ENV2005-04	Identification of marine mammals captured in New Zealand	1. To determine the species- sex- and where possible- age and reproductive status of marine mammals captured in New Zealand fisheries. 2. To necropsy marine mammals captured incidentally to New Zealand fishing operations to determine life-history characteristics and the likely cause of mortality. 3. To determine- through examination of returned marine mammal carcasses- the taxon to species-level- sex- and reproductive status- and age-class of marine mammals captured in New Zealand fisheries. 4. To detail the injuries and where possible the cause of mortality of marine mammals returned from New Zealand fisheries- along with their body condition and breeding status- and other associated demographic characteristics. 5. To detail the protocol used for the necropsy of marine mammals- to provide a standardised procedure for autopsy to determine species- age- sex and associated demographic characteristics for fishery-killed specimens.	Completed	Roe 2007
PRO	ENV2005-06	Estimation of protected species captures in longline fisheries	1. To provide estimates of seabird and marine mammal mortalities from longline fisheries in New Zealand using electronic monitoring systems and to recommend deployment and data management options for	Completed	McElderry et al. 2007

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		using electronic monitoring	ongoing use of these systems for estimation of protected species incidental take.		
PRO	ENV2005-09	Data collection to estimate key performance indicators in the Chatham albatross, *Diomedea eremita*.	1. To gather data on key population parameters for Chatham albatross *Diomedea eremita*- to enable population viability to be assessed- and the responses of key parameters to fisheries mortality and fisheries management activities to mitigate fisheries related risk 2. To undertake field research to collect data on population growth rates- adult survival- inter-breeding season survival- mortality due to predation at the colony- fecundity and associated parameters for Chatham Albatross- following the study design project 3. To undertake field research to determine the range and extent foraging movements of Chatham albatrosses within New Zealand fishing waters- and examine the nature and extent of any association between Chatham albatrosses and fishing activities.	Completed	No reports specified as required output
PRO	ENV2005-13	Assessment of risk to yellow-eyed penguin Megady-ptes antipodes from fisheries incidental mortality	1. To review existing data on yellow-eyed penguin M. antipodes population performance and fisheries information and provide an analysis of the potential effect of fishing mortality and other factors on population viability. 2. To recommend data collection requirements and protocols for the assessment of the effects of fishing on yellow-eyed penguins.	Completed	Maunder 2007
PRO	ENV2004-02	Estimation of New Zealand sea lion incidental captures in New Zealand Fisheries	1. To estimate the level of New Zealand sea lion (*Phocartos hookeri*) incidental capture in New Zealand fisheries	Completed	Smith & Baird 2007a

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	ENV2004-04	Characterisation of seabird captures in New Zealand fisheries	1. Characterisation of seabird captures in New Zealand fisheries.	Completed	Mackenzie & Fletcher 2006
PRO	ENV2004-05	Modelling of impacts of fishing-related mortality on New Zealand seabird populations	1. To examine and identify modelling approaches to analyse seabird demographic impacts that may be occurring as a result of fisheries mortality. 2. To compile databases of available demographic and distributional data on selected seabirds affected by fisheries mortality and New Zealand fisheries and estimate key population parameters and seasonal distribution for each species. 3. To estimate rates of removals related to fishing activities in New Zealand for selected seabird species, where possible by age class and sex. 4. To describe the spatial overlap of seabird distributions at sea, with fisheries where the risk of incidental mortality has been demonstrated to be moderate to high. 5. To examine the potential for factors other than fisheries removals within the New Zealand zone to influence the population dynamics of the selected study species. 6. To characterise selected seabird populations' abilities to sustain removals related to fishing operations within the New Zealand EEZ, and to recommend, where possible environmental standards for assessing the sustainability of selected fishing operations in relation to impacts on seabird populations.	Completed	Fletcher *et al.* 2008
PRO	ENV2004-06	Maui's dolphin study	1. To quantify and compare summer and winter distribution of Maui's dolphin	Completed	Slooten *et al.* 2005

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	IPA2004-14	Seabird warp strike in the southern squid trawl fishery	1. To document seabird warp strike in the southern squid trawl fishery, 2004-05	Completed	Abraham & Kennedy 2008
PRO	ENV2003-05	Review of the Current Threat Status of Associated or Dependent Species	1. To assess the current threat status of selected associated or dependent species.	Completed	Baird *et al.* 2010
PRO	No project number	QMA SQU6T New Zealand sea lion incidental catch and necropsy data for the fishing years 2000-01, 2001-02 and 2002-03	Report on New Zealand sea lion incidental catch and necropsy data for the fishing years 2000-01, 2001-02 and 2002-03	Completed	Mattlin 2004
PRO	MOF2002-03L	Exploring alternative management procedures for controlling bycatch of Hooker's sea lions in the SQU 6T squid fishery	Report on exploring alternative management procedures for controlling bycatch of Hooker's sea lions in the SQU 6T squid fishery	Completed	Breen & Kim 2006

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	ENV2001-01	Estimation of seabird incidental captures in New Zealand fisheries	1. To estimate the level of seabird incidental capture in New Zealand fisheries. 2. To recommend appropriate levels of observer coverage for estimation of seabird incidental capture in New Zealand fisheries.	Completed	Baird 2004a; b; c; Smith & Baird 2008b
PRO	ENV2001-02	Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2001-02.	1. To estimate and report the total numbers of captures, releases, and deaths of *Phocarctos hookeri* caught in fishing operations, including separate estimates for SQU 6T and other areas, as appropriate, during the 2001102 fishing year, including confidence limits and an investigation of any statistical bias in the estimate.	Completed	Baird 2005a; b; Baird & Doonan 2005
PRO	ENV2001-03	Estimation of *Arctocephalus forsteri* (New Zealand fur seal) incidental captures in New Zealand fisheries	1. To estimate the level of *Arctocephalus forsteri* incidental capture in New Zealand fisheries. 2. To recommend appropriate levels of observer coverage for estimation of *Arctocephalus forsteri* incidental capture in New Zealand fisheries.	Completed	Smith & Baird 2008a; Baird 2005c; d; e
PRO	ENV2000-01	Protected species bycatch	1. To estimate the total numbers of captures, releases, and deaths of seabirds and marine mammals - by species -caught in fishing operations during the 1999-2000 fishing year.	Completed	Baird 2003
PRO	ENV2000-02	Estimation of incidental mortality of New	1. To examine the factors that may influence the level of incidental mortality of New Zealand sea lion in New Zealand fisheries 2. To recommend appropriate levels of observer coverage for estimation	Completed	Doonan 2001; Bradford 2002;

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		Zealand sea lions in New Zealand fisheries	of incidental mortality of New Zealand sea lion in New Zealand sea lion fisheries		Smith & Baird 2005a; b
PRO	ENV2000-03	ENV 2000-A Estimation of seabird and marine mammal incidental capture in New Zealand fisheries	1. To estimate the level of seabird and marine mammal incidental capture in New Zealand fisheries. 2. To determine the factors that influence the level of seabird and marine mammal incidental capture in New Zealand fisheries. 3. To recommend appropriate levels of observer coverage for estimation of seabird and marine mammal incidental capture in New Zealand fisheries.	Completed	Bradford 2002; 2003; Francis *et al.* 2004
PRO	ENV99-01	Incidental capture of seabirds, marine mammals and sealions in commercial fisheries in New Zealand waters	To estimate the level of seabird and marine mammal incidental captures in New Zealand fisheries.	Completed	Baird 2001; Doonan 2000
PRO	No project number	Factors influencing bycatch of protected species	To determine the factors that influence the level of seabird and marine mammal incidental capture in New Zealand fisheries.	Completed	Baird & Bradford 2000a; b
PRO	ENV98-01	Estimation of non-fish bycatch in commercial fisheries in New	To estimate the level of non-fish bycatch in New Zealand fisheries.	Completed	Baird 1999b; Baird & Bradford 1999

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		Zealand waters, 1997–98			
PRO	No project number	Annual review of bycatch in southern bluefin and related tuna longline fisheries in the New Zealand 200 n. mile Exclusive Economic Zone	Review bycatch in New Zealand's southern bluefin and related tuna longline fisheries.	Completed	Baird *et al.* 1998
PRO	SANF01	Report on the incidental capture of nonfish species during fishing operations in New Zealand waters	To report on incidental captures of non-fish species in New Zealand fisheries.	Completed	Baird 1997
PRO	No project number	Non-fish Species and Fisheries Interactions	To estimate the level of non-fish bycatch in New Zealand fisheries.	Completed	Baird 1996
PRO	No project number	Analyses of factors which influence seabird bycatch in the Japanese southern bluefin tuna longline	1. To assess the influence that 15 monitored environmental and fishery related factors had on seabird bycatch rates, and to gauge the effectiveness of various mitigation measures	Completed	Duckworth 1995

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		fishery in New Zealand waters, 1989-93			
PRO	No project number	Incidental catch of Hooker's sea lion in the southern trawl fishery for squid, summer 1994	Report on the incidental catch of Hooker's sea lion in the souther trawl fishery for squid, summer 1994.	Completed	Doonan 1995
PRO	No project number	Nonfish Species and Fisheries Interactions	To estimate the level of non-fish bycatch in New Zealand fisheries.	Completed	Baird 1995
PRO	No project number	Nonfish Species and Fisheries Interactions	To estimate the level of non-fish bycatch in New Zealand fisheries.	Completed	Baird 1994
PRO	No project number	Incidental catch of fur seals in the west coast South Island hoki trawl fishery, 1989-92	To report on incidental captures of fur seals in the west coast South Island hoki trawl fishery 1989-92.	Completed	Mattlin 1993
PRO	No project number	Incidental catch of non-fish species by setnets in New Zealand waters	To report on incidental captures of non-fish species in New Zealand setnet fisheries.	Completed	Taylor 1992

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
PRO	No project number	Seabird bycatch by Southern Fishery longline vessels in New Zealand waters	1. To describe the tuna longline fishery in the New Zealand EEZ and how seabirds are caught by longline vessels, 2. To summarise information available on seabird population trends, and estimates the scale of the incidental capture of seabirds in the larger of two tuna longline fisheries in the EEZ. 3. To describe measures which could reduce the number of seabirds caught by tuna longlines.	Completed	Murray *et al.* 1992
NPB	ENV2015-01	Updating tools for at-sea fish identification	1.To review the level of information required by the seafood sector and other users of fish identification guides in New Zealand 2.To evaluate the most beneficial and cost-effective methods of delivery that are practicable and consistent with MPI policy directions 3.To review, revise and produce the appropriate information tools on fish identification.	Approved, but not yet contracted	
NPB	ENV2015-03	Addressing key information gaps identified by the shark qualitative risk assessment	1. To collect and analyse biological information to improve estimates of risk for inshore and deepwater shark species identified as being at relatively high risk.	Approved, but not yet contracted	
NPB	No Project Code	Qualitative Shark risk assessment	To produce a qualitative risk assessment for all shark species possible within the New Zealand EEZ.	Completed	Ford *et al.* 2015
NPB	ENV2014-01	NPOA-sharks: comprehensive risk assessment	1. Conceptual framework definition, taxonomic resolution and definition of fishery groups.	Not yet contracted	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			2. Species distribution modelling. 3. Spatial overlap of deepwater fish species with commercial fishery groups 4. Life history parameters distribution and Maximum impact sustainable threshold (MIST) estimation for sharks.		
NPB	ENV2014-02	NPOA-sharks: age and growth of selected at-risk species	1. To estimate basic biological parameters for high risk, high uncertainty chondrichthyans.	Ongoing analysis	
NPB	No project code	Mitigation options for shark bycatch in longline fisheries	Conduct a literature review and assess the options for improvements in the practice of fisheries to mitigate shark bycatch	Completed	Howard 2015
NPB	SEA2013-16	Data collation for shark risk assessments	1. To assemble and collate all available information on the distribution and intensity of all fishing methods for the most recent five full fishing years that potential cause fishing-related mortality of chondrichthyans 2. To assemble and collate all available information on the distribution, abundance, demographics and productivity of all New Zealand chondrichthyans.	Completed	Francis 2015
NPB	ENV2013-01	Development of model-based estimates of fish bycatch	1. To develop a statistical modelling approach to estimating total captures of fish and invertebrates using observer and catch-effort information from selected fisheries. 2. To compare estimates of total captures, confidence limits, and trends for selected species, species groups, and fisheries made using existing	Completed	Edwards *et al.* 2015

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			ratio-based methods and statistical models. 3. To estimate, within a simulation framework, the potential for bias in ratio-based and model-based methods, the sizes of confidence limits for estimates from the two approaches in comparable situations, and identify the factors associated with good and poor performance.		
NPB	DAE2010-02	Bycatch monitoring & quantification for scampi bottom trawl	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded in the specified fishery, for the fishing years since the last review, using data from Ministry of Fisheries Observers and commercial fishing returns. 2. To compare estimated rates and amounts of bycatch and discards from this study with previous projects on bycatch in the specified fishery. 3. To compare any trends apparent in bycatch rates in the specified fishery with relevant fishery independent trawl surveys. 4. To provide annual estimates of bycatch for nine Tier 1 species fisheries and incorporate into the Aquatic Environment and Biodiversity Report specified in Objective 3 for SQU, SCI, HAK, HOK, JMA, ORH, OEO, LIN, SBW	Completed	Anderson 2012, 2013a, b, 2014a, b, Ballara 2015, Ballara & O'Driscoll 2015.
NPB	ENV2009-02	Bycatch and discards in oreo and orange roughy trawl fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for oreos for the fishing years 2002/03 to 2008/09 using data from Scientific Observers and commercial fishing returns. 2. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for orange roughy for the fishing years 2004/05 to 2008/09 using data from Scientific Observers and commercial fishing returns.	Completed	Anderson 2011

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NPB	IDG2009-01	Finfish field identification guide	1. To complement the field identification guide under IDG2006/01 with the remaining 120 fish species caught by commercial fishers in New Zealand waters	Completed	McMillan *et al.* 2011 a,b,c;
NPB	ENV2008-01	Fish and invertebrate bycatch and discards in southern blue whiting fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for southern blue whiting for the fishing years 2002/03 to 2006/07 using data from Scientific Observers and commercial fishing returns.	Completed	Anderson 2009b
NPB	ENV2008-02	Estimation of non-target fish catch and both target and non-target fish discards in hoki, hake and ling trawl fisheries	Estimates of the catch of non-target fish species, and the discards of target and non-target fish species in the hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*), and ling (*Genypterus blacodes*) trawl fisheries for the fishing years 2003–04 to 2006–07 using data from Scientific Observers and commercial fishing returns	Completed	Ballara *et al.* 2010
NPB	ENV2008-04	Productivity of deepwater sharks	1. To determine the growth rate, age at maturity, longevity and natural mortality rate of shovelnose dogfish (*Deania calcea*) and leafscale gulper shark (*Centrophorus squamosus*).	Completed	Parker & Francis 2012
NPB	ENV2007-01 & ENV2007-02	Bycatch and Discards in Squid Trawl Fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for squid for the fishing years 2001/02 to 2005/06 using data from MFish Observers and commercial fishing returns.	Completed	Ballara & Anderson 2009

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NPB	ENV2007-03	Productivity and Trends in Rattail Bycatch Species	1. To estimate growth, longevity, rate of natural mortality, and length at maturity of four key rattail bycatch species in New Zealand trawl fisheries. 2. To examine data from trawl surveys and other data sources for trends in catch rates or indices of relative abundance for species in Objective 1.	Completed	Stevens *et al.* 2010
NPB	DEE2006-03	Monitoring the abundance of deepwater sharks	1. To monitor the abundance of deepwater sharks taken by commercial trawl fisheries	Completed	Blackwell 2010
NPB	ENV2006-01	Bycatch and discards in ling longline fisheries	To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the longline fisheries for ling for the fishing years 1998/99 to 2005/06 using data from MFish Observers and commercial fishing returns.	Completed	Anderson 2008
NPB	IDG2006-01	Finfish field identification guide	1. To produce a field guide for fish species in New Zealand 2. To produce a field identification guide for all QMS and other fish species commonly caught in commercial and non-commercial fisheries	Completed	McMillan 2011 a,b,c
NPB	TUN2006-02	Estimation of non-target fish catches in the tuna longline fishery	1. To estimate the catches, catch rates, and discards of non-target fish in tuna longline fisheries data from the Observer Programme and commercial fishing returns for the 2005/06 fishing year. 2. To describe bycatch trends in tuna longline fisheries using data from this project and the results of previous similar projects.	Completed	Griggs *et al.* 2008
NPB	ENV2005-17	Estimation of non-target fish catch and both target and non-target fish	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for jack	Completed	Anderson 2007a

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		discards in jack mackerel trawl fisheries	mackerel for the fishing years 20011/2002 to 2004/05 using data from Mfish observers and commercial fishing returns.		
NPB	ENV2005-18	Estimation of non-target fish catch and both target and non-target fish discards in orange roughy trawl fisheries	1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for orange roughy for the fishing years 1999/2000 to 2003/04 using data from Scientific Observers and commercial fishing returns.	Completed	Anderson 2009a
NPB	TUN2004-01	Estimation of non-target fish catches in the tuna	To estimate the catch rates of non-target fish in the 10ngline fisheries for tuna using data from the Observer Programme and commercial fishing returns for the 2002/03, 2003/04 and 2004/05 fishing years. 2. To estimate the quantities of non-target fish caught in the longline fisheries for tuna using data from the Observer Programme and commercial fishing returns for the 2002/03, 2003/04 and 2004/05 fishing years. 3. To estimate the discards of non-target fish caught in the longline fisheries for tuna using data from the Observer Programme and commercial fishing returns for the 2002/03, 2003/04 and 2004/05 fishing years. 4. To describe trends in the non-target fish catches in the tuna longline fisheries using data from this project and the results of previous similar projects.	Completed	Griggs *et al.* 2007
NPB	ENV2003-01	Estimation of non-target catches in the hoki fishery	1. To estimate the catch rates, quantity and discards of non-target fish catches and the discards of target fish catches in trawl fisheries for hoki, using data from the Observer Programme and commercial fishing returns for the 1999/00 to 2002/03 fishing years.	Completed	Anderson & Smith 2005

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			2. To compare and contrast the estimates from the four years of data in Specific Objective 1 above with the 1990/91 through 1998/99 series previously reported.		
NPB	ENV2002-01	Estimation of non-target fish catch and both target and non-target fish discards for the tuna longline fishery	1. To estimate the catch rates, quantity and discards of non-target fish, particularly oceanic shark species, broadbill swordfish and marlin species, caught in the longline fisheries for tuna, using data from Scientific Observers and commercial fishing returns for the 2000/01 and 2001/02 fishing years.	Completed	Ayers *et al.* 2004
NPB	ENV2001-04	Non-target fish catch and discards in selected New Zealand fisheries	To generate estimates of the catch of non-target fish species, and the discards of target and non-target fish species in three important New Zealand trawl fisheries: arrow squid (*Nototodarus sloani & N. gouldi*), jack mackerel (*Trachurus declivis, T. novaezelandiae, & T. symmetricus murphyi*) and scampi (*Metanephrops challengeri*)	Completed	Anderson 2004
NPB	ENV2001-05	To assess the productivity and relative abundance of deepwater sharks	1. To review the relative abundance, distribution and catch composition of the most commonly caught deepwater shark species: shovelnose dogfish (*Deania catcea*), Baxter's dogfish (*Etmopterus baxten*), Owston's dogfish (*Cenhoscymnus owstoni*), longnosed velvet dogfish (*Centroscymnus crepidater*), leafscale gulper shark (*Cenhophom squamosus*), and the seal shark (*Dalatias ticha*).	Completed	Blackwell & Stevenson 2003
NPB	ENV2001-07	Reducing bycatch in scampi trawl fisheries	1. Collate and review the international literature on methods of reducing bycatch in crustacean trawl fisheries. 2. Review and analyse the data from New Zealand studies. 3. Develop recommendations on future approaches to reducing bycatch	Completed	Hartill *et al.* 2006

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			in the New Zealand scampi fishery, including some general thoughts on the experimental design of field trials.		
NPB	PAT2000-01	Review of rattail and skate bycatch, and analysis of rattail standardised CPUE from the Ross Sea toothfish fishery in Subarea 88.1, from 1997-1998 to 2001-02	Report on review of rattail and skate bycatch, and analysis of rattail standardised CPUE from the Ross Sea toothfish fishery in Subarea 88.1, from 1997-1998 to 2001-02	Completed	Fenaughty *et al.* 2003; Marriot *et al.* 2003
NPB	ENV99-02	Estimation of non-target fish catch and both target and non-target fish discards in selected New Zealand fisheries	1. To estimate the quantity of non-target fish species caught in the trawl fisheries for hoki and orange roughy for the fishing years 1990-91 to 1998-99 using data from Scientific Observers, commercial fishing returns and from research trawl surveys. 2. To estimate the quantity of target and non-target fish species discarded in the trawl fisheries for hoki and orange roughy for the fishing years 1990-91 to 1998-99 using data from Scientific Observers, commercial fishing returns and from research trawl surveys. 3. To explore the effects of various factors on the total catch of non-target fish species and the discards of target and non-target fish species in the trawl fisheries for hoki and orange roughy for the fishing years 1990-91 to 1998-99. 4. To recommend appropriate levels of observer coverage for estimation of non-target fish catch and discards of target and non-target fish species in the hoki and orange roughy fisheries.	Completed	Anderson et al. 2001

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
NPB	ENV99-05	To identify trends in abundance of associated or dependent species from selected commercial fisheries	To estimate trends in abundance of associated and depeadent species, including invertebrates, from deepwater and middle depth fisheries on the Chatham Rise.	Completed	Livingston *et al.* 2003
NPB	ENV98-02	Pelagic shark bycatch in the New Zealand tuna longline fishery	To determine pelagic shark bycatch in the New Zealand tuna longline fishery	Completed	Francis *et al.* 2001
NPB	No project number	Fish bycatch in New Zealand tuna longline fisheries	To report on fish bycatch in New Zealand tuna longline fisheries	Completed	Francis *et al.* 1999; 2000
NPB	ENV97-01	Estimation of nonfish bycatch in New Zealand fisheries	To estimate non-fish bycatch in New Zealand fisheries	Completed	Doonan 1998; Baird 1999a; Baird *et al.* 1999
NPB	SCI97-01	Scampi stock assessment for 1998 and an analysis of the fish and invertebrate bycatch of scampi trawlers	1. To summarise catch, effort, observer, and research information for scampi fisheries in QMAs 1,2,3,4 (east and western portions), and 6A in 1998	Completed	Cryer *et al.* 1999

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BEN	BEN2014-01	Risk assessment for benthic habitats, biodiversity, and production	1. To review the design and implementation of management frameworks, including objectives and targets, to manage the effects of mobile bottom fishing methods on vulnerable benthic taxa and habitats 2. To complete spatially explicit quantitative impact assessments for benthic taxa and/or habitats affected by bottom fisheries, within spatially distinct or overlapping zones within the New Zealand EEZ, consistent with available databases and the outputs of existing projects 3. To compile and combine impact assessments from Objective 2, to inform a spatially explicit quantitative risk assessment with reference to potential management targets for benthic taxa and/or habitats (from Objective 1) combined across all bottom fisheries in the New Zealand EEZ, 4. To conduct spatially explicit Management Strategy Evaluation to simulate and evaluate the effects of alternate fisheries management scenarios on benthic taxa and/or habitats in the EEZ	Approved but not contracted	
BEN	BEN2014-02	Monitoring recovery of benthic fauna on the Graveyard complex	1. To repeat the quantitative photographic survey of benthic invertebrate communities on the Graveyard complex. 2. To assess changes in benthic communities since the first survey in 2001	Ongoing analysis	
BEN	BEN2014-03	Monitoring recovery of benthic fauna in Spirits Bay	1. Using previous survey results, conduct a power analysis to estimate the likelihood of a range of survey designs consistent with the monitoring programme from project ENV2005/23 detecting changes in key indicators of the state of the benthic communities in Spirits Bay and Tom Bowling Bay since the last survey.	Approved but not contracted	

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			2. To survey Spirits Bay and Tom Bowling Bay benthic invertebrate communities in accordance with an agreed design from Objective 1. 3. To assess changes in benthic communities inside and outside of the closed area since 1997		
BEN	SEA2014-09	Review of New Zealand's SPRFMO VME protocol	1. To prepare a review of the scientific basis for the 'biodiversity component' of the move-on-rule thresholds comprising the current New Zealand Vulnerable Marine Ecosystem Evidence Process.	Completed	Penney 2014
BEN	BEN2012-02	Spatial overlap of mobile bottom fishing methods and coastal benthic habitats	1. To use existing information and classifications to describe the distribution of benthic habitats throughout New Zealand's coastal zone (0–200 m depth). 2. To rank the vulnerability to fishing disturbance of habitat classes from Objective 1. 3. To describe the spatial pattern of fishing using bottom trawls, Danish seine nets, and shellfish dredges and assess overlap with each of the habitat classes developed in Objective 1.	Completed	Baird *et al.* 2015
BEN	DEE2010-06	Design a camera / transect study	1. To design and provide indicative costs for a programme to monitor trends in deepwater benthic habitats and communities. 2. To explore the feasibility of using existing trawl and acoustic surveys to capture data relevant to monitoring trends in deepwater benthic habitats and communities.	Completed	Bowden *et al.* (2015)
BEN	DAE2010-04	Monitoring the trawl footprint for deepwater fisheries	1. To estimate the 2009/10 trawl footprint and map the spatial and temporal distribution of bottom contact trawling throughout the EEZ between 1989/90 and 2009/10. 2. To produce summary statistics, for major deepwater fisheries and the aggregate of all deepwater fisheries, of the spatial extent and frequency	Ongoing analysis	Black *et al.* 2013; Black & Tilney 2015.

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			of fishing by year, by depth zone, by fishable area, and by habitat class, and to identify any trends or changes.		
BEN	Internally funded 1	SPRFMO	1. To develop detection criteria for measuring trawl impacts on vulnerable marine ecosystems in high sea fisheries of the South Pacific Ocean	Completed	Parker and Bowden 2010
BEN	Internally funded 2	SPRFMO	1. To document protection measures implemented by New Zealand for vulnerable marine ecosystems in the South Pacific Ocean	Completed	Penney *et al.* 2009
BEN	Internally funded 3	CCAMLR	1. An Impact Assessment Framework for Bottom Fishing Methods in the CCAMLR Convention Area	Completed	Sharp *et al.* 2009
BEN	Internally funded 4	SPRFMO	1. to develop a bottom Fishery Impact Assessment: Bottom Fishing Activities by New Zealand Vessels Fishing in the High Seas in the SPRFMO Area during 2008 and 2009	Completed	Ministry of Fisheries 2008
BEN	BEN2009-02	Monitoring recovery of benthic communities in Spirits Bay	1. To survey Spirits Bay and Tom Bowling Bay benthic invertebrate communities according to the monitoring programme designed in ENV2005/23. 2. To assess changes in benthic communities inside and outside the closed area since 1997.	Completed	Tuck & Hewitt 2013
BEN	IFA2008-04	Guide for the rapid identification of material in the process of managing	To produce a guide for the rapid identification of material in the process of managing Vulnerable Marine Ecosystems	Completed	Tracey *et al.* 2008

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		Vulnerable Marine Ecosystems			
BEN	BEN2007-01	Assessing the effects of fishing on soft sediment habitat, fauna, and processes	1. To design and test sampling and analytical strategies for broad-scale assessments of habitat and faunal spatial structure and variation across a variety of seafloor habitats. 2. To design and carry out experiments to assess the effects of bottom trawling and dredging on benthic communities and ecological processes important to the sustainability of fishing at scales of relevance to fishery managers.	Ongoing analysis	
BEN	IFA2007-02	Development of a Draft New Zealand High-Seas Bottom Trawling Benthic Assessment Standard	1. To generate data summaries and maps of New Zealand's recent historic high-seas bottom trawling catch and effort in the proposed convention area of the South Pacific Regional Fisheries Management Organization (SPRFMO). 2. To map vulnerable marine ecosystems (VMEs) in the SPRFMO area. 3. To develop a draft standard for assessment of benthic impacts of high-seas bottom trawling on VMEs in the proposed SPRFMO convention area.	Completed	Parker 2008
BEN	BEN2006-01	Mapping the spatial and temporal extent of fishing in the EEZ	1. To update maps and develop GIS layers of fishing effort from project ENV2000/05 to show the spatial and temporal distribution of mobile bottom fishing throughout the EEZ between 1989/90 and 2004/05. 2. To produce summary statistics of major fisheries and the aggregate of all bottom impacting fisheries in terms of the extent and frequency of fishing by year, by depth zone, by fishable area, and, to the extent possible, by habitat type. 3. To identify and document any major trends or changes in fishing effort or fishing behaviour. 4. To identify, discuss the implications of, and make recommendations on data quality and other problems with current reporting systems that complicate characterisation and quantification of bottom fishing effort.	Completed	Baird *et al.* 2009; 2011; Baird & Wood 2010; Leathwick *et al.* 2010; 2012

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			5. To integrate information on the distribution, frequency, and magnitude of fishing disturbance with habitat characteristics throughout the EEZ, using information stored in national databases, expert opinion, and the MEC.		
BEN	ENV2005-15	Information for managing the Effects of Fishing on Physical Features of the Deep-sea Environment	1. To provide an updated database that identifies all known seamounts in the "New Zealand region", encompassing the area from 24°00' – 57°30'S, 157°00'E – 167°00'W. The database will catalogue relevant data (e.g. physical, biological, location, fishing effort) for individual seamounts. 2. To identify indicators and measures suitable for the assessment of risk pertaining to the effects of fishing disturbance on the benthic biota of seamounts, and review suitable ecological risk assessment methods, that can be derived or utilise information contained within the seamount database.	Completed	Rowden *et al.* 2008; Clark *et al*. 2010b
BEN	ENV2005-16	Investigate the Effects of Fishing on Physical Features of the Deep-sea Environment	1. To monitor changes in fauna and habitats over time on selected UTFs in the Chatham Rise area that have a range of fishing histories. 2. To continue development of the risk assessment model to predict the effects of fishing, and provide options for the management of UTF ecosystems.	Completed	Clark *et al*. 2010a; b; c; 2011
BEN	ENV2005-20	Benthic invertebrate sampling and species identification in trawl fisheries	1. To produce identification guides for benthic invertebrate species encountered in the catches of commercial and research trawlers.	Completed	Tracey *et al.* 2007; Williams *et al.* 2010; Clark *et al.* 2009

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BEN	ENV2005-23	Monitoring recovery of the benthic community between North Cape and Cape Reinga	1. To design a monitoring programme that will provide the following quantitative estimates: i) Estimates of the nature and extent of past fishing impacts on the benthic community between North Cape and Cape Reinga; ii) Estimates of change over time in areas previously fished but subsequently closed to fishing. Estimated parameters will include indices representing biodiversity, community composition, and biogenic structure; iii) Estimates of change over time in areas environmentally comparable to those assessed in (ii), above, but subject to ongoing fishing impacts; and iv) Estimates of change over time in areas comparable to those above, but not impacted by fishing (if any such areas can be found).	Completed	Tuck *et al.* 2010
BEN	ZBD2005-04	Information on benthic impacts in support of the Foveaux Strait Oyster Fishery Plan	1. To assess the distribution- vulnerability to disturbance- and ecological importance of habitats in Foveaux Strait- and describe the spatial distribution of the Foveaux Strait oyster fishery relative to those habitats. 2. To assemble and collate existing information on the Foveaux Strait system between the Solander Islands and Ruapuke Island or other area to be agreed with MFish. 3. To map- using best available information- substrate type- bathymetry- wave energy- and tidal flow in this area. 4. To assess the extent to which these data can be used to define useful functional categories that might serve as habitat classes. 5. To rank the vulnerability to fishing disturbance of habitat classes developed in Objective 3 using approximate regeneration times. 6. To describe the functional role and ecosystem services provided by each habitat class developed in Objective 3- including an assessment of the relative importance of each to overall ecosystem function and productivity. 7. To describe the spatial pattern and intensity of dredge fishing for Foveaux Strait oysters over the past 10 fishing years and relate this to	Completed	Michael et al. 2006

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			natural disturbance regimes and habitat classes developed in Objective 3. 8. To carry out a qualitative video survey of benthic habitats in Foveaux Strait- both within the established commercial oyster fishery area and areas outside the fishery area but within OYU 5.		
BEN	ZBD2005-15	Information on benthic impacts in support of the Coromandel Scallops Fishery Plan	1. To assemble and collate existing information on the coromandel Scallop Fishery between cape Rodney and Town Point or other, wider area to be agreed with Mfish. 2. To map, using best available information, substrate type, bathymetry, wave energy, and tidal flow in this area. 3. To assess the extent to which data can be used to define useful functional categories that might serves as habitat classes. 4. To rank the vulnerability of fishing disturbance of habitat classes developed in Objective 3 using approximate regeneration times. 5. To describe the functional role and ecosystem services provided by each habitat class developed in Objective 3, including an assessment of the relative importance of each to overall ecosystem function and productivity. 6. To describe the spatial pattern and intensity of dredge and trawl fishing within the Coromandel scallop fishery over the past 15 fishing years and relate this to natural disturbance regimes and habitat classes developed in Objective 3.	Completed	Tuck *et al.* 2006a; b
BEN	ZBD2005-16	Information on benthic impacts in support of the Southern Blue Whiting Fishery Plan	1. To assemble and collate existing information on the Southern Blue Whiting fishery in SBW6A, SBW6B, SBW6I, and SBW6R or other wider area to be agreed with MFish 2. To map, using best available information, substratum type, bathymetry, wave energy, tides, and ocean currents in these areas 3. To assess the extent to which these data can be used to define useful functional categories that might serve as habitat categories. 4. To rank the vulnerability to fishing disturbance of habitat classes	Completed	Cole *et al.* 2007

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			developed in Objective 3 using approximate regeneration times. 5. To describe the functional role and ecosystem services provided by each habitat class developed in Objective 3, including an assessment of the relative importance of each to overall ecosystem function and productivity. 6. To describe the spatial pattern and intensity of trawl fishing within the Southern Blue Whiting fishery over the past 10 fishing years and relate this to natural disturbance regimes and habitat classes developed in Objective 3.		
BEN	ENV2003-03	Determining the spatial extent, nature and effect of mobile bottom fishing methods	1. To determine the spatial extent, nature and time between disturbances of mobile bottom fishing methods in the Chatham Rise trawl fisheries.	Completed	Baird *et al.* 2006
BEN	ENV2002-04	Benthic invertebrate sampling and specific identification in trawl fisheries	1. To quantify and map the benthic invertebrate species incidental catch in commercial and research trawling throughout the New Zealand EEZ	Completed	Tracey *et al.* 2005
BEN	ENV2001-09	The effects of mobile bottom fishing gear on bentho-pelagic coupling	To describe any effects of fishing that might modify bentho-pelagic coupling (a complex, interlinked suite of processes transferring energy, oxygen, carbon, and nutrients between pelagic and benthic systems), to consider the scale of such possible effects, and to put the summary in a New Zealand context.	Completed	Cryer et al. 2004

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BEN	ENV2001-15	The effects of bottom impacting trawling on seamounts	1. To design a programme in New Zealand waters previously trawled and now closed to trawling to monitor the rate of regeneration of benthic communities on seamounts.	Completed	Clark & O'Driscoll 2003; Clark & Rowden 2009
BEN	OYS2001-01	Foveaux Strait oyster stock assessment	1. To carry out a survey and determine the distribution and absolute abundance of pre-recruit and recruited oysters in both non-commercial and commercial areas of Foveaux Strait. The target coefficient of variation (c.v.) of the estimate of absolute recruited abundance is 20%. 2. To estimate the sustainable yield for the areas of the commercial oyster fishery in Foveaux Strait for the year 2002 oyster season. 3. To identify and count benthic macro-biota collected during the dredge survey.	Completed	Rowden *et al.* 2007
BEN	ENV2000-05	Spatial extent, nature and impact of mobile bottom fishing methods in the New Zealand EEZ	1. To determine the spatial extent, nature and impact of mobile bottom fishing methods within the New Zealand EEZ.	Completed	Cryer and Hartill 2002; Baird et al. 2002
BEN	ENV2000-06	Review of technologies and practices to reduce bottom trawl bycatch and seafloor disturbance in New Zealand	To review technologies and practices to reduce bottom trawl bycatch and seafloor disturbance in New Zealand	Completed	Booth *et al.* 2002; Beentjes & Baird 2004

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BEN	ENV98-05	The effects of fishing on the benthic community structure between North Cape and Cape Reinga	1. To determine the effects of fishing on the benthic community structure between North Cape and Cape Reinga.	Completed	Cryer *et al.* 2000
ECO	MDC2015-01	MDC Benthic coring	To support benthic coring in the Marlborough Sounds by the Marlborough District Council (MDC). The results of this will provide historical information to support environmental restoration and reporting goals. It will also support potential restoration using empty mussel shell disposal.	Ongoing	
ECO	ENV2014-09	Spatial decision support tools for multi-use and cumulative effects	To provide a customised GIS decision support tool to help assess the cumulative effects of fishing.	Ongoing	
ECO	SEA2013-01	Provision of identification guides (sea pens and black corals)	To produce identification guides for sea pens and black corals electronically as AEBR (including MPI review).	Completed	Tracey *et al.* 2014; Williams *et al.* 2014; Opresko *et al.* 2014, Clark *et al.* 2015
ECO	ENV2012-01	A literature review of Nitrogen levels and adverse ecological effects	1. To complete a literature review of Nitrogen levels and adverse ecological impacts from temperate embayments in order to assist aquaculture consenting authorities in determining at what concentration of Nitrogen adverse effects may be expected.	Completed	Hartstein & Oldman 2015

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		in embayments in temperate regions.			
ECO	SEA2012-17	NPOA Sharks extension work	NPOA Sharks extension work	Completed	Clark *et al.* 2013
ECO	ZBD2012-02	Tier 1 statistic: Ocean	1. To identify candidate oceanographic variables for potential development as part of the proposed Tier 1 Statistic, Atmospheric and Ocean Climate Change	Completed	Pinkerton *et al.* 2015a
ECO	DAE2010-01	Taxonomic identification of benthic specimens	1. To identify benthic invertebrates in samples taken during research trawls and by Observers on fishing vessels. 2. To update relevant databases recording the catch of invertebrates in research trawls and commercial fishing.	Completed	Mills *et al.* 2013
ECO	DAE2010-03	Ecological risk assessment for deepwater stocks	1. To undertake a qualitative (level 1) risk assessment for tier 3 fishstocks within the deepwater fisheries plan.	Deferred	
ECO	DEE2010-04	Development of a methodology for Environmental Risk Assessments for deepwater fisheries	To review approaches to Ecological Risk Assessments (ERA) and methods available for deepwater fisheries both QMS and non-QMS. 2. To develop and recommend a generic, cost effective, method for ERA in deepwater fisheries by using or modifying methods identified in Objective 1.	Completed	Clark *et al.* Submitted; Mormede & Dunn 2013
ECO	DEE2010-05	Development of a suite of environmental	1. To review the literature and hold a workshop to recommend a suite of ecosystem and environmental indicators that will contribute to assessing the performance of deepwater fisheries within an environmental context.	Completed	Tuck *et al.* 2014

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		indicators for deepwater fisheries	2. To examine available data and design a data collection programme to enable future calculation of the indicators identified in Specific Objective 1.		
ECO	ENV2010-03	Habitats of particular significance for inshore finfish fisheries management	1. To review the literature to determine the most important juvenile or reproductive (spawning, pupping or egg-laying) areas for inshore finfish target species. 2. To use a gap analysis to prioritize areas for future research concerning the important juvenile or reproductive (spawning, pupping or egg-laying) areas for target inshore finfish fisheries	Completed	Morrison *et al.* 2014 b
ECO	ENV2010-05A&B and SEA2010-15	Habitats of particular significance for fisheries management: shark nursery areas	1. Identify, from the literature, important nursery grounds for rig in estuaries around mainland New Zealand. 2. Design and carry out a survey of selected estuaries and harbours around New Zealand to quantify the relative importance of nursery ground areas. 3. Identify threats to these nursery ground areas and recommend mitigation measures.	Completed	Francis *et al.* 2012; Jones *et al.* 2015.
ECO	ZBD2010-42	Development of a National Marine Environment Monitoring Programme	1. To design a Marine Evnvironment Monitoring Programme (MEMP) to track the physical, chemical and biological changes taking place across New Zealand's marine environment over the long term 2. To prepare an online inventory (metadatabase) of repeated (time series) biological and abiotic marine observations/datasets in New Zealand 3. To review, evaluate fitness for purpose, and identify gaps in the utility and interoperability of these datasets for inclusion in MEMP from both science and policy perspectives 4. To design a MEMP that includes relevant existing data collection and proposed new time series	Completed	Hewitt *et al.* 2014

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ECO	ENV2009-04	Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys	1. To evaluate relative changes in abundance of mesopelagic fish and other biological components from acoustic records collected during Chatham Rise and Sub-Antarctic trawl surveys. 2. To explore links between trends in mesopelagic biomass and climate variables and variations, and condition indices of commercial species in the Chatham Rise and Sub-Antarctic areas.	Completed	O'Driscoll *et al.* 2011
ECO	ENV2009-07	Habitats of particular significance for fisheries management: kaipara harbour	1. Collate and review information on the role and spatial distribution of habitats in the Kaipara Harbour that support fisheries production. 2. Assess historical, current, and potential anthropogenic threats to these habitats that could affect fisheries values, including fishing and land-based threats. 3. Design and implement cost-effective habitat mapping and monitoring surveys of habitats of particular significance for fisheries management in the Kaipara Harbour.	Completed	Morrison *et al.* 2014 d
ECO	GMU2009-01	Spatial Mixing of GMU1 using Otolith Microchemistry	1. To determine the level of spatial mixing and connectivity of grey mullet (*Mugil cephalus*) populations using otolith microchemistry. 2. To collect and analyse the chemical composition of grey mullet otoliths. 3. To analyse the otoliths collected under Objective 1 to determine if the samples can be spatially separated.	Ongoing analysis	
ECO	IPA2009-11	Trophic studies publication of review	1. To publish the comprehensive review of New Zealand-wide trophic studies completed in 2000 that was prepared by NIWA.	Completed	Stevens *et al.* 2011
ECO	FLA2009-01	Assess the feasibility of using	1. Assess the feasibility of using juvenile netting surveys to predict adult yellow-belly and sand founder abundance in the Manukau Harbour and	Completed	McKenzie *et al.* 2013

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		juvenile netting surveys to predict adult yellow-belly & sand flounder	Firth of Thames (this also examined correlations between juvenile catch and environmental factors).		
ECO	AQE2008-02	Review of ecological effects of farming shellfish and other species	1. To collate and review information on the ecological effects of farming mussels (*Perna canaliculus*), including offshore mussel farming and spat catching, in the New Zealand marine environment. 2. To collate and review information on the ecological effects of farming oysters in the New Zealand marine environment. 3. To collate and review information on the ecological effects of farming species other than mussels (*Perna canaliculus*), oysters, and finfish, in the New Zealand marine environment.	Completed	Keeley et al. 2009
ECO	IFA2008-08	Inputs to the Ross Sea bioregionalisation	1. To produce one or more benthic invertebrate classifications of the Ross Sea region; 2. To use fishery catch data to examine spatial distributions of major demersal fish species; 3. To prepare other biological or environmental spatial data layers for use in the Ross Sea workshop.	Completed	Pinkerton *et al.* 2009a
ECO	TOH2008-01	Distribution and abundance of Toheroa	1. To estimate the size structure and absolute abundance of toheroa on Oreti Beach, during February 2009. The target c.v. for the estimate of absolute abundance of legal sized toheroa (100 mm shell length) is 20%. 2. To describe changes in the size structure and absolute abundance of toheroa on Oreti Beach by comparing the results from this work with those from previous surveys. 3. To estimate the size structure and absolute abundance of toheroa on Bluecliffs Beach, during February 2009. The target c.v. for the estimate of absolute abundance of legal sized toheroa (100 mm shell length) is 20%. 4. To describe changes in the size structure and absolute abundance of	Completed	Beentjes 2010

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			toheroa on Bluecliffs Beach by comparing the results from this work with those from previous surveys.		
ECO	TOH2007-03	Toheroa Abundance	1. To investigate variations in the abundance of toheroa. 2. To investigate sources of mortality of toheroa and factors affecting the recruitment of toheroa	Completed	Williams *et al.* 2013
ECO	BEN2007-05	Risk assessment framework for assessing fishing &other anthropogenic effects on coastal fisheries	1. To collate existing information on the distribution, intensity, and frequency of anthropogenic disturbances in the coastal zone that could be used in a risk assessment model to estimate their likely aggregate effect on ecosystem function across habitats and over different scales of ecosystem functioning and biological organization. 2. To develop a risk assessment framework in conjunction with a variety of stakeholders and environmental scientists.	Completed	MacDiarmid *et al.* 2012
ECO	ENH2007-01	Stock enhancement of blackfoot paua	1. To assess the survival rate of enhanced paua from introduction into the wild through to harvest. 2. To assess the genetic diversity of hatchery spawned juvenile paua bred for enhancement purposes. 3. To assess interactions between introduced and wild paua populations and to recommend research and monitoring to quantify those impacts that are potentially adverse.	Completed	McCowan 2013 Submitted
ECO	ENV2007-04	Climate and Oceanographic Trends Relevant to New Zealand Fisheries	1. To summarise, for fisheries managers, climatic and oceanographic fluctuations and cycles that affect productivity, fish distribution and fish abundance in New Zealand.	Completed	Hurst *et al.* 2012

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ECO	ENV2007-06	Trophic Relationships of Commercial Middle Depth Species on the Chatham Rise	1. To quantify the inter-annual variability in the diets of hoki, hake and ling on the Chatham Rise 1992–2007 2.To quantify seasonal dietary cycles for hoki, hake and ling that have been collected from the commercial fleet throughout the year	Completed	Horn & Dunn 2010
ECO	HAB2007-01	Biogenic habitats as areas of particular significance for fisheries management	1. To collate and review available information on the location, value, functioning, threats to, and past and current status of biogenic habitats that may be important for fisheries production in the New Zealand marine environment. 2. To identify information gaps, in the New Zealand context, and recommend measures to address those important to an ecosystem approach to fisheries management	Completed	Morrison *et al.* 2014 a
ECO	IPA2007-07	Land Based Effects on Costal Fisheries	1. To review and collate scientific knowledge and research on the impacts of land-based activities on coastal fisheries and biodiversity	Completed	Morrisson *et al.* 2009
ECO	ENV2006-04	Ecosystem indicators for New Zealand fisheries	1. To carry out a literature review of potential fish-based ecosystem indicators and identify a suite of indicators to be tested in Objective 2 2. To test a suite of fish-based ecosystem indicators (identified by Objective 1) on existing trawl survey time series in New Zealand. The utility of these indicators for monitoring the effects of fishing in New Zealand should also be evaluated	Completed	Tuck *et al.* 2009
ECO	GBD2006-01	DNA database for commercial marine fish and invertebrates	1. To collect DNA sequences for vouchered specimens of commercially important marine fishes and submit the DNA data to the international Barcode of Life Database (BOLD). 2. To collect DNA sequences for vouchered specimens of commercially	Completed	No reports specified as required output

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			important marine invertebrates and submit the DNA data to the international Barcode of Life Database (BOLD). Note: The funding was limited to $60 000 for this Objective. Therefore MFish agreed to omit the invertebrate species (Objective 2) from this project and reduce the number of fish species sequenced from 100 to 80 (up to 5 specimens per species). During the course of the project MFish staff asked NIWA to identify smoked eel product, suspect shark fillets, and possible paua slime with DNA markers, consequently the project was modified to accommodate these requests		
ECO	IPA2006-08	Review of the Ecological Effects of Marine Finfish aquaculture: Final Report	1. Summarise and review existing information on ecological effects of finfish farming on the marine environment in New Zealand and overseas	Completed	Forrest *et al.* 2007
ECO	SAP2006-06	West coast south island review	1. To publish a review document summarising oceanic and environmental research information particularly relevant to hoki- but also other fisheries- that spawn off Westland in winter 2. Update the draft chapters prepared in 2004 by oceanographers-modellers and scientists towards the overall objective 3. Incorporate a section on other west coast spawning fisheries	Completed	Bradford-Grieve & Livingston 2011
ECO	ENV2005-08	Experimental design of a programme of indicators	1. To assess the utility/feasibility of using demographic information to assess the effects of fishing on seabird populations. 2. To identify population indicators and to provide sampling protocols and experimental design for selected high to medium priority seabird populations. 3. To recommend experimental protocols for sampling of selected seabird populations in New Zealand	Completed	MacKenzie & Fletcher 2010

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			influenced by fisheries mortality, employing robust-design methodology and including recommendations for inclusions of data into Ministry of Fisheries databases.		
ECO	IPA2005-02 and MOF2003-03A	A guide to common offshore crabs in New Zealand Waters	1. Develop a guide to common offshore crabs in new Zealand waters	Completed	Naylor *et al*. 2005
ECO	SAM2005-02	Effects of climate on commercial fish abundance	To examine the possible effects of climate on fishery yields and abundance indices for commercial fisheries around New Zealand	Completed	Dunn *et al*. 2009
ECO	HOK2004-01	Hoki Population modelling and stock assessment	2. To investigate the prediction of year class strength from environmental variables.	Completed	Francis *et al.* 2005
ECO	AQE2003-01	Effects of aquaculture and enhancement stock sources on wild fisheries resources and the marine environment.	1. To identify, discuss the effects and qualitatively assess the risks of aquaculture and enhancement stocks improved by hatchery technology on New Zealand's wild fisheries resources and the marine environment. 2. To identify, discuss the effects and qualitatively assess the risks associated with the translocation of aquaculture and enhancement stocks on New Zealand's wild fisheries resources and the marine environment. 3. To make recommendations on priority issues, risks, or research to be	Completed	Speed 2005

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			undertaken, as a result of information discussed and evaluated in objectives 1-2.		
ECO	EEL2003-01	Non-fishing mortality of freshwater eels	1. To undertake a feasibility study on establishing an estimate of the mortality of eels caused by hydroelectric turbines and other point sources of mortality caused by human activity.	Completed	Bentjees *et al.* 2005
ECO	MOF2003-01	The implications of marine reserves for fisheries resources and management in the New Zealand context	Investigations of the implications of marine resources for fisheries resources and management in the New Zealand context.	Completed	Speed *et al.* 2006
ECO	ENV2002-03	Beach cast seaweed review	1. To collate existing information on the role of beach-cast seaweed in coastal ecosystems to assess the nature and extent of the impacts that the removal of beach cast seaweed may have on the marine environment. 2. On the basis of the review in Specific Objective 1 above, to identify key research gaps related to any marine environment impacts that the removal of beach cast seaweed may have.	Completed	Zemke-White et al. 2005
ECO	ENV2002-07	Energetics and trophic relationships of important fish and invertebrate species	1. To quantify food webs supporting important fish and invertebrate species	Completed	Livingston 2004

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ECO	CRA2000-01	Rock lobster stock assessment	Objective 11: To conduct a desktop study to identifi and explore data needs associated with managing the effects of rock lobsterfishing on the environment.	Completed	Breen 2005
ECO	ENV2000-04	Identification of areas of habitat of particular significance for fisheries management within the New Zealand EEZ	1. To review literature and existing data for all significant fish species, including all QMS species, encountered from the 200 1500 m contour within the New Zealand EEZ to: a) determine areas of important juvenile fish habitat; b) determine areas of importance to spawning fish populations; and c) determine areas of importance for shark populations for pupping or egg laying. 2. To review literature and existing data for all significant pelagic fish species (excluding highly migratory species) encountered within the New Zealand EEZ to: a) determine areas of important juvenile fish habitat; b) determine areas of importance to spawning fish populations; and c) determine areas of importance for shark populations for pupping or egg laying 3. To review literature and existing data for all significant marine invertebrate species encountered within the New Zealand EEZ to: a) determine areas of important juvenile habitat; and b) determine areas of importance to spawning populations	Completed	O'Driscoll *et al.* 2003
ECO	MOF2000-02A	Future research requirements for the Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) fishery.	To reccomend future research requirements for the Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) fishery.	Completed	Hanchet 2000

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ECO	ENV99-03	Identification of areas of habitat of particular significance for fisheries management within the NZ EEZ.	1. To determine areas of habitat of importance to fisheries management within the New Zealand EEZ for selected fish species in selected areas	Completed	Hurst *et al.* 2000
ECO	ENV99-04	A framework for evaluating spatial closures as a fisheries management tool	To design a framework for evaluating spatial closures as a fisheries management tool	Completed	Bentley *et al.* 2004
ECO	No project number	The fishery for freshwater eels (*Anguilla spp*.) in New Zealand	To review the fishery for freshwater eels (*Anguilla spp*.) in New Zealand	Completed	Jellyman 1994
ZBD	DAE2015-05	Taxonomic ID of benthic samples	To identify benthic invertebrates in samples taken during research trawls and by observers on fishing vessels.	Ongoing	
ZBD	ZBD2014-01	Live corals: Age and growth study of deepsea coral in aquaria.	Ocean acidification and temperature manipulation are now underway to look at the physiological responses (e.g., growth) of deepsea corals to future predicted environmental conditions.	Experimental work completed	

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ZBD	ZBD2014-03	Sublethal effects of environment change on fish populations	Co-funded by MBIE, this project explores the effects of ocean acidification on the behaviour of young snapper with a view to scaling up these effects to model long-term effects on the snapper population.	Ongoing analysis - in first year of programme	
ZBD	ZBD2014-04	Isoscapes for Trophic and Animal Studies	1. To generate a new tool for fisheries management and conservation. Specifically, to produce a validated, modelled, south-west Pacific and Southern Ocean carbon and nitrogen isotopic map, referred to as an "isoscape", which will improve our understanding of trophic interactions and its relationship with marine animals.	Underway - in first year of programme	
ZBD	ZBD2014-05	Modelling the effects of ocean acidification.	1. Determine how much the aragonite and calcite saturation horizons (ASH and CSH) have changed over the industrial era for the southwest Pacific, including New Zealand's EEZ.	Almost complete - a one year programme	
ZBD	ZBD2014-06	Macroalgae mapping and potential as national scale indicators	Many countries use seaweeds to monitor the state of the marine environment, however this approach has not been explored in New Zealand. In this project, seaweeds will be selected according to their mapped distribution and availability, and assessed for their indicator potential	Underway - in first year of programme	
ZBD	ZBD2014-07	Southern coralline algae shellfish habitat	Coralline algae are a structurally important component of coastal habitats, and play an important role in ecosystem processes. They produce chemicals which promote the settlement of the larvae of certain herbivorous invertebrates, particularly paua. Coralline algae appear to enhance larval metamorphosis and the survival of larvae through the critical settlement period. The first objective is to document	Underway - in first year of programme	

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			critical baseline information on the diversity of coralline algae in southern New Zealand using morphological and molecular identification		
ZBD	ZBD2014-09	Climate change risks and opportunities	Objective 1. To prepare a technical report that explains the most up to date issues and hypotheses with regard to observed and predicted changes to the physical, chemical and biological properties of New Zealand coastal and offshore waters. Objective 2. To prepare a synthesis of the Technical Report that will be informative and provide guidance on what can be done, for stakeholders, policymakers and resource managers.	Underway - in first year of programme	
ZBD	ZBD2014-10	BPA Biodiversity	Obj 1. To update the inventory of benthic samples and biodiversity data available within BPA and Seamount Closure areas Obj 2. To process and identify undescribed samples and material in selected BPAs and for selected taxonomic groups Obj 3. To identify gaps in sample coverage, evaluate priority areas and design a sampling programme to collect appropriate data Obj 4 To undertake an objective spatial management planning exercise to assess the effectiveness of the current BPAs to protect biodiversity	Underway - In first year of programme	
ZBD	ZBD2013-02	VME Genetic Connectivity	This project addresses the critical lack of data concerning deep sea genetic connectivity of VME indicator taxa, and will clarify the spatial relationships and distribution of biodiversity of several protected invertebrate VME species within New Zealand's EEZ and beyond.	Ongoing	Rowden *et al.* 2015

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ZBD	ZBD2013-03	Continuous Plankton Recorder - Phase 2	The overall objective of the CPR programme is to map changes in the quantitative distribution of epipelagic plankton, including phytoplankton, zooplankton and euphausiid (krill) life stages, in New Zealand's EEZ and transit to the Ross Sea, Antarctica. To enable trend analysis, the Contractor will continue the annual time series for a further 5 year period (years 6-10).	Ongoing analysis	
ZBD	ZBD2013-04	NZ-Ross sea connectivity Humpback whales	1. To determine the migration path and Antarctic feeding grounds for New Zealand humpback whales.	Ongoing analysis	
ZBD	ZBD2013-06	Shell generation and maintenance of aquaculture species	Shells of individuals of NZ paua, flat oysters and cockles will undergo detailed analysis to determine how the decreased pH/increased temperature modified their shell (i) thickness, (ii) mineralogy and (iii) construction.	Underway	
ZBD	ZBD2013-07	Interactive keys for easy identification keys of amphipods	Generate interactive identification keys for marine Amphipoda families Synopiidae and Epimeriidae for easy and free use online.	Underway	
ZBD	ZBD2012-01	Tier 1 Stat. Marine Biodiversity	To perform a preliminary investigation of the utility and feasibility of developing the variables published by Costello et al (2010) as a Tier 1 statistic.	Completed	Lundquist *et al.* 2015 Approved for publication

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ZBD	ZBD2012-03	Chatham Rise Benthos - Ocean Survey	1. In relation to the Fishing Intensity Effects Survey, determine whether there are quantifiable effects of variations in seabed trawling intensity on benthic communities. 2. In relation to the Crest Survey, conduct seabed mapping and photographic surveys in previously un-sampled areas on the central crest of the Chatham Rise.	Annual analysis Completed	Pinkerton *et al* Submitted 2015.
ZBD	SRP2011-02	IDG 2009-01 MPI fish ID field guide	1. IDG 2009-01 field guide	Completed	McMillan 2011 a,b,c
ZBD	ZBD2011-01	Evaluation of ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in NZ waters	Evaluation of ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in NZ waters	Completed	Horn *et al.* 2013, McGregor and Horn 2015.
ZBD	ZBD2010-39	Improved benthic invertebrate species identification in trawl fisheries	1. To revise and update the document "A guide to common deepsea invertebrates in New Zealand waters (second edition)" to allow a third edition of this guide to be printed	Completed	Tracey *et al.* 2011a
ZBD	ZBD2010-40	Predictive modelling of the distribution of	1. To develop & test spatial habitat modelling approaches for predicting distribution patterns of vulnerable marine ecosystems in the convention Area of the South Pacific Regional Fisheries Management Organisation	Completed	Rowden *et al* 2013b

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		vulnerable marine ecosystems in the South Pacific Ocean region.	with agreed international partners. 2. To collate datasets and evaluate modelling approaches which are likely to be useful to predict the distribtuion of vulnerable marine ecosystmes in the South pacific Ocean region.		
ZBD	ZBD2010-41	Ocean acidification in fisheries habitat	1. To assess the risks of ocean acidification to deep sea corals and deepwater fishery habitat 2. To determine the carbonate mineralogy of selected deep sea corals found in the New Zealand region 3. To assess the distribution of deep sea coral species in the New Zealand region relative to improved knowledge of current and predicted aragonite and calcite saturation horizons, assessment of potential locations vulnerable to deep water upwelling 4. Through a literature search and analysis, determine the most appropriate tools to age and measure the effects of ocean acidification on deep sea habitat-forming corals, and recommend the best approach for future assessments of the direct effects	Completed	Tracey *et al.* 2011b
ZBD	ZBD2009-25	Predicting impacts of increasing rates of disturbance on functional diversity in marine benthic ecosystems	1. Further develop the landscape ecological model of disturbance/recovery dynamics in marine benthic communities, incorporating habitat connectivity, based on existing model by Lundquist, Thrush, and Hewitt. 2. Predict impacts of increasing rates of disturbance on rare species abundance, functional diversity, relative importance of biogenic habitat structure, and ecosystem productivity. 3. Use literature and expert knowledge to quantify rare species abundance, biomass, functional diversity, habitat structure, and productivity of various successional community types in the model. 4.Field test predictions of the model in appropriate marine benthic communities where historical rates of disturbance are known, and benthic communities have been sampled.	Completed	Lundquist *et al.* 2010; 2013

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ZBD	IPA2009-14	Bryozoan identificaiton guides	1. For each of ~50 species of common bryozoans, provide photos and text to allow for identification. Provide information on distribution and habitat (as far as is known) and further references for each species and on bryozoans as a whole. 2. Submit these data for publication in the Ministry of Fisheries series New Zealand Aquatic Environment and Biodiversity Research.	Completed	Smith & Gordon 2011
ZBD	ZBD2009-03	To evaluate the vulnerability of New Zealand rhodolith species to environmental stressors and to characterise diversity of rhodolith beds.	1. To characterise the distribution and physical characteristics of two New Zealand rhodolith beds and characterise the associated biodiversity. 2. To measure the growth rates and evaluate the vulnerability of New Zealand species of rhodoliths to environmental stressors.	Completed	Nelson *et al.* 2012
ZBD	ZBD2009-10	Multi-species analysis of coastal marine connectivity	1. Determine overall patterns of regional connectivity in a broad range of NZ coastal marine organisms to define the geographic units of genetic diversity for protection and the dispersal processes that maintain this diversity. 2. Review previous studies of marine connectivity and population genetics in NZ coastal organisms to determine the preliminary range of patterns observed and the principal gaps (taxonomic geographic and ecological) in our understanding. 3. In a range of invertebrate and vertebrate marine organisms determine geographic patterns of genetic variation using standardised sampling and molecular techniques. 4. Analyse data across past and present studies to reveal both common	Completed	Gardner *et al.* 2010

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			and unique patterns of connectivity around the NZ coastline and the locations of common barriers to dispersal.		
ZBD	ZBD2009-13	Ocean acidification impact on key nzNZ molluscs	1. Controlled laboratory experiments will be used to determine the effect of pCO2 levels that are predicted to occur in NZ waters over the next few decades on appropriate life history stages of at least two key NZ mollusc species. A number of response variables will be assessed. 2. Implications of these responses to the local and broader ecosystems will be assessed.	Completed	Cummings 2011; Cummings *et al.* 2011b; Cummings *et al* Submitted
ZBD	ZBD2008-01	Biogenic large–habitat–former hotspots in the near-shore coastal zone (50–250 m); quantifying their location, identity, function, threats and protection	1. To collect and integrate existing knowledge on biogenic habitat-formers in the <5–150 m depth zone of New Zealand's continental shelf, from sources including structured fisher interviews, primary and grey literature, and other sources as available. 2. Using the findings of Objective 1, design and deploy a series of sampling voyages to selected locations, to map and characterise locations of significant biogenic structure (either still existing, or historical), and collect relevant biological samples (both through visual census, and physical collection). 3. Process and analyse the samples collected in Objective 2, to provide a hierarchical, quantitative description of the biogenic habitats and associated species encountered. 4. Using the findings from Objective 1–3, assess the present status, likely extent, ecological role, and threats to, biogenic habitat formers in the <5–150 m depth zone. This should include a spatial modelling and risk assessment framework. Integrate (as appropriate) with other information sources and/or approaches that may exist by the year 2010/11.	Analysis completed	Jones *et al.* submitted
ZBD	ZBD2008-05	Macroalgal diversity associated with	1. Conduct a targeted collection programme across diverse soft sediment environments to develop a permanent reference collection of representative macroalgae.	Completed	Neill *et al.* 2012

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		soft sediment habitats	2. Examine algal distribution in soft sediment habitats in relation to selected environmental variables. 3. Prepare an annotated checklist of macroalgae found in soft sediment environments in the New Zealand region.		
ZBD	ZBD2008-07	Carbonate sediments: the positive and negative effects of land-coast interactions on functional diversity	1. To quantify shifts in community structure and functional diversity in mollusc dominated habitats along gradients associated with an estuary-coast interface in two locations. 2. To characterise the influence of estuary-derived food sources across these gradients for key species. 3. To measure changes in growth of key species in relation to changes in food supply and land-derived sediment impacts. 4. To quantify carbon and nitrogen uptake and tissue turnover rates of key species in laboratory experiments.	Completed	Thrush *et al.* In Press; Savage *et al.* 2012
ZBD	ZBD2008-11	Predicting changes in plankton biodiversity and productivity of the EEZ in response to climate change induced ocean acidification	1. To document the spatial and inter-annual variability of coccolithophore abundance and biomass- and assess in terms of the phytoplankton abundance- biomass and community composition in sub-tropical and sub-Antarctic water. 2. To document the seasonal and inter-annual variability of foraminifera and pteropod abundance and biomass at fixed locations in sub-tropical and sub-Antarctic water by analysis of sediment trap material from time-series data collection. 3. To document the spatial and seasonal distribution of the key coccolithophore species- *Emiliana huxleyi*- using both archived and ongoing ingestion of satellite images of Ocean Colour- and ground-truth the reflectance. 4. To determine the sensitivity of- and response of *E. huxleyi* and other EEZ coccolithophores to pH under a range of realistic atmospheric CO2 concentrations in perturbation experiments- using monocultures and mixed populations from in situ sampling.	Ongoing analysis	Law *et al.* 2012: Boyd & Law 2011

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			5. To document the spatial variability of diazotrophs (nitrogen-fixing organisms) and associated nitrogen fixation rate- and assess in terms of phytoplankton abundance- biomass and community composition in sub-tropical waters north of the STF. 7. To determine the sensitivity of- and response of *Trichodesmium* spp. and other diazotrophs to pH under a range of realistic atmospheric CO2 concentrations in perturbation experiments using monocultures		
ZBD	ZBD2008-14	What and where should we monitor to detect long-term marine biodiversity and environmental changes-remote sensing, biota, context, inshore offshore workshop	1. Identify the key questions to be addressed by long-term monitoring of marine biodiversity and environment. 2. Identify appropriate monitoring indices, how they should be spatially distributed and their sampling frequency. 3. Identify relevant existing monitoring programmes across the range of New Zealand agencies and science providers and identify gaps. 4. Provide those agencies setting environmental goals/ standards or research needs (MoRST, FRST, MFish, DoC, MfE, Commissioner for the Environment) with a thorough situational analysis, including a list of priority monitoring projects/plans.	Ongoing analysis	Livingston 2009
ZBD	ZBD2008-15	Continuous plankton recorder project: implementation and identification	1. To set up a time series of annual CPR data collection by deployment from a toothfish vessel on the annual summer transit between New Zealand and the Ross Sea. 2. To identify phytoplankton and zooplankton according to strict observation protocols determined by the SAHFOS[1] CPR Survey and SO-CPR[2]. 3. To enter species data, frequency and location along the transect into a spreadsheet that will allow spatial mapping of the plankton density and distribution. 4. To analyse the full dataset after 5 years of data collection to: (a) determine trends in the dataset and (b) compare results with Australian	Completed	Robinson *et al.* 2014

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			datasets available through SO-CPR. 5. To evaluate the continuation of the programme		
ZBD	ZBD2008-20	Ross sea benthic ecosystem function: predicting consequences of shifts in food supply	1. To increase understanding of Ross Sea coastal benthic ecosystem function 2. Conduct in situ investigations into responses to and utilisation of primary food sources by key species, at two contrasting coastal Ross Sea locations	Completed	Cummings & Lohrer 2011; Cummings *et al.* 2011a; Lohrer *et al.* 2012
ZBD	ZBD2008-22	Acidification and ecosystem impacts in NZ and southern ocean waters (data collected during IPY).	1. To assess the response of cocolithophorids, and their replacement by non-calcifying organisms during incubation under a range of dissolved CO2 concentrations. 2. To describe and characterise changes in abundance and biodiversity of microbial components of the samples incubated at sea under a range of dissolved CO2 concentrations. 3.To predict the likely impacts of higher acidity on foodwebs and on carbon fixation under scenarios to be encountered in the Southern Ocean under forecasted trends associated with climate change.	Completed	Maas *et al.* 2010b
ZBD	ZBD2008-23	Macroalgae diversty and benthic community structure at the Balleny Islands	1. To describe and characterise macroalgae diversity from the Balleny Islands and the Western Ross Sea. 2. To describe and quantify benthic community structure from one location at the Balleny Islands 3. To complete anatomical and morphological investigations & molecular sequencing required for the identification of macroalgae samples from the Balleny Islands & western Ross Sea coastline to describe & characterise macroalgae diversity in Balleny Isds 4. To process and analyse samples collected at the Balleny Islands- to analyse them using ICECUBE methodology- and compare results with	Completed	Nelson *et al.* 2010

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			those from other ICECUBE sampling locations along the Ross Sea coastline		
ZBD	ZBD2008-27	Scoping investigation into New Zealand abyss and trench biodiversity	1. Review what is already known of abyssal, canyon and trench faunas in NZ. 2. Review what is already known of abyssal, canyon and trench faunas around the world. 3. Prioritise science questions and locations for exploration. 4. Assess NZ capacity to sample at the required depths; identify sampling equipment needs. 5. Design a suitable vessel-based sampling programme	Completed	Lörz *et al.* 2012
ZBD	ZBD2008-50	OS2020 Chatham Rise Biodiversity Hotspots	1. To improve understanding of the effects of trawl fishing in New Zealand on the biodiversity of seamounts- knolls and hills. 2. To describe differences in benthic biodiversity between northwestern and eastern regions of the Chatham Rise 3. To continue the time series of observations in the NW Chatham Rise to demonstrate recovery in terms of biodiversity 4. To extend the observations on fished-unfished contrasts and recovery of fauna on protected seamounts to an oceanographically distinct location	Completed	Clark *et al.* 2009
ZBD	IPY2007-01	International polar year census of antarctic marine life post-voyage analysis: Ross Sea - Southern Ocean Biodiversity	1. To measure seabed depth and rugosity using the multibeam system to identify topographic features such as bottom type, iceberg scouring, seamounts etc and to determine areas for targeted benthic faunal sampling. 2. To continue the analysis of opportunistic seabird and marine mammal distribution observations from this and previous BioRoss voyages and published records, and in relation to environmental variables. 3. To identify and determine near-surface spatial distribution, diversity and abundance of phytoplankton, and zooplankton, based on Continuous	Completed	Allcock *et al*. 2009; 2010; Submitted; Alvaro *et al.* 2011; Baird *et al.* 2014; Bowden *et al.* 2011a; In Prep; Clark *et al*. 2010a; Dettai et al. 2011;

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			Plankton Recorder samples collected during transit to and from the Ross Sea. 4. To collect & analyse data collected both underway, & at stations for salinity, temperature nutrient and chlorophyll a data, spot optical measurements with the SeaWiFS. 5. To identify and determine the spatial distribution, abundance (biomass), diversity, and size structure of epipelagic, mesopelagic (and possibly bathypelagic) species using acoustics and net sampling. 6. To identify and measure diversity, distribution & densities of mesozooplankton, macrozooplankton & meroplankton (as collected by all plankton sampling methods except transit CPR samples). 7. To determine diversity, distribution & densities of viral, bacterial, phytoplankton & microzooplankton species in the water column. 8. To determine the spatial distribution, abundance (biomass), diversity, and size structure of shelf and slope demersal fish species and associated invertebrate species using a demersal survey. 9. To determine the diversity, abundance/density, spatial distribution, and physical habitat associations of benthic assemblages across a body size spectrum from megafauna to bacteria, for shelf, slope, seamounts, and abyssal sites in Ross Sea. 10. To describe trophic/ecosystem relationships in the Ross Sea ecosystem (pelagic and benthic, fish and invertebrates). 11. Assess molecular taxonomy and population genetics of selected Antarctic fauna and flora to estimate evolutionary divergence within and among ocean basins in circumpolar species. Provide DNA barcoding.		Eakin *et al*. 2009; Eleaume *et al*. 2011; In Prep; Ghiglione *et al.* 2012; Gordon 2000; Grotti *et al.* 2008; Hanchet *et al*. 2008a; 2008b; 2008c; 2008d; Hanchet 2009; 2010; Hanchet *et al.* 2013; Heimeier *et al.* 2010; Hemery *et al*. In prep; Koubbi *et al*. 2011; Leduc *et al.* 2012a; b; c; 2013; 2014*;* Linse *et al.* 2007; Lörz 2009; Lörz 2010a; 2010b; 2010c; Lörz & Coleman 2009; Lörz *et al*. 2007; 2009; 2012a; b;c ; In Prep; Maas *et al*. 2010a; McMillan *et al.* 2012.; Mitchell 2008; Nielsen *et al.* 2009*;* Norkko *et al.* 2005*;* O'Driscoll 2009;

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					O'Driscoll *et al.* 2009; 2010; O'Driscoll *et al*. 2012; O'Loughlin *et al.* 2011; Pakhomov *et al*. 2011; Pinkerton *et al*. 2007a; Pinkerton *et al*. 2009b; 2010; Pinkerton *et al*. 2010; 2013; Schiaparelli *et al*. 2006; 2008; 2010; Smith *et al*. 2011a; b; Stein 2012; Strugnell *et al.* 2012
ZBD	IPY2007-02	International polar year census of antarctic marine life post-voyage analysis:Ross Sea - Southern Ocean Biodiversity	1. To measure and describe key elements of species distribution- abundance (density or biomass) & biodiversity for the Ross Sea and Southern Ocean for main habitats and key functional ecosystem roles- for major groups- viruses- bacteria- archaea. 2. To report on the diversity of Antarctic Cephalopoda (Octopus and Squid)- including a complete inventory of taxa- & reports on ontogenetic & sexual variation in species- their systematics- diversity- distribution- life histories- & trophic importance. 3. To Beak/Biomass Regression Equations 4. Life cycle determination	Completed	Garcia 2010

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ZBD	ZBD2007-01	Chatham-Challenger Oceans 20/20 Post-Voyage	1. To quantify in an ecological manner- the biological composition and function of the seabed at varying scales of resolution- on the Chatham Rise and Challenger Plateau 2. To elucidate the relative importance of environmental drivers- including fishing- in determining sea bed community composition and structure. 3. To determine if remote-sensed data (e.g. acoustic) and environmentally derived classification schemes (e.g. marine environmental classification system) can be utilized to predict bottom community composition- function and diversity 4. To count- measure- and identify to species-level (where possible- otherwise to genus) all macro invertebrates (> 2 mm) and fish collected during Oceans 20/20 voyages. 5. To count- measure and identify to species-level (where possible- otherwise to genus or family) all meiofauna (> 2 mm) from multicore samples collected during the Oceans 20/20 voyages. 6. To count- measure and identify to species- level (where possible- otherwise to genus or family) all fauna collected by hyper-benthic sled during the Oceans 20/20 voyages. 7. To count- measure- and identify to species-level all macrofauna observed on DTIS images collected during the Oceans 20/20 voyages. The number of biogenic features (burrows/mounds) and habitat (spatial) complexity should also be estimated. 8. To count- measure- and identify to species-level (where possible- otherwise to genus or family) all macrofauna observed on DTIS video footage collected during the Oceans 20/20 voyages. 9. To calculate and compare the performance of a suite of diversity measures (species and taxonomic-based) at varying levels of resolution. 10. To estimate particle size composition and organic content of sediment samples. Sediment samples should be aggregated over the top 5 cm of sediment. 11. To measure the bacterial biomass (top 2 cm) of the sediment and in	Completed	Bowden 2011; Bowden *et al.* 2011b ; 2014; Bowden & Hewitt 2012; Compton *et al.* 2012; Coleman and Lörz 2010; Hewitt *et al.* 2011a; 2011b; Lörz 2011a; 2011b; Nodder *et al.* 2012; Floerl et al. 2012a; b

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			the sediment surface water samples- collected during the Oceans 20/20 voyages 12. To elucidate the relationships- patterns and contrasts in species composition- assemblages- habitats- biodiversity and biomass (abundance) both within and between stations- strata and areas. 13. To define habitats (biotic) encountered during the survey and assess their relative sensitivity to modification by physical disturbance- their recoverability and their importance to ecosystem function / production. 14. To quantify the productivity- energy flow (trophic networks) and the energetic coupling (bentho pelagic or otherwise) of the area surveyed areas at various levels of resolution. 15. To assess the extent to which patterns of species distributions and communities can be predicted using environmental data (including fishing) collected during the Ocean 20/20 voyages or held in other databases. 16. To provide an interactive- high resolution mapping facility for displaying & plotting all data collected & derived indices. Includes environmental data- the abundance of species- indices of biomass or diversity- and statistically derived groupings 17. To assess the extent to which acoustic- environmental- or other remote-sensed data can provide cost-effective- reliable means of assessing biodiversity at the scale of the Oceans 20/20 surveys. 18. To assess the extent to which the 2005 MEC and subsequent variants can provide cost-effective- reliable means of assessing biodiversity at the scale of the Oceans 20/20 surveys. 19. Collating all information and analysis from all objectives- devise a series of statistically supported recommendations for surveying marine biodiversity in the future. Including- but may not be limited to- statistical analyses and modelling.		

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ZBD	ZBD2006-02	Ongoing NABIS development	As part of NABIS, users will be able to identify spatial information relating to the annual distribution (average distribution over the period of a year) of particular species within the waters around New Zealand and in the terrestrial environment (including off shore islands) of New Zealand. Users will also be able to interrogate metadata and attribute data related to the information layers presented. Users will employ NABIS to identify where a particular species is found, to identify what species are found within an area of interest, and be able to compare the spatial distribution of a particular species with other information layers. 2. Some species may have notable changes in their spatial distribution throughout a year. For such species, users of NABIS will be able to view spatial information relating to the seasonal distribution of particular species within the waters around New Zealand and in the terrestrial environment (including offshore islands) of New Zealand. Users will also be able to interrogate metadata and attribute data related to the information layers presented. For species with a seasonal component to their biological distribution, users will employ NABIS to identify where a particular species is found within the waters around New Zealand and in the terrestrial environment (including off shore islands) of New Zealand at a particular time of the year, to identify what species are found within an area of interest at a particular time of year, or be able to compare the distribution of a particular species at a particular time of year, with other information layers. 3. To provide analysis of the data used in determining the hotspot distribution.	Completed	Anderson 2007b
ZBD	ZBD2006-03	Antarctic coastal marine systems	1. Quantify patterns in benthic community structure and function at two coastal Ross Sea locations (Terra Nova Bay and Cape Evans). 2. Quantify benthic community structure and function at selected locations in Terra Nova Bay and Cape Evans.	Completed	Cummings *et al.* 2003; 2006b; 2008; Thrush &

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					Cummings 2011; Thrush *et al.* 2010
ZBD	ZBD2006-04	Chatham/challenger oceans 20/20	1. To collect seabed fauna, sediment samples and photographic images along transects in the Chatham Rise and the Challenger Plateau, as determined by the sampling protocol described in the Voyage Programmes for Voyages 2 and 3 of the project. Multibeam data should be collected opportunistically as time allows. 2. To describe the distribution of broad macro epifauna groups (I.D. level to be determined at sea during Surveys 2 & 3), their relative abundance, the substrate and habitat types, including representative photographic images of each sea-bed habitat and associated fauna along transects in the survey areas. 3. To provide a description of the observed evidence of fishing along transects. 4. To provide indicative measures of alpha biodiversity (richness, number of taxonomic groups) at appropriate scales within and between transects, and between the Chatham Rise and the Challenger Plateau. 5. To determine broad scale variability in sea-bed habitats and associated biodiversity within and between MEC classes at 20 class level. 6. To process and archive biological samples and data into databases and collections for future analysis in meeting the Overall Objectives above.	Completed	Nodder 2008; Nodder *et al.* 2011
ZBD	ZBD2005-01	Balleny Islands Ecology Research, Tiama Voyage (2006)	1. To characterise shallow benthic communities across a range of habitat settings around the Balleny Islands, utilising a range of data collection methodologies (including SCUBA-based rock-wall suspension feeder photo quadrats, SCUBA-based linear video transects, and drop camera photography), and to analyse community patterns with reference to possible physical/oceanographic, biological, and/or biogeographic influences on community structure. 2. To characterise aspects of the marine food web of the Balleny Islands	Terminated	Smith 2006

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			area, using stable isotope analysis of specimens from important functional groups, and to make inferences about factors affecting ecosystem-scale trophodynamics in the Balleny Islands area and potential implications for the function of the wider ecosystem. 3. To characterise the spatial and temporal distributions of higher-level consumer species (birds, seals and whales) and of dominant pelagic prey (i.e. krill swarms) by opportunistically recording all at-sea sightings, and by systematic observation of landbased top predators (birds and seals) while sailing along the coast of the islands. 4. To collect and photograph and/or retain fish specimens from shallow benthic environments using a range of fishing methods, including food-baited fish traps, lightbaited fish traps, rotenone sampling, and/or baited lines. 5. To continuously collect bathymetric data and water-column acoustic data (i.e. mesopelagic acoustic marks) throughout the voyage, using an acoustic sounder. 6. To opportunistically collect a variety of data/materials during shore-based landings, including wherever possible: i) breast feathers from living penguins; ii) tissue samples/feathers/bones from dead seals/penguins/other sea birds; iii) seal scats; iv) visual estimates of adult and juvenile penguin numbers; v) visual assessments of penguin colony status; vi) photographs of penguin colonies; vii) sediment excavations of occupied and abandoned colonies. (Where appropriate these data will contribute to Objective 2).		
ZBD	ZBD2005-02	Marine Environment Classification Project	1. Co-fund the Marine Environment Classification Project (being done by NIWA) with the Department of Conservation.	Completed	Snelder *et al.* 2005; 2006; Leathwick *et al.* 2006a; b; c

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ZBD	ZBD2005-03	Tangaroa ross seaRoss Sea voyage	1. To test the feasibility of obtaining estimates of demersal fish relative abundance using cameras with and without flood lights in areas of high importance for the Ross Sea toothfish fishery (principally 800-1200 m). 2. To utilise deepwater camera transects, supported by other direct sampling methods, to characterise the relative abundance, distribution, and diversity of demersal fish species (assuming Objective 1 yields satisfactory results) and of benthic macro-invertebrates, and to examine relationships between demersal fishes and benthic habitats/communities. Camera transects will be deployed opportunistically, with focus on the following high-priority areas (in order of high to low priority) wherever possible: i) Areas of the continental shelf break at depths of high importance for the toothfish fishery (principally 800-1200 m but also 600-800m & 1200-1500 m if time permits), ii) Shallow (50-200 m) water in the immediate vicinity of the Balleny Islands; iii) Deeper water in the vicinity of the Balleny Islands; iv) seamounts around and between Scott Island and the Balleny Islands; and v) at other locations (< 600 m) as opportunity arises (e.g. around Scott Island, western Ross Sea, south-eastern Ross Sea). 3. To collect specimens/tissues of selected benthic and pelagic organisms with priority in the vicinity of the Balleny Islands (and to the east/southeast, for pelagic specimens especially Antarctic krill species) and deliver specimens to other projects for stable isotope analysis in order to contribute to understanding of trophic relationships. 4. To acquire a continuous acoustic survey of the water column, opportunistically undertake species verification of acoustic marks, integrate the acoustic marks and produce a GIS map of verified and unverified distributions of functionally important mesopelagic species (e.g. krill, Antarctic silverfish). 5. To undertake routine identification and abundance estimates of marine mammal and seabird species and deliver raw and GIS summarised	In the process of publication	MacDiarmid & Stewart 2015; Mitchell & MacDiarmid 2006

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			data to other related projects in order to generate spatially and temporally explicit population biomass and foraging distribution estimates for top air-breathing predators in the Ross Sea. 6. To undertake automated water sampling in order to monitor the identities and spatial and temporal distributions of plankton in the Ross Sea region and to allow ground-truthing of data collection from satellites (e.g. surface seawater temperature, and chlorophyll-a concentration).		
ZBD	ZBD2005-05	Long-term effects of climate variation and human impacts on the structure and functioning of New Zealand shelf ecosystems	1. To estimate changes in marine productivity via fluctuations in ocean climate and terrestrial nutrient input over the last 1000 years. 2. To assess and collate existing archaeological, historical and contemporary data (including catch records and stock assessments) on relevant components of the marine ecosystem to provide a detailed description of change in the shelf marine ecosystem in two areas of contrasting human occupation over last 1000 years. 3. To collect additional oral histories from Maori and non-Maori fishers and shellfish gathers regarding the distribution, sizes and relative abundance (compared to present availability) of key fish and invertebrate stocks in both regions during the first half of the 20th century before the start of widespread modern industrial fishing. 4. To build mass-balance ecosystem models (e.g. Ecopath) of the coastal and shelf ecosystem in each area for five critical time periods: now, 60 years BP (before modern industrial fishing), 250 years BP (before European whaling and sealing), 600 y BP (early Maori phase) and 1000 years BP (before human settlement). 5. To use qualitative modelling techniques to determine the critical interactions amongst species and other ecosystem components in order to identify those that should be a priority for future research.	In the process of publication	Carroll *et al.* Submitted; Jackson *et al.* Submitted; Lalas *et al.* In Press, 2014; Lalas & MacDiarmid 2014; Lorrey *et al.* 2013; MacDiarmid *et al.* Submitted a; b c; d; Maxwell & MacDiarmid Submitted; McKenzie & MacDiarmid Submitted; Neil et al. In Press; Paul 2012; 2014; Parsons *et al.* In Press; Pinkerton *et al.* 2015b; Smith 2011

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ZBD	ZBD2005-09	Rocky reef ecosystems - how do they function? Integrating the roles of primary and secondary production, biodiversity and connectivity across coastal habitats	1. To develop a qualitative numerical model of how New Zealand's rocky reef systems are functionally structured 2. To quantify the effects of human predation, and environmental degradation across reef gradients – top-down, or bottom-up functioning? 3. To advance our understanding of how subtidal reef systems are fuelled through primary and secondary production (from a range of sources), the role that biodiversity plays, and how this varies across different reef settings. 4. To quantify how subtidal reef systems are linked with other habitats and ecosystems at broader spatial scales, including the connectivity of MPAs with other habitats and areas.	In the process of publication	MacDiarmid *et al.* Submitted e
ZBD	ZBD2004-01	Baseline information on the diversity and function of marine ecosystems	1. To quantify, and compare, the macro-invertebrate assemblage composition of a number of seamounts at the southernmost end of the Kermadec volcanic arc. 2. To compare the macro-invertebrate diversity of the southernmost end of the Kermadec volcanic arc with that of seamounts already sampled and reported on.	Completed	Rowden & Clark 2010; Smith *et al.* 2008
ZBD	ZBD2004-02	Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the chatham rise	1. To quantitatively characterise the diets of abundant middle-depth fish species on the Chatham Rise, by analysis of fish stomach contents collected from the January 2005, January 2006 and January 2007 Chatham Rise middle-depths trawl surveys. 2. To quantitatively characterise Chatham Rise fish diets throughout the year, for a period of 24 months, by analysis of fish stomach contents collected opportunistically aboard industry vessels. 3. To describe and examine patterns of diet variation within each fish species as a function of spatial, temporal, and environmental variables, and of fish size. 4. To define and characterise trophic guilds for abundant fish species on the Chatham Rise, using multivariate analysis of fish diet data, and to	Completed	Connell *et al.* 2010; Dunn 2009; Dunn *et al.* 2010a; b; c; Dunn *et al.* In press; Forman & Dunn 2010; Horn *et al.* 2010; Stevens & Dunn 2011;

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			analyse the nature and relative strength of potential trophic interactions between guilds. 5. To create and populate a diets database to store all of the dietary information collected under Objectives 1 and 2, and for use in subsequent dietary studies.		
ZBD	ZBD2004-05	Assessment and definition of the biodiversity of coralline algae of northern New Zealand	1. To assess and define the biodiversity of coralline algae in northern New Zealand. 2. To develop rapid identification tools for coralline algae using molecular sequencing data. 3. To contribute representative material to the national Coralline Algal Collections. 4. To produce ID guides to common coralline algae of northern New Zealand.	Completed	Farr et al. 2009
ZBD	ZBD2004-08	Sea-grass meadows as biodiversity and connectivity hotspots	1.Quantify the biodiversity values and functioning of New Zealand sea-grass assemblages 2.Complete national bio-geographic assessment of sea-grass associated biodiversity 3.Quantify sea-grass connectivity with surrounding marine landscapes through nursery functions and detritus export 4.Quantify sea-grass replication connectivity mechanisms 5.Develop a risk assessment and appraisal model for sea-grass systems	Ongoing analysis	Morrison *et al.* 2014 c
ZBD	ZBD2004-10	Development of bioindicators in coastal ecosystems	1. Investigate linkages between land use patterns in catchments and nitrogen loading to recipient estuaries and coastal ecosystems 2. Characterise isotopic signatures of selected bioindicator organisms in relation to different terrestrial nutrient loads; and	Completed	Savage 2009

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			3. Validate the use of bioindicators using controlled laboratory and field experiments.		
ZBD	ZBD2004-19	Ecological function and critical trophic linkages in New Zealand soft-sediment habitats	1. Define the interactive effects of two functionally important benthic species in maintaining critical trophic linkages in soft-sediment systems from a series of integrated field experiments. 2. Quantify effects of heart urchins (*Echinocardium australe*) on sediment properties- benthic primary production- and macrofaunal diversity through manipulative field experiments in Mahurangi Harbour. 3. Test for interactions between pinnid bivalves (*Atrina zelandica*) and heart urchins (*Echinocardium australe*) in field experiments- and measure their respective and combined contributions to sediment properties- benthic primary production- and macrofau na 4. Determine the dependence of results from objectives 1 and 2 (functional contributions of *Echinocardium* and *Atrina*) in an environmental context by conducting experiments along an estuarine-coastal gradient.	Completed	Lohrer *et al.* 2010
ZBD	ZBD2003-02	Biodiversity of Coastal Benthic Communities of the North Western Ross Sea.	1. Quantify patterns in biodiversity and community structure in the coastal Ross Sea region 2. Quantify biodiversity in benthic communities at selected locations in the Ross sea north of Terra Nova Bay 3. Describe ecosystem function at selected locations in the Ross Sea north of Terra Nova Bay.	Completed	Cummings *et al.* 2003; 2006a; 2010; De Domenico et al. 2006; Guidetti et al. 2006; Norkko et al. 2004
ZBD	ZBD2003-03	Biodiversity of deepwater invertebrates and fish communities	1. To describe, and quantify the diversity of, the benthic macroinvertebrates and fish assemblages of the Balleny Islands and adjacent seamounts, and to determine the importance of certain environmental variables influencing assemblage composition.	Completed	Rowden *et al.* 2012a; 2013a; Mitchell & Clark 2004

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
		of the north western Ross Sea			
ZBD	ZBD2003-04	Fiordland Biodiversity Research Cruise	1. How can ecotone boundaries be defined? 2. If you have an ecotone boundary defining the edge of a commercial exclusion zone how wide is the transition zone across the boundary? 3. If you have an area delineated as a marine protected area or a commercial exclusion zone, does it adequately represent the different habitats or biodiversity of the whole region?	Completed	Wing 2005
ZBD	ZBD2003-09	Macquarie Ridge Complex Research Review	To review and summarise both biological and physical research carried out on or around the section of the Macquarie Ridge Complex that lies between New Zealand and Macquarie Island	Completed	Grayling 2004
ZBD	ZBD2002-01	Ecology of Coastal Benthic Communities in Antarctica	To research the ecology of coastal benthic Communities in Antarctica	Completed	Schwarz *et al.* 2003; 2005; Thrush *et al.* 2006; Thrush & Cummings 2011; Cummings *et al.* 2003; Sharp *et al.* 2010; Sutherland 2008
ZBD	ZBD2002-02	Whose larvae is that? Molecular identification of planktonic larvae of the Ross Sea.	1. To use molecular sequencing tools in the taxonomic identification of cryptic/invasive marine 2. To provide a molecular description and characterisation of gobies that are introduced (*Arenigobius bifrenatus* and *Acentrogobius pflaumii*) cryptogenic (*Parioglossus marginalis*) or native (eg.*Favonigobius lentiginosus* and *F. expuisitus*).	Completed	Sewell 2005; 2006; Sewell *et al.* 2006

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
			3. To describe the molecular diversity of the above species throughout their native and introduced distributions- and characterise a range of the greatest potential invasive gobioid and blennioid species from the Australasian region. 4. To develop molecular criteria to rapidly identify invasive or cryptogenic gobioid and blennioid fish		
ZBD	ZBD2002-06A	Impacts of terrestrial run-off on the biodiversity of rocky reefs	1. Conduct field and laboratory experiments to determine relationships between sediment loading, epifaunal assemblages, and mortality of filter feeding invertebrates. 2. Conduct field and laboratory experiments to identify the influence of sediment on early life stages of key grazers. 3. Determine photosynthetic characteristics and survival of large brown seaweeds and understorey algal species in relation to a sediment gradient.	Completed	Schwarz *et al.* 2006
ZBD	ZBD2002-12	Molecular identification of cryptogenic/invasive marine species – gobies.	1. To use molecular sequencing tools in the taxonomic identification of cryptic/invasive marine species 2. To provide a molecular description and characterisation of gobies that are introduced (*Arenigobius bifrenatus* and *Acentrogobius pflaumii*) cryptogenic (*Parioglossus marginalis*) or native (eg.*Favonigobius lentiginosus* and *F. expuisitus*). 3. To describe the molecular diversity of the above species throughout their native and introduced distributions- and characterise a range of the greatest potential invasive gobioid and blennioid species from the Australasian region. 4. To develop molecular criteria to rapidly identify invasive or cryptogenic gobioid and blennioid fish.	Completed	Lavery *et al.* 2006

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
ZBD	ZBD2002-16	Joint New Zealand and Australian Norfolk Ridge	1. To describe the marine biodiversity of the Norfolk Ridge and Lord Howe Rise seamount communities. 2. To survey- sample and document the marine biodiversity and environmental data from seamounts on the Norfolk Ridge and Lord Howe Rise to a depth of at least 1-000m depth. (b) To preserve samples of fishes and invertebrates and hold these in ac...	Completed	Clark & Roberts 2008
ZBD	ZBD2002-18	Quantitative survey of the intertidal benthos of Farewell Spit Golden Bay	1. To undertake a baseline survey of intertidal macrobenthic organisms at Farewell Spit Nature Reserve and adjacent flats. 2. To undertake an initial field survey of Zostera distribution at Farewell Spit Nature Reserve and adjacent intertidal flats. 3. To undertake a preliminary survey of sediment characteristics of the intertidal flats at Farewell Spit Nature Reserve and adjacent flats.	Completed	Battley *et al.* 2005
ZBD	ZBD2001-02	Documentation of New Zealand Seaweed	1. To publish a regional algal flora of Fiordland based on voucher herbarium specimens. 2. To assemble a database of references and to review the current state of knowledge about New Zealand macroalgae.	Completed	Nelson et al. 2002
ZBD	ZBD2001-03	Ecology and biodiversity of coastal benthic communities in Antarctica.	1. To develop sampling protocols for estimating the relative abundance of algae and benthic invertebrates 2. To quantify patterns in biodiversity and benthic community structure at two locations in McMurdo Sound 3. To analyse Ross Island Sea-Level data.	Completed	Norkko et al 2002
ZBD	ZBD2001-04	“Deep Sea New Zealand”	To help publish the book "Deep Sea New Zealand"	Completed	Batson 2003

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
ZBD	ZBD2001-05	Crustose coralline algae of New Zealand	1. To assess the biodiversity of crustose coralline algae in NZ using modern taxonomic methods and molecular sequence tools. 2. To establish the NZ National Coralline Algal Collection. 3. To produce identification guides to NZ species.	Completed	Harvey et al. 2005; Farr et al. 2009; Broom et al 2008
ZBD	ZBD2001-06	Biodiversity of New Zealand's soft-sediment communities	1. To review the current knowledge of the biodiversity of macroinvertebrates and macrophytes living in and on soft-sediment substrates in New Zealand"s harbours- estuaries- beaches and to 1000 m water depth. 2. To review existing published and unpublished sources of information on soft-sediment marine assemblages around New Zealand. 3. Using the results of Objective 1- identify gaps in the knowledge- hotspots of biodiversity- areas of particular vulnerability- and make recommendations on areas or assemblages that could be the subject of directed research in future years.	Completed	Rowden *et al.* 2012b
ZBD	ZBD2001-10	Additional Research on Biodiversity of Seamounts	1. To determine the macro-invertebrate assemblage composition on Cavalii seamount, and adjacent seamount W1, by photographic transects and epibenthic sled sampling. 2. To determine the distniution of macro-invertebrate assemblages on the seamounts. 3. To compare the macro-invertebrate species diversity of neighbouring seamounts. 4. To evaluate and collect samples fiom suitable macro-invertebrate species for genetic analysis. 5. To map bathymetry and habitat characteristics of the seamounts. 6. To compare macro-invertebrate assemblage composition of the seamounts with nearby hard bottom low relief (under 100 m) on the slope, if suitable areas can be located.	Completed	Rowden *et. al* 2004

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
ZBD	MOF2000-01	Bryozoan thickets off Otago Peninsula	To research the bryozoan thickets off the Otago Penninsula	Completed	Batson & Probert 2000
ZBD	ZBD2000-01	A review of current knowledge describing the biodiversity of the Ross Sea region	1. To review and document existing published and unpublished information describing the biodiversity of the Ross Sea region. 2. To identify and document Ross Sea region marine communities that are under high pressure or likely to come under high pressure from human activities in the near future.	Completed	Bradford-Grieve & Fenwick 2001a; 2001b; Fenwick & Bradford-Grieve 2002a; 2002b; Bradford-Grieve & Fenwick 2002; Varian 2005
ZBD	ZBD2000-02	Exploration and description of the biodiversity, in particular the benthic macrofauna, of the western Ross Sea	1. To utilise sampling opportunities provided by the presence of RV Tangaroa in the western Ross Sea in February / March 2001 to make collections of (primarily) benthic organisms as a contribution to the understanding of biodiversity in the region. 2. To identify and document the organisms collected and provide for their proper storage in national collections. 3. To describe the logistic constraints of working in the Ross Sea region, and make recommendations for future research to improve understanding of biodiversity in the Ross Sea.	Completed	Page *et al.* 2001
ZBD	ZBD2000-03	The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay	1. To assess the present state and extent of bryozoan communities around Separation Point. 2. To characterise the bryozoan communities around Separation Point.	Completed	Grange *et al.* 2003

Theme	Project Code	Project Title	Specific Objectives	Status	Citation/s
ZBD	ZBD2000-04	Supplementary Research on Biodiversity of Seamounts	1. To determine the biodiversity of seamounts of the southern Kermadec volcanic arc (Rumble V, Rumble 111, Brothers). 2. To describe the distribution of fauna, with an emphasis on mapping the nature and extent, of biodiversity associated with hydrothermal vents. 3. To compare the biodiversity of the three seamounts, and adjacent slope. 4. To collect samples from near the vent sources (if possible, as these are thought to be very localised) to measure chemical and thermal aspects of the environment	Completed	Rowden *et al.* 2002 and 2003; Clark & O'Driscoll 2003
ZBD	ZBD2000-06	"The Living Reef: The Ecology of New Zealand's Rocky Reefs"	1. Funding to support the publication of this book.	Completed	Andrew & Francis (Eds.) 2003
ZBD	ZBD2000-08	A review of current knowledge describing New Zealand's Deepwater Benthic Biodiversity	1. To review and document existing published and unpublished reports and data describing New Zealand's deepwater benthic biodiversity. 2. To make recommendations on representative communities and potentially impacted communities that could be the subject of directed research.	Completed	Key 2002
ZBD	ZBD2000-09	Antarctic fish taxonomy	1. Ross Sea fishes processing and identification	Completed	Roberts & Stewart & 2001

Appendix 17.10: Bycatch trends for seven deepwater trawl fisheries and one longline fishery (1990–91 to 2012–13). Regression slopes for each species/species group and fishery. Slopes indicating a decline in bycatch over time are highlighted in red, and slopes indicating an increase in bycatch over time are highlighted in green. Species/species groups are ordered alphabetically; blank cells = not estimated; LLL = ling longline fishery; HHL = hoki/hake/ling fishery. NB: These linear regression slopes should be considered only a simple indicator of general changes as relationships may be non-linear; some trends may be strongly influenced by changes in observer recording of species over time. The main purpose of the highlighted cells is to draw attention to species for which closer examination of trends may be warranted.

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
ACS		0.01	0.22			0.07		0.18	*Actinostolidae*
ADT			0.02						*Aphrodita spp.*
AER			0.02						*Aeneator recens*
AFO			0.05						*Aristaeomorpha foliacea*
AGR								-0.2	*Agrostichthys parkeri*
AIR									*Argyripnus iridescens*
ALB		0.02			0.14				*Thunnus alalunga*
ALL			0.08						*Alcithoe larochei*
ANC					0.01				*Engraulis australis*
ANT			-0.1			0.04	-0.01	0.1	*Anthozoa*
ANZ		0.02							*Ecionemia novaezelandiae*
API		-0.04	0.03						*Alertichthys blacki*
APR		0.02	0.08			0.03	0.02	0.09	*Apristurus spp.*
ARE			0.02						*Apatopygus recens*
ASR	0.01	0.12	0.08	0.12			-0.02	0.18	-
AST									*Astronesthinae (Subfamily)*
ATT					0.08				*Arripis trutta*
AWI			0.02						*Alcithoe wilsonae*
BAC						-0.03			*Bathygadus cottoides*
BAM			0.05						*Bathyplotes spp.*
BAR		-0.01			0.04			-0.1	*Thyrsites atun*
BAS			-0.2	0.08				0.07	*Polyprion americanus*
BAT		-0.01					-0.01		*Rouleina spp.*
BBE	-0.02	0.04				-0.04	0.04	0.03	*Centriscops humerosus*
BCA		0						-0.1	*Magnisudis prionosa*
BCD		0.24		0.01					*Paranotothenia magellanica*
BCO	-0.03	0.13			-0.1				*Parapercis colias*
BCR									*Brotulotaenia crassa*
BDA									*Sphyraena novaehollandiae*
BEE						-0.08	0.12	0.03	*Diastobranchus capensis*
BEL		0.09	0.03			-0.01		0.15	*Centriscops spp.*
BEN					0.07			0.21	*Benthodesmus spp.*
BER			-0.1					-0	*Typhlonarke spp.*
BES			0.02					0.04	*Benthopecten spp.*
BFI									*Bathophilus filifer*
BFL		0.01							*Rhombosolea retiaria*
BGZ		0.1							*Kathetostoma binigrasella*
BIG		0.01							*Thunnus obesus*
BJA						-0.02			*Mesobius antipodum*
BKM					0.02				*Makaira indica*
BNE					0.01				*Benthodesmus elongatus*
BNS		-0.06	-0.3	-0.1	-0.1	-0.18	0.01	-0.1	*Hyperoglyphe antarctica*
BNT									*Benthodesmus tenuis*
BOA	-0.04		0.04						*Paristiopterus labiosus*

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
BOC		0.01	0.1						*Bolocera spp.*
BOE						-0.19		0.04	*Allocyttus niger*
BOO						0.02			*Keratoisis spp.*
BOT									*Bothidae*
BPE					-0.1				*Caesioperca lepidoptera*
BPI								0.03	*Benthopecten pikei*
BRA		-0.01			-0.1			0.01	*Dasyatis brevicaudata*
BRC			-0.1	0.02		-0.02		0.01	*Pseudophycis breviuscula*
BRG						0.1			*Brisingida*
BRS	-0.01								*Echinorhinus brucus*
BRZ			0.02						*Xenocephalus armatus*
BSH	-0.01	-0.06	-0.1	0.14		-0.09	0.02		*Dalatias licha*
BSK		0.22				-0.02		-0.1	*Cetorhinus maximus*
BSL						-0.11	0.04	0.08	*Xenodermichthys spp.*
BSP									*Taractichthys longipinnis*
BSQ	-0.02					-0.03		-0.1	*Sepioteuthis australis*
BTA			0.06					0.04	*Brochiraja asperula*
BTH	-0.04	0.01	0.07	0.01		0.04	0.02	0.06	*Notoraja spp.*
BTS			-0.1					0.08	*Brochiraja spinifera*
BWH			0.08		0.05				*Carcharhinus brachyurus*
BWS		0.02		-0.1	0.05			-0.1	*Prionace glauca*
BYD								0.1	*Beryx decadactylus*
BYS		0	0.03	0.02		0.1		0.2	*Beryx splendens*
BYX		0.01	-0.3			-0.23		-0.1	*Beryx splendens & B. decadactylus*
CAL			0.08						*Caenopedina porphyrogigas*
CAM			0.09						*Camplyonotus rathbunae*
CAR		0.25	0.12	0.27	-0.3	-0.02		0.14	*Cephaloscyllium isabellum*
CAS		0.04	0.06					-0	*Coelorinchus aspercephalus*
CAY							0.01		*Caryophyllia spp.*
CBB		0.02	0.02			0.08			-
CBD		0.1				0.01	0.02		-
CBE		0.02			0.01			0.04	*Notopogon lilliei*
CBI								-0	*Coelorinchus biclinozonalis*
CBO	-0.05	0.01						-0.1	*Coelorinchus bollonsi*
CBX								0	*Cubiceps baxteri*
CCA								0.01	*Cubiceps caeruleus*
CCO			0.02					0.03	*Coelorinchus cookianus*
CCR									*Cetonurus crassiceps*
CCX								0.05	*Coelorinchus parvifasciatus*
CDL						-0.2		0.01	*Epigonidae*
CDO		0.06	0.04		0.05			0.18	*Capromimus abbreviatus*
CDX			0.16						*Coelorinchus maurofasciatus*
CDY			0.01						*Cosmasterias dyscrita*
CEN						-0.04			*Squalidae*
CFA			0.04						*Coelorinchus fasciatus*
CHA								0.01	*Chauliodus sloani*
CHC		0.02							*Chaceon bicolor*
CHG				0.06			0.08	0.04	*Chimaera lignaria*
CHI				0.02		0.07	-0.02	-0.1	*Chimaera spp.*
CHM									*Chiasmodontidae*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
CHP						0.02	0.06		*Chimaera sp.*
CHQ		0.04						0.02	*Cranchiidae*
CHR							0.04		*Chrysogorgia spp.*
CHX								0.01	*Chaunax pictus*
CJA			0.1					0.11	*Crossaster multispinus*
CMT		0.02							*Comatulida*
CMU							0.01		*Coryphaenoides murrayi*
COB						0.01			*Antipatharia (Order)*
COD						0.01	-0.01		-
COF		0.02						0.02	*Flabellum spp.*
COL			0.03			-0.02		0.1	*Coelorinchus oliverianus*
CON	-0.02	0.08	0.01	-0.1	-0.1	-0.04		0.11	*Conger spp.*
COR						0.01			*Stylasteridae (Family)*
COU		-0.01				-0.01	-0.03	0.02	*Alcyonacea,Gorgonacea,Scleractinia,Antipatharia*
CPA			0.12	0.05				0.07	*Ceramaster patagonicus*
CPD									*Centrolophidae*
CRA		-0.01							*Jasus edwardsii*
CRB		-0.14	-0.1			-0.02		0.03	-
CRM		0.1							*Callyspongia cf ramosa*
CRN		0.02							-
CRS						-0.01			*Callyspongia ramosa*
CRU		-0.04	-0.1						-
CSH		0.05	0.04	0.06	-0.1	-0.04	-0.01	0.14	-
CSP		-0.01							*Coelorinchus spathulatus*
CSQ	-0.02	-0.01	0.02	0.29		0.11	0.03	0.09	*Centrophorus squamosus*
CST									*Caristius sp.*
CSU						0.03			*Coryphaenoides subserrulatus*
CTU									*Cookia sulcata*
CUB									*Cubiceps spp.*
CUC		-0.02	-0.1						*Paraulopus nigripinnis*
CVI			0.02						*Pycnoplax victoriensis*
CYL						0.13		0.19	*Centroscymnus coelolepis*
CYO						0.14		0.1	*Centroscymnus owstoni*
CYP			0.01	0.02		0.18	0.13	0.11	*Centroscymnus crepidater*
DAP			0.15						*Dagnaudus petterdi*
DAS			0.01						*Pteroplatytrygon violacea*
DCO			0.02						*Notophycis marginata*
DCS			-0.1	0.13		-0.02			*Bythaelurus dawsoni*
DDI			0.05			0.02	0.01		*Desmophyllum dianthus*
DEA					0.04			-0.1	*Trachipterus trachypterus*
DEQ						-0.02			*Deania quadrispinosum*
DHO			0.02					0.01	*Dermechinus horridus*
DIR			0.09						*Diacanthurus rubricatus*
DMG			0.13	0.09				0.08	*Dipsacaster magnificus*
DPO								-0	*Desmodema polystictum*
DSK		0.01	-0.1			0.02	-0.04	0.11	*Amblyraja hyperborea*
DSP	-0.02	0.04							*Congiopodus coriaceus*
DSS								-0	*Bathylagus spp.*
DWE						-0.06	-0.01	0.18	-
DWO								0.16	*Graneledone spp.*
ECH						-0.01			*Echinodermata (Phylum)*
ECN			0.04				-0.01		-

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
EEL			-0.2			0.01		-0.1	-
EEX		0.04							*Enypniastes eximia*
EGA			0.02						*Euciroa galatheae*
EGR					0.1				*Myliobatis tenuicaudatus*
ELE					0.05				*Callorhinchus milii*
ELT				0.02					*Electrona spp.*
EMA								-0.2	*Scomber australasicus*
EMO								0.02	*Etmopterus molleri*
EPD								0.02	*Epigonus denticulatus*
EPL		0.03	0.01			-0.1	-0.03	0.21	*Epigonus lenimen*
EPO									*Melanostigma gelatinosum*
EPR			0.02			0.04		0.16	*Epigonus robustus*
ERA								0.03	*Torpedo fairchildi*
ERO						0.04			*Enallopsammia rostrata*
ETB	-0.03	0.06	0.07	0.19		0.08	0.27	0.22	*Etmopterus baxteri*
ETL		0.05	0.06	0.04		-0.14	0.05	0.06	*Etmopterus lucifer*
ETM		-0.03		-0.1		-0.08	0.04	-0.3	*Etmopterus sp.*
ETP				0.02		-0.04	-0.01	-0	*Etmopterus pusillus*
EUC			0.01			-0.02		0.13	*Euclichthys polynemus*
EZE		0.05	0.06						*Enteroctopus zealandicus*
FAN								-0	*Pterycombus petersii*
FHD		0.04	0.03					0.09	*Hoplichthys haswelli*
FLA		0.16							-
FLO		0.01							-
FMA		0.01	0.19					0.18	*Fusitriton magellanicus*
FOR									*Forsterygion spp.*
FRO		0.08			0.04	-0.03		-0.1	*Lepidopus caudatus*
FRS						-0.05			*Chlamydoselachus anguineus*
FRX									*Trichiuridae*
FTU		0.01							*Auxis thazard*
GAO									*Gadomus aoteanus*
GAS			0.18	0.01				0.05	*Gastropoda*
GAT			0.04						*Gastroptychus spp.*
GDU			0.03			0.17	0.11		*Goniocorella dumosa*
GFL		0.14							*Rhombosolea tapirina*
GIZ		0.06	-0.1		-0.2	-0.03			*Kathetostoma giganteum*
GLS	0.01					0.03		0.15	*Hexactinellida (Class)*
GMC		0.05	0.22						*Leptomithrax garricki*
GMU									*Mugil cephalus*
GOB							-0.01		*Mitsukurina owstoni*
GON		0.26						0.06	*Gonorynchus forsteri & G. greyi*
GOR								0.06	*Gorgonocephalus spp.*
GOU			0.02			0.03			*Goniocidaris umbraculum*
GPA			0.04						*Goniocidaris parasol*
GRC						0.01	0.05		*Tripterophycis gilchristi*
GRM							0.02	0.05	*Gracilechinus multidentatus*
GSA									*Hoplostethus gigas*
GSC		0.39	0.12	0.01				0.07	*Jacquinotia edwardsii*
GSH	-0.1	0.1	0.01	-0.1	-0.3	-0.17	-0.19	-0.1	*Hydrolagus novaezealandiae*
GSP	0.12	0.15	0.14	0.28		0.11	0.19	0.16	*Hydrolagus bemisi*
GSQ						0.02		0.02	*Architeuthis spp.*
GUR								0.01	*Chelidonichthys kumu*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
GVO			0.11					0.01	*Provocator mirabilis*
HAG			-0.1	0.2				0.18	*Eptatretus cirrhatus*
HAK	-0.05	0.04	-0.1	0.16	-0.1	-0.03	-0.02		*Merluccius australis*
HAL								0.02	*Halosauropsis macrochir*
HAP		0.1	-0.1	0.06	0.02				*Polyprion oxygeneios*
HAT									*Sternoptychidae*
HCO	-0.02	0.02	0.02	0.34		-0.01			*Bassanago hirsutus*
HEC			0.02						*Henricia compacta*
HEP				0.04				0.05	*Heptranchias perlo*
HEX		0.07	-0.1	0.13				0.14	*Hexanchus griseus*
HGB						0.01			*Hydrolagus sp. d*
HIS			0.02						*Histocidaris spp.*
HJO						0.06	0.1		*Halargyreus johnsonii*
HMT			0.2	0.02				0.08	*Hormathiidae*
HOK	-0.14	0.04	-0.1	0.13	-0.1	-0.08	0.14		*Macruronus novaezelandiae*
HOL								0.01	*Holtbyrnia sp.*
HOR									*Atrina zelandica*
HPB		-0.11	-0.2	-0.1	-0.2			-0.2	*Polyprion oxygeneios & P americanus*
HSI			0.18						*Haliporoides sibogae*
HTH		-0.02	0.02			0.09	0.04	0.07	*Holothurian unidentified*
HTR			0.08					0.1	*Hippasteria phrygiana*
HYA	0.03	0.04	0.08			0.02		0.3	*Hyalascus sp.*
HYB				0.01					*Hydrolagus homonycteris*
HYD							0.01	0.01	*Hydrolagus sp.*
HYM			0.08						*Hymenocephalus spp.*
HYP									*Hydrolagus trolli*
IBR						0.06	0.02		*Isistius brasiliensis*
ISI							0.01		*Isididae*
JAV	0.08	0.21		0.09	0.1	0.01	0.1	0.05	*Lepidorhynchus denticulatus*
JDO									*Zeus faber*
JFI		-0.04	-0.1		0.07	0.02	0.02	0.02	-
JGU		-0.01	-0.1		-0.1			0	*Pterygotrigla picta*
JMA		-0.16	-0.1			-0.03		-0.2	*Trachurus declivis, T. murphyi, T. novaezelandiae*
KIC						0.05	-0.02	0.06	*Lithodes murrayi, Neolithodes brodiei*
KIN					0.18			0.01	*Seriola lalandi*
KWH			0.01					0.01	*Austrofucus glans*
LAE						-0.03	-0.01		*Laemonema spp.*
LAG			0.1						*Laetmogone spp.*
LAN		0.17			0.03		0.01	0.07	*Myctophidae*
LCH						0.01	0.03	0.02	*Harriotta raleighana*
LDO	-0.01	0.06			0.06	-0.06			*Cyttus traversi*
LEA					-0.1				*Meuschenia scaber*
LEG						-0.05	0.02		*Lepidion schmidti & Lepidion inosimae*
LHE									*Lampanyctodes hectoris*
LHO			0.06					0.03	*Lipkius holthuisi*
LIN	-0.04	0.06	-0.1		-0.1	-0.07	-0.06		*Genypterus blacodes*
LLC		0.09	0.02					0.02	*Leptomithrax longipes*
LMI			0.04						*Leptomithrax spp.*
LMU						0.01		0.03	*Lithodes murrayi*
LNV								0.06	*Lithosoma novaezelandiae*
LPI									*Lepidion inosimae*
LPS							-0.01		*Lepidion schmidti*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
LSK		0.01	0.11			-0.02		0.12	*Arhynchobatis asperrimus*
LSO		-0.02	0.02					0.01	*Pelotretis flavilatus*
LUC						-0.02			*Luciosudus sp.*
MAK	0.04	0.04		0.04	0.13	-0.05		-0.1	*Isurus oxyrinchus*
MAN	-0.04	-0.02				0.02		-0.1	*Neoachiropsetta milfordi*
MCA						0.13	0.28		*Macrourus carinatus*
MDO		0.03	0.01			-0.03			*Zenopsis nebulosa*
MIC	-0.02								*Microstoma microstoma*
MIQ	-0.05		-0.1			-0.09		0.07	*Onykia ingens*
MNI			0.12						*Munida spp.*
MOC						0.07	0.02		*Madrepora oculata*
MOD				0.02		0.18	0.17	0.16	*Moridae*
MOK		-0.02				-0.02		-0.1	*Latridopsis ciliaris*
MOL									-
MOO	-0.12	0.01			-0.1			-0.2	*Lampris guttatus*
MOR									*Muraenidae (Family)*
MRQ									*Onykia robsoni*
MSL			0.06						*Mediaster sladeni*
MST						0.03		0.02	*Melanostomiidae*
MUR						-0.02			*Muraenolepis marmoratus*
MUU									-
NCA		0.06							*Nectocarcinus antarcticus*
NCB		0.49						0.02	*Nectocarcinus bennetti*
NEB						0.08		0.01	*Neolithodes brodiei*
NEX									*Nemichthyidae*
NMP		0.13	-0.1	0.01	-0.1			-0.1	*Nemadactylus macropterus*
NOC								0.02	*Notacanthus chemnitzi*
NOR							0.01		*Normichthys yahganorum*
NOT		-0.06		-0.3					*Nototheniidae*
NSD		0.02		0.17	-0.1			0.21	*Squalus griffini*
NTO		0.01							*Notomithrax spp.*
NTU									*Thunnus thynnus*
NUD			0.05						*Nudibranchia (Order)*
OAR								-0.1	*Regalecus glesne*
OCP			0.01						-
OCT		0.05				-0.01	-0.01	-0.1	*Pinnoctopus cordiformis*
ODO			0.02	0.02					*Odontaspis ferox*
OEO						-0.13		-0.1	*P. maculatus, A. niger, & N. rhomboidalis*
OFH			-0.1	0.02		0.02		-0	*Ruvettus pretiosus*
OLY			0.02						*Ophiomusium lymani*
ONG	-0.04	0.18	0.1			0.09		0.09	*Porifera (Phylum)*
OPA	-0.02	0.15	0.04					0.02	*Hemerocoetes spp.*
OPE		0.16	-0.1			-0.01			*Lepidoperca aurantia*
OPH						-0.02			-
OPI			0.14					0.26	*Opisthoteuthis spp.*
OPL		0.01							*Opheliidae*
ORH						-0.08	0.02	-0.1	*Hoplostethus atlanticus*
OSE									*Ophisurus serpens*
OSK			0.2			0.04		0.17	*Rajidae (Family)*
OSP							0.01		*Crassostrea gigas*
PAB						0.04	0.09		*Paragorgia arborea*
PAD		-0.3							*Ovalipes catharus*

Species	Fishery								Scientific name
	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	
PAG			0.05						*Paguroidea*
PAH	0.23								*Lampris immaculatus*
PAL									*Paralepididae*
PAM			0.06						*Pannychia moseleyi*
PAO			0.02					0.02	*Pillsburiaster aoteanus*
PCH			0.01						*Penion chathamensis*
PCO			-0.1						*Auchenoceros punctatus*
PDG		0.04				-0.06		0.06	*Oxynotus bruniensis*
PDS								0.03	*Paradiplospinus gracilis*
PED									*Aristaeopsis edwardsiana*
PFL			0.02						*Pseudechinus flemingi*
PHO		0.04				-0.01		0.04	*Phosichthys argenteus*
PHW		0.02							*Psammocinia cf hawere*
PIG	-0.08	0.22	0.06					0.06	*Congiopodus leucopaecilus*
PIL					0.24				*Sardinops sagax*
PIN								0.01	*Idiolophorhynchus andriashevi*
PKN				0.02				0.07	*Plutonaster knoxi*
PLS		0.02		0.16		0.03	0.01	0.02	*Proscymnodon plunketi*
PLT			0.01					0.03	*Plutonaster spp.*
PLY			0.02						*Polycheles spp.*
PLZ			-0.1						*Pleuroscopus pseudodorsalis*
PMO			0.04					0.02	*Pseudostichopus mollis*
PMU			0.1						*Paramaretia peloria*
PNE			0.1	0.02					*Proserpinaster neozelanicus*
PNN			0.02						*Pennatula spp.*
PNO			0.04						*Pteropeltarion novaezelandiae*
POM	0.01								*Bramidae*
POP					0.02				*Allomycterus jaculiferus*
POR	-0.02	-0.04						-0.2	*Nemadactylus douglasii*
POS	0.01	0.02			-0.1			-0.1	*Lamna nasus*
PRA			0.03						-
PRK			0.17						*Ibacus alticrenatus*
PRO									*Protomyctophum spp.*
PRU			0.04					0.01	*Pseudechinaster rubens*
PSE							-0.01		*Pseudechinus spp.*
PSI			0.23	0.02				0.14	*Psilaster acuminatus*
PSK		0.01	0.09	0.01		0.08		0.16	*Bathyraja shuntovi*
PSL						-0.02	0.02		*Paralomis dosleini*
PSO									*Psolus spp.*
PSP								0.02	*Psenes pellucidus*
PSQ						0.02		0.06	*Pholidoteuthis massyae*
PSY						0.03	0.01		*Psychrolutes microporos*
PTO				0.04					*Dissostichus eleginoides*
PZE								0.01	*Paralomis zealandica*
QSC		0.14							*Zygochlamys delicatula*
RAG						0.03	0.02	-0.1	*Pseudoicichthys australis*
RAT	-0.06	0.08		0.13	-0.1	-0.01	0.1	0.03	*Macrouridae*
RAY			-0.1		-0.1		-0.02	0.04	*Torpedinidae okas Dasyatidae Myliobatidae Mobulidae*
RBM	0.1	-0.1		-0.1	0.05	-0.01		-0.1	*Brama brama*
RBT		0.02	0.02		0.05			0.05	*Emmelichthys nitidus*
RBY		0.01	-0.1					-0.2	*Plagiogeneion rubiginosum*
RCH						0.05		0.02	*Rhinochimaera pacifica*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
RCK									*Acanthoclinidae*
RCO	0.02	0.05	-0.1	0.04	-0.2			-0.1	*Pseudophycis bachus*
RDO		0.14			0.05			0.1	*Cyttopsis roseus*
RHY			0.16			0.07		0.2	*Paratrachichthys trailli*
RIB		0.05	-0.2			-0.06	-0.02		*Mora moro*
RIS								0.06	*Bathyraja richardsoni*
RMU									*Upeneichthys lineatus*
ROC		0.01		0.01		0.03	0.02		*Lotella rhacinus*
RPE									-
RPI									*Bodianus vulpinus*
RSC						0.01			*Scorpaena papillosa*
RSK	0.03	0.24	0.14	0.32	-0.1	0.01		0.11	*Zearaja nasuta*
RSN					-0.1				*Centroberyx affinis*
RSO		-0.13	-0.1	0.04	-0.1				*Rexea solandri*
RSQ		0.02				-0.07			*Ommastrephes bartrami*
RUD			-0.1			-0.05	-0.03		*Centrolophus niger*
SAF						0.01			*Synaphobranchus affinis*
SAI								0.01	*Istiophorus platypterus*
SAR									*Squilla armata*
SAW									*Serrivomer spp.*
SBI	0.02					-0.13	-0.02		*Alepocephalus australis*
SBK						-0.03		0.05	*Notacanthus sexspinis*
SBO	-0.04		0.05			0.01		0.05	*Pseudopentaceros richardsoni*
SBR			-0.1	0.01		-0.03	0.01	0.04	*Pseudophycis barbata*
SBW		0.13	0.01				0.02	0.2	*Micromesistius australis*
SCA		0.02							*Pecten novaezelandiae*
SCD		0.11						0.01	*Notothenia microlepidota*
SCG			-0.1		0.12			0.01	*Lepidotrigla brachyoptera*
SCH		0.11	-0.1	0.08	-0.1	0.03		0.03	*Galeorhinus galeus*
SCI								0.1	*Metanephrops challengeri*
SCM		0.01				0.05	0.01	0.12	*Centroscymnus macracanthus*
SCO				0.03		0.01		0.1	*Bassanago bulbiceps*
SDE									*Cryptopsaras couesii*
SDF			0.02						*Azygopus pinnifasciatus*
SDL						0.01			*Scorpaena cardinalis*
SDM			0.13					0.02	*Sympagurus dimorphus*
SDO		0.39			0.17			0.12	*Cyttus novaezealandiae*
SDR						-0.01		0.02	*Solegnathus spinosissimus*
SEE				0.11				0.1	*Gnathophis habenatus*
SER			0.02						*Sergestes spp.*
SEV		0.06	0.04					0.1	*Notorynchus cepedianus*
SFL		0.07							*Rhombosolea plebeia*
SHA		0.06	-0.1	0.1	-0.1	-0.13	-0.13		-
SHE						-0.01			*Scymnodalatias sherwoodi*
SHL			-0.1						*Scyllarus sp.*
SHR									*Aplysiomorpha (Order)*
SIA						0.15	0.04		*Scleractinia*
SKA	-0.06	-0.08	-0.4	-0.4	-0.2	-0.07	-0.03	-0.3	*Rajidae Arhynchobatidae (Families)*
SKJ		0.01							*Katsuwonus pelamis*
SLB								0.03	*Scymnodalatias albicauda*
SLC						-0.02			*Slosarczykovia circumantarctica*
SLG									*Scutus breviculus*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
SLK						0.04	0.16	0.16	*Alepocephalidae*
SLR									*Optivus elongatus*
SMA		0.01			0.01				*Stigmatophora macropterygia*
SMC			0.02			-0.03	0.07		*Lepidion microcephalus*
SMI		0.03						0.04	*Somniosus microcephalus*
SMK		0.02	0.28						*Teratomaia richardsoni*
SMO		0.06							*Sclerasterias mollis*
SMT			0.04						*Spatangus mathesoni*
SNA		-0.04	-0		0.16	-0.04		-0.1	*Pagrus auratus*
SND		0.04	-0.1	0.18		0.04	0.05		*Deania calcea*
SNE								0.02	*Simenchelys parasitica*
SNI		-0.02						0.01	*Macroramphosus scolopax*
SNO						0.01		0.02	*Sio nordenskjoldii*
SNR				0.01		-0.02	0.03	0.01	*Deania histricosa*
SOL			0.02						-
SOM						0.02			*Somniosus rostratus*
SOP	0.02					0.01			*Somniosus pacificus*
SOR						-0.1			*Neocyttus rhomboidalis*
SOT			0.02	0.01				0.03	*Solaster torulatus*
SPD	0.03	0.04	0.08	0.09	-0.1	-0.19	-0.03		*Squalus acanthias*
SPE		0.06			-0.3	-0.08		0.01	*Helicolenus spp.*
SPF									*Pseudolabrus miles*
SPI	0.01	-0.06	-0.1			-0.03	-0.01	-0.1	-
SPK									*Macrorhamphosodes uradoi*
SPL									*Scopelosaurus sp.*
SPO		0.03	-0.1		-0.3			-0.1	*Mustelus lenticulatus*
SPP					0.01				*Callanthias spp.*
SPR									*Sprattus antipodum, S. muelleri*
SPT			0.19					0.01	*Spatangus multispinus*
SPZ								-0.1	*Genyagnus monopterygius*
SQA				0.02		0.02	0.04	0.04	*Squalus spp.*
SQI		-0.03							*Pristilepis oligolepis*
SQU	-0.01		0.02		-0.1	-0.11	-0.03		*Nototodarus sloanii & N. gouldi*
SQX	0.02		-0.1		0.02	0.02	-0.03	0.13	-
SRB	0.02							0.02	*Brama australis*
SRH			0.01			-0.01		0.12	*Hoplostethus mediterraneus*
SRI						0.01		0.04	*Scymnodon ringens*
SSC		-0.14	-0.1					0.01	*Leptomithrax australis*
SSH		0.01		0.03				0.17	*Gollum attenuatus*
SSI	0.03	0.21	0.04			0.01	-0.04	0.05	*Argentina elongata*
SSK			0.02	0.12	-0.2	-0.03	0.08	0.03	*Dipturus innominatus*
SSM						-0.03	0.08		*Alepocephalus antipodianus*
SSO						-0.19			*Pseudocyttus maculatus*
SSP									*Pecten novaezelandiae*
STG		-0.01	0.03					-0.1	-
STN		0.03						0.06	*Thunnus maccoyii*
STO								0.02	*Stomias spp.*
STR		0.02			0.01				-
STU	-0.02	-0.06			0.06			-0.1	*Allothunnus fallai*
SUH									*Schedophilus huttoni*
SUN		-0.03	0.01		0.11	0.01			*Mola mola*
SUR			-0.1						*Evechinus chloroticus*

	Fishery								
Species	SBW	SQU	SCI	LLL	JMA	ORH	OEO	HHL	Scientific name
SVA						0.06	0.1		*Solenosmilia variabilis*
SWA	0.05	0.06	-0.2			-0.04			*Seriolella punctata*
SWO					0.04	-0.04			*Xiphias gladius*
SWR						-0.02			*Coris sandageri*
SYD								0.01	*Systellaspis debilis*
SYN						-0.03		0.02	*Synaphobranchidae*
TAM			0.04			0.06	0.1	0.23	*Echinothuriidae & Phormosomatidae*
TAY			0.13					0.05	*Typhlonarke aysoni*
TDQ								0.02	*Taningia danae*
TFA			0.23						*Trichopeltarion fantasticum*
THR		-0.07		0.02				-0.1	*Alopias vulpinus*
TLD								0.03	*Tetilla leptoderma*
TLO			0.01						*Telesto spp.*
TOA		0.14		0.04		0.08		0.09	*Neophrynichthys sp.*
TOD		0.06	0.04					0.08	*Neophrynichthys latus*
TOP	-0.03			0.06		0.01		0.1	*Ambophthalmos angustus*
TOR		0.08						0.13	*Thunnus orientalis*
TRA									*Trachichthyidae (Family)*
TRE					0.06				*Pseudocaranx georgianus*
TRS						-0.02			*Trachyscorpia eschmeyeri*
TRU									*Latris lineata*
TSQ						0.03		0.1	*Todarodes filippovae*
TTA			0.04						*Typhlonarke tarakea*
TUR		0.02							*Colistium nudipinnis*
TVI								0.03	*Trachonurus villosus*
URP		0.02	0.02						*Uroptychus spp.*
VCO						0.07	0.11		*Antimora rostrata*
VIT							-0.01		*Vitjazmaia latidactyla*
VOL								0.01	*Volutidae (Family)*
VSQ						0.04		0.19	*Histioteuthis spp.*
WAR		-0.01			-0.1			-0.2	*Seriolella brama*
WHE								0.03	-
WHR						-0.04		-0.1	*Trachyrincus longirostris*
WHX			0.01			0.06		0.17	*Trachyrincus aphyodes*
WIT	-0.01	0.11	0.07			0.05		0.14	*Arnoglossus scapha*
WOE						-0.03	-0.03		*Allocyttus verrucosus*
WPS		0.06			0.01	0.01		0.01	*Carcharodon carcharias*
WRA								0.04	*Dasyatis thetidis*
WSE									*Labridae (Family)*
WSQ		0.09	0.03			0.05	0.17		*Onykia spp.*
WWA	-0.02	0.05	-0.1				0.04	0.06	*Seriolella caerulea*
YBF								0.02	*Rhombosolea leporina*
YBO			0.1					0.12	*Pentaceros decacanthus*
YCO		0.08							*Parapercis gilliesi*
YEM		-0.02							*Aldrichetta forsteri*
YFN		0.01						0.01	*Thunnus albacares*
YSG			0.01						*Pterygotrigla pauli*
YSP			0.02						*Yaldwynopsis spinimana*
ZAS						0.03			*Zameus squamulosus*
ZOR			0.16	0.03				0.11	*Zoroaster spp.*

Appendix 17.11: BYCATCH: Annual bycatch (t) by fishery area for the species categories QMS, non-QMS, Invertebrate, and overall, for seven Deepwater trawl fisheries and one longline fishery (1990–91 to 2012–13). Where data have not yet been updated for recent years for a fishery figures from the last available year have been assumed, in order for annual totals to be calculated. LLL = ling longline fishery; HHL = hoki/hake/ling fishery; – = not estimated.

AUCKLAND ISLANDS									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	12	642	24	66	7	0	0	0	750
1992	1318	300	24	60	0	0	0	0	1701
1993	1009	422	24	38	0	24	48	0	1564
1994	882	497	0	158	0	9	585	0	2132
1995	866	189	21	127	0	64	2079	0	3346
1996	853	5445	36	166	57	17	996	0	7570
1997	1954	1641	51	198	17	11	503	0	4374
1998	893	209	15	550	0	18	554	0	2240
1999	1040	276	21	255	0	33	1042	0	2667
2000	1084	416	65	130	0	61	290	0	2046
2001	751	353	64	304	0	12	277	0	1762
2002	1191	362	2	546	0	25	147	0	2272
2003	1249	1196	0	501	0	44	94	0	3085
2004	1258	1773	27	262	0	19	85	0	3423
2005	1177	1203	1	187	0	5	26	0	2599
2006	458	2013	0	36	0	2	0	0	2509
2007	950	1016	0	39	0	2	0	0	2007
2008	510	1521	0	130	0	13	77	0	2250
2009	836	1628	0	109	0	28	44	0	2645
2010	717	1351	24	29	0	28	44	0	2192
2011	717	1438	111	147	0	28	44	0	2484
2012	717	1438	10	43	0	28	44	0	2280
2013	717	1438	10	56	0	28	44	0	2293
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	4	535	22	45	–	0	0	–	–
1992	345	274	22	41	–	0	0	–	–
1993	418	317	22	18	–	1	0	–	–
1994	279	248	0	109	–	0	3	–	–
1995	325	125	18	88	–	17	0	–	–
1996	489	5319	33	114	–	0	8	–	–
1997	744	1385	50	137	–	0	1	–	–
1998	232	43	13	379	–	0	0	–	–
1999	374	218	19	176	–	4	0	–	–
2000	361	354	43	70	–	1	1	–	–
2001	317	218	64	237	–	0	1	–	–
2002	566	127	2	376	–	0	1	–	–
2003	566	564	0	345	–	1	0	–	–
2004	439	1056	22	181	–	2	0	–	–
2005	391	509	1	129	–	0	0	–	–
2006	46	639	0	25	–	0	0	–	–
2007	323	315	0	27	–	0	0	–	–
2008	117	515	0	74	–	1	0	–	–
2009	412	532	0	78	–	2	0	–	–
2010	132	590	18	20	–	2	0	–	–
2011	132	738	111	107	–	2	0	–	–
2012	132	738	6	30	–	2	0	–	–
2013	132	738	6	38	–	2	0	–	–
Non-QMS									

Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	6	48	2	19	–	–	–	–	–
1992	860	22	2	17	–	–	–	–	–
1993	535	83	2	19	–	–	–	–	–
1994	523	83	0	45	–	–	–	–	–
1995	513	24	3	36	–	–	–	–	–
1996	314	35	3	47	–	–	–	–	–
1997	613	65	1	56	–	–	–	–	–
1998	321	1	2	156	–	–	–	–	–
1999	583	23	2	72	–	–	–	–	–
2000	534	30	22	47	–	–	–	–	–
2001	340	17	0	58	–	–	–	–	–
2002	428	50	0	155	–	–	–	–	–
2003	457	284	0	142	–	–	–	–	–
2004	604	36	5	74	–	–	–	–	–
2005	596	395	0	53	–	–	–	–	–
2006	117	131	0	10	–	–	–	–	–
2007	412	131	0	11	–	–	–	–	–
2008	268	118	0	53	–	–	–	–	–
2009	339	124	0	29	–	–	–	–	–
2010	526	46	6	8	–	–	–	–	–
2011	526	149	0	38	–	–	–	–	–
2012	526	149	4	12	–	–	–	–	–
2013	526	149	4	16	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	2	58	0	2	–	–	–	–	–
1992	113	3	0	2	–	–	–	–	–
1993	55	21	0	1	–	–	–	–	–
1994	80	166	0	4	–	–	–	–	–
1995	28	39	0	3	–	–	–	–	–
1996	50	91	0	5	–	–	–	–	–
1997	597	191	0	5	–	–	–	–	–
1998	340	166	0	15	–	–	–	–	–
1999	83	35	0	7	–	–	–	–	–
2000	188	32	0	13	–	–	–	–	–
2001	94	119	0	9	–	–	–	–	–
2002	196	185	0	15	–	–	–	–	–
2003	226	348	0	14	–	–	–	–	–
2004	215	682	0	7	–	–	–	–	–
2005	190	299	0	5	–	–	–	–	–
2006	294	1243	0	1	–	–	–	–	–
2007	215	570	0	1	–	–	–	–	–
2008	125	888	0	3	–	–	–	–	–
2009	85	972	0	2	–	–	–	–	–
2010	60	715	0	1	–	–	–	–	–
2011	60	551	0	2	–	–	–	–	–
2012	60	551	0	1	–	–	–	–	–
2013	60	551	0	2	–	–	–	–	–

CHATHAM RISE									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	344	1919	1831	8349	1111	1430	15909	0	30893
1992	4343	4000	1831	8993	72	356	15677	0	35272
1993	5603	1781	1831	6467	549	592	6877	0	23700
1994	2644	5273	1795	3974	1019	499	15043	0	30247
1995	4422	2954	1870	7551	1855	145	12057	0	30854
1996	3865	5328	1970	11340	272	781	8664	0	32221
1997	1191	4350	1881	15042	1472	444	7808	0	32188
1998	585	3537	2392	16757	1515	1137	5685	0	31609
1999	777	4819	1020	17707	1944	1744	2913	0	30925
2000	1548	3798	1277	19485	2603	414	2763	0	31887
2001	1987	10277	1240	16745	106	236	6016	0	36606
2002	1798	8014	2781	16872	698	250	2262	0	32674
2003	1312	5697	1430	20002	2351	353	3102	0	34247
2004	888	1820	1239	19822	89	480	4423	0	28762
2005	2874	6548	1518	13797	48	688	4466	0	29938
2006	941	4152	1576	12470	48	343	2482	0	22012
2007	2032	16957	849	9970	48	563	1708	0	32127
2008	2182	1689	1364	11551	48	208	2757	0	19799
2009	1448	409	1366	8766	48	944	2918	0	15898
2010	1622	992	1587	14552	48	944	2918	0	22663
2011	1622	1304	1751	8130	48	944	2918	0	16717
2012	1622	1304	1041	8772	48	944	2918	0	16649
2013	1622	1304	1041	9879	48	944	2918	0	17756
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	147	1831	1625	4592	–	64	211	–	–
1992	1962	3832	1625	3882	–	16	34	–	–
1993	2631	1691	1625	3719	–	58	103	–	–
1994	1157	5097	1460	2047	–	59	1176	–	–
1995	2124	2782	1574	3917	–	17	59	–	–
1996	737	5149	1682	5521	–	77	182	–	–
1997	544	4153	1696	6083	–	89	57	–	–
1998	308	3459	2018	7088	–	68	208	–	–
1999	292	4556	981	7082	–	102	40	–	–
2000	500	3582	1277	9492	–	48	66	–	–
2001	812	9372	1123	7852	–	61	320	–	–
2002	653	7444	2546	5931	–	33	181	–	–
2003	842	5285	1288	8106	–	48	186	–	–
2004	456	1729	1103	9711	–	43	180	–	–
2005	1282	5475	1293	5313	–	59	118	–	–
2006	382	3872	1464	5830	–	49	172	–	–
2007	901	15871	678	4093	–	46	163	–	–
2008	909	1564	1223	4734	–	32	91	–	–
2009	501	374	1284	2345	–	20	172	–	–
2010	307	916	1414	5349	–	20	172	–	–
2011	307	1191	1188	3057	–	20	172	–	–
2012	307	1191	814	4234	–	20	172	–	–
2013	307	1191	814	3984	–	20	172	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	190	84	206	3667	–	–	–	–	–
1992	2364	163	206	4841	–	–	–	–	–
1993	2951	73	206	2533	–	–	–	–	–

1994	1472	174	334	1841	–	–	–	–	–
1995	2276	155	296	3509	–	–	–	–	–
1996	2748	158	289	5683	–	–	–	–	–
1997	593	178	185	8832	–	–	–	–	–
1998	265	60	374	9448	–	–	–	–	–
1999	481	245	34	10149	–	–	–	–	–
2000	1031	208	0	9193	–	–	–	–	–
2001	1162	863	117	8301	–	–	–	–	–
2002	1122	559	215	10312	–	–	–	–	–
2003	448	393	121	11636	–	–	–	–	–
2004	418	85	129	9848	–	–	–	–	–
2005	1539	1048	225	8281	–	–	–	–	–
2006	481	262	110	6467	–	–	–	–	–
2007	1005	1004	168	5791	–	–	–	–	–
2008	1169	119	139	6670	–	–	–	–	–
2009	886	33	81	6375	–	–	–	–	–
2010	1282	72	172	9069	–	–	–	–	–
2011	1282	108	562	4987	–	–	–	–	–
2012	1282	108	225	4482	–	–	–	–	–
2013	1282	108	225	5804	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	8	5	0	90	–	–	–	–	–
1992	17	5	0	270	–	–	–	–	–
1993	21	18	0	215	–	–	–	–	–
1994	16	2	0	86	–	–	–	–	–
1995	22	17	0	125	–	–	–	–	–
1996	381	21	0	136	–	–	–	–	–
1997	53	19	0	127	–	–	–	–	–
1998	13	18	0	221	–	–	–	–	–
1999	5	17	4	476	–	–	–	–	–
2000	17	9	0	800	–	–	–	–	–
2001	12	43	0	592	–	–	–	–	–
2002	23	10	20	629	–	–	–	–	–
2003	22	19	20	260	–	–	–	–	–
2004	15	6	8	263	–	–	–	–	–
2005	53	25	0	203	–	–	–	–	–
2006	78	18	2	173	–	–	–	–	–
2007	126	82	3	86	–	–	–	–	–
2008	104	6	2	147	–	–	–	–	–
2009	60	1	1	46	–	–	–	–	–
2010	34	3	2	134	–	–	–	–	–
2011	34	4	1	86	–	–	–	–	–
2012	34	4	2	56	–	–	–	–	–
2013	34	4	2	91	–	–	–	–	–

COOK STRAIT									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	9	1501	4	9	1059	0	2582
1992	0	0	9	1068	9	7	1089	0	2182
1993	0	58	9	1090	0	2	469	0	1629
1994	0	0	5	2621	0	12	878	0	3517
1995	33	1	9	2400	0	0	1060	0	3504

1996	0	19	8	3274	0	3	373	0	3677
1997	0	0	3	4525	0	8	396	0	4933
1998	0	1	20	2249	113	9	221	0	2612
1999	2	90	56	2035	423	3	181	0	2791
2000	2	2	67	3244	155	12	132	0	3614
2001	0	47	221	1561	312	12	72	0	2225
2002	53	0	40	882	26	12	65	0	1079
2003	8	8	22	3197	0	5	58	0	3298
2004	0	0	54	1396	0	2	36	0	1489
2005	28	0	103	1825	12	2	51	0	2021
2006	0	0	128	507	12	3	74	0	725
2007	0	0	126	1070	12	1	51	0	1260
2008	0	0	201	790	12	0	90	0	1092
2009	0	0	29	660	12	2	68	0	771
2010	0	0	21	700	12	2	68	0	803
2011	0	0	28	325	12	2	68	0	435
2012	0	0	11	532	12	2	68	0	624
2013	0	0	11	645	12	2	68	0	737
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	8	1279	–	0	231	–	–
1992	0	0	8	910	–	0	441	–	–
1993	0	57	8	929	–	0	692	–	–
1994	0	0	3	1884	–	0	791	–	–
1995	16	1	7	2044	–	0	275	–	–
1996	0	19	5	3145	–	0	747	–	–
1997	0	0	2	3855	–	0	182	–	–
1998	0	1	13	2204	–	0	55	–	–
1999	1	87	43	1974	–	0	129	–	–
2000	1	2	43	3222	–	0	114	–	–
2001	0	45	132	1515	–	0	50	–	–
2002	19	0	27	861	–	0	61	–	–
2003	5	7	13	3178	–	0	45	–	–
2004	0	0	37	1249	–	0	24	–	–
2005	12	0	63	1722	–	0	24	–	–
2006	0	0	84	479	–	0	47	–	–
2007	0	0	91	958	–	0	28	–	–
2008	0	0	193	627	–	0	41	–	–
2009	0	0	20	480	–	0	45	–	–
2010	0	0	14	308	–	0	45	–	–
2011	0	0	19	304	–	0	45	–	–
2012	0	0	5	460	–	0	45	–	–
2013	0	0	5	477	–	0	45	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	2	215	–	–	–	–	–
1992	0	0	2	153	–	–	–	–	–
1993	0	1	2	156	–	–	–	–	–
1994	0	0	2	717	–	–	–	–	–
1995	16	0	2	344	–	–	–	–	–
1996	0	0	2	129	–	–	–	–	–
1997	0	0	1	648	–	–	–	–	–
1998	0	0	7	39	–	–	–	–	–
1999	1	2	13	59	–	–	–	–	–
2000	1	0	24	21	–	–	–	–	–
2001	0	1	85	46	–	–	–	–	–
2002	30	0	13	21	–	–	–	–	–
2003	3	1	8	18	–	–	–	–	–

2004	0	0	17	27	–	–	–	–	–
2005	14	0	40	100	–	–	–	–	–
2006	0	0	44	28	–	–	–	–	–
2007	0	0	36	108	–	–	–	–	–
2008	0	0	8	161	–	–	–	–	–
2009	0	0	10	177	–	–	–	–	–
2010	0	0	7	390	–	–	–	–	–
2011	0	0	9	21	–	–	–	–	–
2012	0	0	6	71	–	–	–	–	–
2013	0	0	6	167	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	7	–	–	–	–	–
1992	0	0	0	5	–	–	–	–	–
1993	0	0	0	5	–	–	–	–	–
1994	0	0	0	20	–	–	–	–	–
1995	1	0	0	12	–	–	–	–	–
1996	0	0	0	0	–	–	–	–	–
1997	0	0	0	22	–	–	–	–	–
1998	0	0	0	6	–	–	–	–	–
1999	0	1	0	2	–	–	–	–	–
2000	0	0	1	1	–	–	–	–	–
2001	0	1	4	0	–	–	–	–	–
2002	5	0	0	0	–	–	–	–	–
2003	0	0	0	1	–	–	–	–	–
2004	0	0	0	120	–	–	–	–	–
2005	1	0	0	3	–	–	–	–	–
2006	0	0	0	0	–	–	–	–	–
2007	0	0	0	4	–	–	–	–	–
2008	0	0	0	2	–	–	–	–	–
2009	0	0	0	3	–	–	–	–	–
2010	0	0	0	2	–	–	–	–	–
2011	0	0	0	0	–	–	–	–	–
2012	0	0	0	1	–	–	–	–	–
2013	0	0	0	1	–	–	–	–	–

EAST COAST NORTH ISLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	2390	0	69	725	12	22	1438	0	4655
1992	916	0	69	540	9	22	992	0	2548
1993	1466	0	69	561	16	15	509	0	2636
1994	1233	0	196	1563	10	12	732	0	3747
1995	1255	0	96	1137	0	1	1619	0	4109
1996	1508	0	111	2192	0	34	446	0	4292
1997	720	0	108	3402	4	73	1092	0	5400
1998	883	0	160	2960	0	105	3514	0	7623
1999	1043	0	95	1387	0	31	804	0	3359
2000	956	2	161	1146	0	73	1560	0	3897
2001	1365	0	398	1313	45	45	535	0	3700
2002	3733	0	204	736	53	31	62	0	4818
2003	1534	3	83	1035	19	41	219	0	2934
2004	716	0	247	1031	0	14	681	0	2688
2005	636	0	252	680	0	13	186	0	1767

2006	434	0	399	386	0	7	35	0	1261
2007	544	0	159	543	0	2	101	0	1349
2008	540	0	84	401	0	1	114	0	1140
2009	259	0	283	442	0	2	101	0	1087
2010	525	0	258	421	0	2	101	0	1306
2011	525	0	269	730	0	2	101	0	1625
2012	525	0	229	458	0	2	101	0	1313
2013	525	0	229	507	0	2	101	0	1362
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1039	0	43	390	–	0	241	–	–
1992	603	0	43	290	–	0	186	–	–
1993	914	0	43	302	–	0	350	–	–
1994	830	0	59	841	–	0	79	–	–
1995	747	0	54	612	–	0	116	–	–
1996	635	0	53	1180	–	0	593	–	–
1997	531	0	46	1831	–	0	576	–	–
1998	388	0	73	2416	–	0	1089	–	–
1999	332	0	56	747	–	0	242	–	–
2000	414	2	71	617	–	0	1339	–	–
2001	804	0	262	707	–	0	15	–	–
2002	1777	0	96	396	–	0	12	–	–
2003	917	3	50	557	–	0	16	–	–
2004	346	0	119	555	–	0	5	–	–
2005	291	0	105	366	–	0	9	–	–
2006	158	0	156	208	–	0	7	–	–
2007	181	0	80	292	–	0	26	–	–
2008	201	0	59	216	–	0	17	–	–
2009	69	0	137	238	–	0	31	–	–
2010	192	0	115	227	–	0	31	–	–
2011	192	0	132	393	–	0	31	–	–
2012	192	0	60	247	–	0	31	–	–
2013	192	0	60	273	–	0	31	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1344	0	25	333	–	–	–	–	–
1992	267	0	25	248	–	–	–	–	–
1993	538	0	25	257	–	–	–	–	–
1994	333	0	137	717	–	–	–	–	–
1995	434	0	42	522	–	–	–	–	–
1996	838	0	58	1006	–	–	–	–	–
1997	175	0	62	1561	–	–	–	–	–
1998	419	0	87	536	–	–	–	–	–
1999	683	0	38	636	–	–	–	–	–
2000	511	0	89	526	–	–	–	–	–
2001	492	0	128	602	–	–	–	–	–
2002	1663	0	107	338	–	–	–	–	–
2003	581	0	32	475	–	–	–	–	–
2004	333	0	128	473	–	–	–	–	–
2005	311	0	147	312	–	–	–	–	–
2006	234	0	243	177	–	–	–	–	–
2007	330	0	78	249	–	–	–	–	–
2008	317	0	26	184	–	–	–	–	–
2009	169	0	146	203	–	–	–	–	–
2010	304	0	143	193	–	–	–	–	–
2011	304	0	136	335	–	–	–	–	–
2012	304	0	168	210	–	–	–	–	–
2013	304	0	168	233	–	–	–	–	–

Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	8	0	0	2	–	–	–	–	–
1992	46	0	0	2	–	–	–	–	–
1993	14	0	0	2	–	–	–	–	–
1994	71	0	0	5	–	–	–	–	–
1995	74	0	0	3	–	–	–	–	–
1996	36	0	0	6	–	–	–	–	–
1997	14	0	0	10	–	–	–	–	–
1998	77	0	0	8	–	–	–	–	–
1999	29	0	0	4	–	–	–	–	–
2000	31	0	1	3	–	–	–	–	–
2001	69	0	8	4	–	–	–	–	–
2002	293	0	0	2	–	–	–	–	–
2003	36	0	1	3	–	–	–	–	–
2004	36	0	0	3	–	–	–	–	–
2005	34	0	0	2	–	–	–	–	–
2006	41	0	0	1	–	–	–	–	–
2007	33	0	0	2	–	–	–	–	–
2008	23	0	0	1	–	–	–	–	–
2009	20	0	0	1	–	–	–	–	–
2010	28	0	0	1	–	–	–	–	–
2011	28	0	0	2	–	–	–	–	–
2012	28	0	0	1	–	–	–	–	–
2013	28	0	0	1	–	–	–	–	–

NORTHLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1422	0	75	24	0	0	70	0	1591
1992	919	36	75	120	4	0	12	0	1166
1993	667	13	75	104	22	0	19	0	901
1994	456	0	152	83	6	0	50	0	747
1995	1208	0	81	303	0	0	42	0	1635
1996	803	0	58	393	0	0	450	0	1705
1997	584	8	67	1205	0	0	3240	0	5104
1998	392	0	109	959	0	0	569	0	2029
1999	230	0	29	359	8	0	93	0	718
2000	482	0	24	318	0	0	132	0	956
2001	603	6	70	200	179	0	30	0	1087
2002	1085	0	14	270	0	0	10	0	1379
2003	673	24	29	189	0	0	54	0	969
2004	657	15	18	243	0	0	14	0	948
2005	245	1	64	155	0	0	105	0	570
2006	257	16	37	275	0	0	21	0	606
2007	583	21	36	232	0	0	7	0	879
2008	557	5	46	216	0	0	11	0	835
2009	357	15	38	183	0	0	27	0	620
2010	424	0	38	396	0	0	27	0	885
2011	424	0	63	277	0	0	27	0	791
2012	424	0	44	244	0	0	27	0	740
2013	424	0	44	383	0	0	27	0	879

QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	599	0	63	17	–	0	21	–	–
1992	400	35	63	80	–	0	7	–	–
1993	243	13	63	76	–	0	38	–	–
1994	174	0	84	68	–	0	61	–	–
1995	428	0	64	237	–	0	15	–	–
1996	291	0	42	313	–	0	1247	–	–
1997	245	8	46	894	–	0	2116	–	–
1998	239	0	77	583	–	0	195	–	–
1999	113	0	23	202	–	0	70	–	–
2000	202	0	17	199	–	0	149	–	–
2001	261	6	52	129	–	0	29	–	–
2002	410	0	10	128	–	0	11	–	–
2003	267	21	19	101	–	0	45	–	–
2004	245	14	13	158	–	0	6	–	–
2005	81	1	55	84	–	0	64	–	–
2006	43	13	26	157	–	0	16	–	–
2007	134	17	24	137	–	0	2	–	–
2008	153	4	40	113	–	0	4	–	–
2009	87	12	28	95	–	0	19	–	–
2010	159	0	27	179	–	0	19	–	–
2011	159	0	46	140	–	0	19	–	–
2012	159	0	23	138	–	0	19	–	–
2013	159	0	23	194	–	0	19	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	779	0	12	7	–	–	–	–	–
1992	498	0	12	35	–	–	–	–	–
1993	384	0	12	25	–	–	–	–	–
1994	253	0	67	13	–	–	–	–	–
1995	755	0	17	60	–	–	–	–	–
1996	464	0	16	76	–	–	–	–	–
1997	327	0	22	303	–	–	–	–	–
1998	88	0	32	365	–	–	–	–	–
1999	114	0	6	148	–	–	–	–	–
2000	270	0	7	109	–	–	–	–	–
2001	296	0	18	64	–	–	–	–	–
2002	503	0	3	129	–	–	–	–	–
2003	354	2	10	82	–	–	–	–	–
2004	363	0	5	77	–	–	–	–	–
2005	142	0	9	68	–	–	–	–	–
2006	187	1	11	111	–	–	–	–	–
2007	313	1	13	91	–	–	–	–	–
2008	366	0	6	98	–	–	–	–	–
2009	236	1	10	85	–	–	–	–	–
2010	228	0	11	207	–	–	–	–	–
2011	228	0	16	128	–	–	–	–	–
2012	228	0	22	100	–	–	–	–	–
2013	228	0	22	178	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	43	0	0	0	–	–	–	–	–
1992	21	0	0	5	–	–	–	–	–
1993	40	0	0	3	–	–	–	–	–
1994	29	0	0	2	–	–	–	–	–
1995	24	0	0	6	–	–	–	–	–
1996	48	0	0	4	–	–	–	–	–

1997	12	0	0	8	–	–	–	–	–
1998	66	0	0	11	–	–	–	–	–
1999	4	0	0	9	–	–	–	–	–
2000	9	0	0	10	–	–	–	–	–
2001	47	0	0	7	–	–	–	–	–
2002	172	0	0	13	–	–	–	–	–
2003	52	1	0	6	–	–	–	–	–
2004	50	1	0	8	–	–	–	–	–
2005	22	0	0	3	–	–	–	–	–
2006	27	3	0	7	–	–	–	–	–
2007	136	3	0	4	–	–	–	–	–
2008	38	1	0	5	–	–	–	–	–
2009	34	2	0	3	–	–	–	–	–
2010	38	0	0	10	–	–	–	–	–
2011	38	0	0	9	–	–	–	–	–
2012	38	0	0	6	–	–	–	–	–
2013	38	0	0	11	–	–	–	–	–

PUYSEGUR									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	6	30	318	0	82	429	0	865
1992	4	118	30	418	143	53	1689	0	2456
1993	35	145	30	144	10	78	909	0	1352
1994	1	12	60	246	14	59	2343	0	2736
1995	8	29	39	414	5	26	444	0	963
1996	0	32	59	153	0	107	921	0	1272
1997	28	125	103	515	4	35	493	0	1302
1998	37	38	219	535	0	417	333	0	1580
1999	212	58	123	658	8	27	53	0	1138
2000	40	74	93	1050	0	200	27	0	1484
2001	148	543	217	2887	0	134	503	0	4432
2002	0	887	99	660	0	189	182	0	2018
2003	167	1341	81	637	19	366	206	0	2818
2004	47	333	62	328	0	39	163	0	972
2005	8	1209	77	368	0	93	298	0	2052
2006	0	271	87	971	0	48	116	0	1492
2007	0	30	71	236	0	12	0	0	350
2008	0	21	190	206	0	23	15	0	455
2009	0	7	25	160	0	26	44	0	262
2010	0	50	5	120	0	26	44	0	245
2011	0	85	95	275	0	26	44	0	525
2012	0	85	21	302	0	26	44	0	478
2013	0	85	21	513	0	26	44	0	689
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	5	22	174	–	1	7	–	–
1992	1	103	22	287	–	0	53	–	–
1993	17	113	22	77	–	0	104	–	–
1994	0	10	42	209	–	1	188	–	–
1995	4	24	25	291	–	6	9	–	–
1996	0	29	34	119	–	1	206	–	–
1997	13	108	53	446	–	1	2	–	–
1998	15	36	121	377	–	0	0	–	–

1999	71	49	84	471	–	0	3	–	–
2000	15	65	54	763	–	15	2	–	–
2001	73	439	118	2594	–	1	163	–	–
2002	0	759	57	624	–	0	13	–	–
2003	100	1045	42	514	–	0	13	–	–
2004	22	283	46	224	–	3	9	–	–
2005	3	765	40	329	–	4	10	–	–
2006	0	218	47	508	–	0	1	–	–
2007	0	23	31	166	–	0	0	–	–
2008	0	17	131	145	–	0	1	–	–
2009	0	5	15	113	–	0	2	–	–
2010	0	39	3	85	–	0	2	–	–
2011	0	65	38	194	–	0	2	–	–
2012	0	65	7	153	–	0	2	–	–
2013	0	65	7	274	–	0	2	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	1	9	123	–	–	–	–	–
1992	3	15	9	90	–	–	–	–	–
1993	18	31	9	54	–	–	–	–	–
1994	1	3	19	22	–	–	–	–	–
1995	4	5	13	105	–	–	–	–	–
1996	0	3	25	28	–	–	–	–	–
1997	9	16	49	62	–	–	–	–	–
1998	14	2	97	135	–	–	–	–	–
1999	136	9	39	175	–	–	–	–	–
2000	24	9	38	279	–	–	–	–	–
2001	68	102	98	245	–	–	–	–	–
2002	0	126	42	32	–	–	–	–	–
2003	58	289	40	113	–	–	–	–	–
2004	22	49	16	100	–	–	–	–	–
2005	4	443	37	34	–	–	–	–	–
2006	0	51	39	431	–	–	–	–	–
2007	0	8	40	60	–	–	–	–	–
2008	0	4	59	52	–	–	–	–	–
2009	0	2	11	40	–	–	–	–	–
2010	0	10	2	30	–	–	–	–	–
2011	0	20	57	69	–	–	–	–	–
2012	0	20	14	131	–	–	–	–	–
2013	0	20	14	212	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	21	–	–	–	–	–
1992	0	0	0	41	–	–	–	–	–
1993	1	1	0	13	–	–	–	–	–
1994	0	0	0	15	–	–	–	–	–
1995	0	0	0	18	–	–	–	–	–
1996	0	0	0	6	–	–	–	–	–
1997	6	1	0	7	–	–	–	–	–
1998	8	0	1	23	–	–	–	–	–
1999	5	0	0	12	–	–	–	–	–
2000	2	0	1	8	–	–	–	–	–
2001	7	2	2	48	–	–	–	–	–
2002	0	3	0	4	–	–	–	–	–
2003	9	8	0	10	–	–	–	–	–
2004	3	1	0	4	–	–	–	–	–
2005	0	1	0	5	–	–	–	–	–
2006	0	1	0	32	–	–	–	–	–

2007	0	0	0	10	–	–	–	–	–
2008	0	0	0	9	–	–	–	–	–
2009	0	0	0	7	–	–	–	–	–
2010	0	0	0	5	–	–	–	–	–
2011	0	0	0	12	–	–	–	–	–
2012	0	0	0	18	–	–	–	–	–
2013	0	0	0	27	–	–	–	–	–

STEWART-SNARES SHELF									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	14215	28	2108	65	55	68	0	16539
1992	1	11222	28	2592	536	40	122	0	14542
1993	11	14924	28	1707	114	14	102	0	16901
1994	0	4669	85	859	159	16	126	0	5914
1995	5	1309	205	1250	298	8	10	0	3085
1996	2	5029	37	1752	204	49	231	0	7304
1997	10	7993	143	1195	257	124	880	0	10601
1998	19	5719	219	3464	506	114	692	0	10733
1999	69	14713	508	2499	1559	288	154	0	19790
2000	8	7685	198	4860	4621	184	90	0	17646
2001	3	8536	165	6069	877	66	165	0	15881
2002	0	15158	164	7148	1567	338	35	0	24410
2003	43	11478	75	2336	1055	205	7	0	15199
2004	29	11354	166	2833	14	35	7	0	14438
2005	5	8904	112	1876	234	60	0	0	11191
2006	0	12609	48	2067	234	72	0	0	15029
2007	0	5095	343	3883	234	32	0	0	9587
2008	0	6847	179	1866	234	12	18	0	9156
2009	0	9859	91	1673	234	76	0	0	11933
2010	0	7911	54	2211	234	76	0	0	10486
2011	0	8407	60	2092	234	76	0	0	10869
2012	0	8407	514	1495	234	76	0	0	10726
2013	0	8407	514	2269	234	76	0	0	11500
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	14189	24	807	–	5	0	–	–
1992	0	11152	24	1346	–	24	0	–	–
1993	6	14803	24	810	–	2	1	–	–
1994	0	4572	64	531	–	1	1	–	–
1995	3	1290	189	577	–	11	0	–	–
1996	1	5024	36	1079	–	2	4	–	–
1997	5	7742	98	548	–	9	0	–	–
1998	7	5697	219	1344	–	1	1	–	–
1999	23	14480	396	1030	–	4	1	–	–
2000	3	7666	133	2602	–	57	1	–	–
2001	1	8386	118	4032	–	6	1	–	–
2002	0	15037	118	2725	–	35	0	–	–
2003	25	11017	60	1190	–	0	0	–	–
2004	13	11232	115	2066	–	11	0	–	–
2005	2	8613	105	661	–	4	0	–	–
2006	0	12319	25	1508	–	6	0	–	–
2007	0	4933	261	3253	–	3	0	–	–
2008	0	6664	135	977	–	3	0	–	–
2009	0	9456	67	935	–	12	0	–	–

2010	0	7643	37	1158	–	12	0	–	–
2011	0	7881	44	1260	–	12	0	–	–
2012	0	7881	455	808	–	12	0	–	–
2013	0	7881	455	1306	–	12	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	16	4	1158	–	–	–	–	–
1992	1	69	4	1026	–	–	–	–	–
1993	6	92	4	777	–	–	–	–	–
1994	0	28	21	241	–	–	–	–	–
1995	2	16	16	588	–	–	–	–	–
1996	1	3	1	548	–	–	–	–	–
1997	3	11	44	603	–	–	–	–	–
1998	7	7	0	1992	–	–	–	–	–
1999	45	148	112	1368	–	–	–	–	–
2000	4	16	63	1999	–	–	–	–	–
2001	2	115	46	1592	–	–	–	–	–
2002	0	106	46	4094	–	–	–	–	–
2003	15	415	16	1043	–	–	–	–	–
2004	14	73	50	694	–	–	–	–	–
2005	3	259	7	1110	–	–	–	–	–
2006	0	202	23	482	–	–	–	–	–
2007	0	124	82	530	–	–	–	–	–
2008	0	109	43	786	–	–	–	–	–
2009	0	280	24	662	–	–	–	–	–
2010	0	230	17	914	–	–	–	–	–
2011	0	413	15	671	–	–	–	–	–
2012	0	413	59	591	–	–	–	–	–
2013	0	413	59	851	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	10	0	143	–	–	–	–	–
1992	0	1	0	220	–	–	–	–	–
1993	0	29	0	120	–	–	–	–	–
1994	0	69	0	87	–	–	–	–	–
1995	0	3	0	85	–	–	–	–	–
1996	0	2	0	125	–	–	–	–	–
1997	2	240	0	44	–	–	–	–	–
1998	5	16	0	128	–	–	–	–	–
1999	2	84	0	101	–	–	–	–	–
2000	1	2	2	259	–	–	–	–	–
2001	0	35	1	445	–	–	–	–	–
2002	0	15	0	329	–	–	–	–	–
2003	2	45	0	103	–	–	–	–	–
2004	2	49	0	73	–	–	–	–	–
2005	0	33	0	105	–	–	–	–	–
2006	0	88	0	77	–	–	–	–	–
2007	0	38	0	100	–	–	–	–	–
2008	0	74	0	103	–	–	–	–	–
2009	0	123	0	76	–	–	–	–	–
2010	0	38	0	139	–	–	–	–	–
2011	0	113	0	161	–	–	–	–	–
2012	0	113	0	96	–	–	–	–	–
2013	0	113	0	112	–	–	–	–	–

SUB-ANTARCTIC									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	38	1078	433	0	3	33	533	2120
1992	14	0	1078	226	0	2	40	1479	2839
1993	95	5	1078	98	0	4	35	206	1521
1994	85	6	705	139	0	12	31	382	1360
1995	3	0	549	95	0	26	76	178	928
1996	8	20	641	106	0	49	538	63	1426
1997	154	0	637	72	0	44	2986	203	4096
1998	66	0	132	306	0	152	1762	296	2714
1999	27	0	759	166	0	124	231	283	1590
2000	9	15	905	442	0	312	147	283	2113
2001	4	21	912	415	0	59	104	223	1739
2002	53	16	537	1223	0	75	45	364	2313
2003	64	544	609	2003	0	715	97	230	4262
2004	95	731	882	1901	0	65	96	390	4160
2005	0	153	212	449	0	116	119	250	1300
2006	0	89	139	86	0	321	241	190	1065
2007	1	255	109	197	0	97	42	40	741
2008	0	5	575	820	0	144	38	40	1622
2009	0	5	474	514	0	273	138	40	1444
2010	1	15	274	83	0	273	138	40	824
2011	1	6	149	335	0	273	138	40	941
2012	1	6	139	95	0	273	138	40	692
2013	1	6	139	133	0	273	138	40	730
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	30	148	154	–	0	0	–	–
1992	8	0	148	115	–	0	0	–	–
1993	61	4	148	36	–	0	0	–	–
1994	57	5	294	83	–	0	0	–	–
1995	3	0	355	56	–	0	0	–	–
1996	5	15	442	63	–	0	4	–	–
1997	103	0	624	43	–	1	0	–	–
1998	35	0	132	182	–	1	0	–	–
1999	19	0	408	56	–	0	1	–	–
2000	6	11	583	188	–	0	1	–	–
2001	2	16	693	194	–	0	0	–	–
2002	34	12	151	413	–	1	0	–	–
2003	41	419	306	1090	–	1	0	–	–
2004	60	556	581	1454	–	2	0	–	–
2005	0	117	142	266	–	4	0	–	–
2006	0	62	79	51	–	4	0	–	–
2007	1	193	68	117	–	1	1	–	–
2008	0	4	408	550	–	4	1	–	–
2009	0	4	238	412	–	6	1	–	–
2010	1	11	242	49	–	6	1	–	–
2011	1	5	128	234	–	6	1	–	–
2012	1	5	76	54	–	6	1	–	–
2013	1	5	76	86	–	6	1	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	1	930	254	–	–	–	–	–
1992	3	0	930	106	–	–	–	–	–
1993	18	0	930	57	–	–	–	–	–
1994	14	0	411	48	–	–	–	–	–
1995	0	0	195	33	–	–	–	–	–

1996	1	0	199	37	–	–	–	–	–
1997	19	0	13	25	–	–	–	–	–
1998	10	0	0	106	–	–	–	–	–
1999	5	0	349	63	–	–	–	–	–
2000	2	0	322	231	–	–	–	–	–
2001	1	1	218	158	–	–	–	–	–
2002	10	1	379	694	–	–	–	–	–
2003	10	25	294	557	–	–	–	–	–
2004	16	17	286	396	–	–	–	–	–
2005	0	6	70	156	–	–	–	–	–
2006	0	3	58	30	–	–	–	–	–
2007	0	10	40	68	–	–	–	–	–
2008	0	0	168	243	–	–	–	–	–
2009	0	0	235	94	–	–	–	–	–
2010	0	1	32	29	–	–	–	–	–
2011	0	0	20	95	–	–	–	–	–
2012	0	0	63	38	–	–	–	–	–
2013	0	0	63	35	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	7	0	25	–	–	–	–	–
1992	3	0	0	5	–	–	–	–	–
1993	16	1	0	5	–	–	–	–	–
1994	15	1	0	8	–	–	–	–	–
1995	0	0	0	6	–	–	–	–	–
1996	2	5	0	6	–	–	–	–	–
1997	33	0	0	4	–	–	–	–	–
1998	21	0	0	18	–	–	–	–	–
1999	3	0	2	47	–	–	–	–	–
2000	1	4	1	23	–	–	–	–	–
2001	1	4	2	63	–	–	–	–	–
2002	9	3	7	116	–	–	–	–	–
2003	13	99	10	356	–	–	–	–	–
2004	19	158	15	51	–	–	–	–	–
2005	0	30	0	27	–	–	–	–	–
2006	0	24	1	5	–	–	–	–	–
2007	0	52	1	12	–	–	–	–	–
2008	0	1	0	27	–	–	–	–	–
2009	0	1	1	8	–	–	–	–	–
2010	0	3	0	5	–	–	–	–	–
2011	0	1	0	6	–	–	–	–	–
2012	0	1	0	3	–	–	–	–	–
2013	0	1	0	12	–	–	–	–	–

WEST COAST NORTH ISLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	2	2	27	1839	0	15	0	1885
1992	4	4	2	28	6978	0	160	0	7175
1993	64	9	2	15	8761	0	474	0	9324
1994	0	23	2	14	4924	2	2397	0	7362
1995	3	2	0	21	1791	1	116	0	1933
1996	0	0	18	100	3621	0	33	0	3771
1997	1	2	79	33	1814	3	200	0	2132
1998	13	0	1	45	5784	0	268	0	6111
1999	11	168	36	24	2010	0	210	0	2460

2000	5	553	4	61	360	0	158	0	1140
2001	0	1155	16	89	1826	2	489	0	3577
2002	10	836	5	48	5693	0	923	0	7515
2003	0	283	0	110	4045	0	491	0	4929
2004	0	19	1	43	7279	8	227	0	7577
2005	8	0	1	20	6614	1	251	0	6894
2006	0	0	5	61	6614	0	186	0	6867
2007	0	5	36	33	6614	0	88	0	6777
2008	0	2	29	94	6614	0	40	0	6779
2009	0	0	36	77	6614	0	77	0	6804
2010	1	0	25	24	6614	0	77	0	6741
2011	1	0	56	26	6614	0	77	0	6774
2012	1	0	14	39	6614	0	77	0	6746
2013	1	0	14	51	6614	0	77	0	6758
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	2	1	19	–	0	3	–	–
1992	1	4	1	19	–	0	66	–	–
1993	31	9	1	11	–	0	667	–	–
1994	0	21	2	12	–	0	2437	–	–
1995	1	2	0	17	–	0	4	–	–
1996	0	0	14	80	–	0	36	–	–
1997	1	2	71	25	–	0	88	–	–
1998	5	0	1	27	–	0	70	–	–
1999	4	163	14	13	–	0	77	–	–
2000	2	543	2	38	–	0	29	–	–
2001	0	1108	11	58	–	0	63	–	–
2002	4	803	4	23	–	0	74	–	–
2003	0	246	0	59	–	0	81	–	–
2004	0	18	1	28	–	0	32	–	–
2005	3	0	1	11	–	0	16	–	–
2006	0	0	4	35	–	0	54	–	–
2007	0	4	15	19	–	0	9	–	–
2008	0	2	24	49	–	0	6	–	–
2009	0	0	27	40	–	0	29	–	–
2010	0	0	20	11	–	0	29	–	–
2011	0	0	40	13	–	0	29	–	–
2012	0	0	9	22	–	0	29	–	–
2013	0	0	9	26	–	0	29	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	1	7	–	–	–	–	–
1992	3	0	1	8	–	–	–	–	–
1993	32	0	1	4	–	–	–	–	–
1994	0	1	0	2	–	–	–	–	–
1995	1	0	0	4	–	–	–	–	–
1996	0	0	5	19	–	–	–	–	–
1997	0	0	8	8	–	–	–	–	–
1998	5	0	0	17	–	–	–	–	–
1999	8	3	22	10	–	–	–	–	–
2000	3	7	1	21	–	–	–	–	–
2001	0	21	5	28	–	–	–	–	–
2002	5	18	1	23	–	–	–	–	–
2003	0	24	0	48	–	–	–	–	–
2004	0	0	0	14	–	–	–	–	–
2005	4	0	0	9	–	–	–	–	–
2006	0	0	1	25	–	–	–	–	–
2007	0	0	21	13	–	–	–	–	–

2008	0	0	5	43	–	–	–	–	–
2009	0	0	9	36	–	–	–	–	–
2010	1	0	5	12	–	–	–	–	–
2011	1	0	15	12	–	–	–	–	–
2012	1	0	6	16	–	–	–	–	–
2013	1	0	6	24	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	1	–	–	–	–	–
1992	0	0	0	1	–	–	–	–	–
1993	1	0	0	0	–	–	–	–	–
1994	0	1	0	0	–	–	–	–	–
1995	0	0	0	0	–	–	–	–	–
1996	0	0	0	1	–	–	–	–	–
1997	0	0	0	0	–	–	–	–	–
1998	3	0	0	1	–	–	–	–	–
1999	0	2	0	1	–	–	–	–	–
2000	0	4	0	2	–	–	–	–	–
2001	0	25	0	3	–	–	–	–	–
2002	1	15	0	2	–	–	–	–	–
2003	0	12	0	3	–	–	–	–	–
2004	0	1	0	1	–	–	–	–	–
2005	0	0	0	0	–	–	–	–	–
2006	0	0	0	1	–	–	–	–	–
2007	0	1	0	1	–	–	–	–	–
2008	0	0	0	2	–	–	–	–	–
2009	0	0	0	1	–	–	–	–	–
2010	0	0	0	1	–	–	–	–	–
2011	0	0	0	1	–	–	–	–	–
2012	0	0	0	1	–	–	–	–	–
2013	0	0	0	1	–	–	–	–	–

WEST COAST SOUTH ISLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	36	164	8589	2206	0	516	0	11513
1992	0	23	164	6335	2864	0	1082	0	10468
1993	95	2	164	3431	800	0	147	0	4639
1994	2	5	320	9426	2129	9	213	0	12103
1995	68	1	223	13187	3253	0	509	0	17240
1996	12	0	401	12211	3050	2	370	0	16045
1997	7	2	480	11341	3535	5	419	0	15789
1998	26	2	406	10964	4376	24	276	0	16074
1999	38	5	292	7028	9536	8	426	0	17333
2000	15	0	281	7168	3906	14	654	0	12037
2001	0	38	463	8222	9191	2	161	0	18076
2002	15	5	221	7245	3903	0	65	0	11453
2003	9	185	282	6077	2810	0	75	0	9437
2004	0	45	158	6830	357	0	85	0	7475
2005	10	76	310	4554	1142	0	62	0	6153
2006	0	16	255	4051	1142	2	89	0	5555
2007	0	41	264	2557	1142	0	34	0	4038
2008	0	0	364	3083	1142	0	0	0	4589
2009	0	6	370	2750	1142	0	14	0	4282
2010	0	9	386	1696	1142	0	14	0	3247
2011	0	0	332	3439	1142	0	14	0	4927

2012	0	0	428	2755	1142	0	14	0	4339
2013	0	0	428	3827	1142	0	14	0	5411
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	36	125	8169	–	0	67	–	–
1992	0	23	125	5923	–	0	532	–	–
1993	47	2	125	3070	–	0	104	–	–
1994	1	5	141	9036	–	0	74	–	–
1995	33	1	157	11886	–	0	142	–	–
1996	3	0	249	11768	–	0	928	–	–
1997	3	2	276	10831	–	0	157	–	–
1998	10	2	247	10105	–	0	31	–	–
1999	12	5	24	5895	–	0	68	–	–
2000	6	0	167	5961	–	0	69	–	–
2001	0	36	298	7199	–	0	68	–	–
2002	6	5	139	5048	–	0	36	–	–
2003	6	161	203	4648	–	0	34	–	–
2004	0	42	83	5259	–	0	34	–	–
2005	4	65	176	3642	–	0	8	–	–
2006	0	13	154	2797	–	0	33	–	–
2007	0	34	172	1979	–	0	11	–	–
2008	0	0	208	2058	–	0	0	–	–
2009	0	5	234	2024	–	0	1	–	–
2010	0	8	231	1117	–	0	1	–	–
2011	0	0	213	2267	–	0	1	–	–
2012	0	0	234	2097	–	0	1	–	–
2013	0	0	234	2380	–	0	1	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	0	39	289	–	–	–	–	–
1992	0	0	39	247	–	–	–	–	–
1993	47	0	39	311	–	–	–	–	–
1994	1	0	179	229	–	–	–	–	–
1995	34	0	66	1088	–	–	–	–	–
1996	7	0	151	394	–	–	–	–	–
1997	2	0	204	454	–	–	–	–	–
1998	10	0	158	804	–	–	–	–	–
1999	25	0	268	1065	–	–	–	–	–
2000	9	0	114	1147	–	–	–	–	–
2001	0	1	165	891	–	–	–	–	–
2002	8	0	83	1775	–	–	–	–	–
2003	3	16	79	1166	–	–	–	–	–
2004	0	0	74	1206	–	–	–	–	–
2005	6	8	135	813	–	–	–	–	–
2006	0	1	101	1103	–	–	–	–	–
2007	0	2	92	473	–	–	–	–	–
2008	0	0	156	945	–	–	–	–	–
2009	0	0	135	668	–	–	–	–	–
2010	0	0	155	518	–	–	–	–	–
2011	0	0	119	1027	–	–	–	–	–
2012	0	0	194	534	–	–	–	–	–
2013	0	0	194	1273	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	131	–	–	–	–	–
1992	0	0	0	165	–	–	–	–	–
1993	2	0	0	50	–	–	–	–	–

1994	0	0	0	161	–	–	–	–	–
1995	1	0	0	213	–	–	–	–	–
1996	1	0	0	49	–	–	–	–	–
1997	2	0	0	56	–	–	–	–	–
1998	6	0	0	55	–	–	–	–	–
1999	1	0	0	68	–	–	–	–	–
2000	1	0	0	60	–	–	–	–	–
2001	0	1	0	132	–	–	–	–	–
2002	1	0	0	422	–	–	–	–	–
2003	0	8	0	263	–	–	–	–	–
2004	0	3	0	365	–	–	–	–	–
2005	0	3	0	99	–	–	–	–	–
2006	0	3	0	151	–	–	–	–	–
2007	0	5	0	105	–	–	–	–	–
2008	0	0	0	80	–	–	–	–	–
2009	0	1	0	58	–	–	–	–	–
2010	0	1	0	61	–	–	–	–	–
2011	0	0	0	145	–	–	–	–	–
2012	0	0	0	124	–	–	–	–	–
2013	0	0	0	174	–	–	–	–	–

Appendix 17.12: DISCARDS: Annual discards (t) by fishery area for the species categories QMS, non-QMS, Invertebrate, and overall, for seven Deepwater trawl fisheries and one longline fishery (1990–91 to 2010–11). Where data have not yet been updated for recent years for a fishery figures from the last available year have been assumed, in order for annual totals to be calculated. LLL = ling longline fishery; HHL = hoki/hake/ling fishery; – = not estimated.

AUCKLAND ISLANDS									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	4	74	17	5	0	0	0	0	100
1992	90	18	17	5	0	0	0	0	130
1993	278	68	17	9	0	9	2	0	383
1994	539	37	0	12	0	1	12	0	601
1995	707	32	12	10	0	47	20	0	829
1996	716	55	18	13	6	5	17	0	830
1997	1383	183	34	15	2	6	10	0	1634
1998	517	332	8	42	0	4	14	0	917
1999	645	101	13	19	0	27	15	0	820
2000	790	55	52	47	0	18	8	0	970
2001	421	115	58	69	0	5	6	0	674
2002	610	191	1	41	0	10	4	0	856
2003	747	671	0	38	0	18	4	0	1478
2004	129	962	12	20	0	7	2	0	1132
2005	621	403	1	14	0	1	1	0	1042
2006	369	926	0	3	0	1	0	0	1299
2007	628	546	0	3	0	0	0	0	1176
2008	371	197	0	3	0	4	3	0	577
2009	352	670	0	0	0	4	0	0	1027
2010	576	587	12	2	0	4	0	0	1181
2011	576	638	66	0	0	4	0	0	1284
2012	576	638	6	3	0	4	0	0	1226
2013	576	638	6	4	0	4	0	0	1227
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	10	15	3	–	0	0	–	–
1992	24	3	15	3	–	0	0	–	–
1993	18	16	15	6	–	0	0	–	–

1994	74	30	0	8	–	0	0	–	–
1995	261	16	10	7	–	0	0	–	–
1996	73	1	17	9	–	0	0	–	–
1997	249	51	33	11	–	0	0	–	–
1998	51	41	6	29	–	0	0	–	–
1999	52	67	11	14	–	0	0	–	–
2000	126	6	33	33	–	0	0	–	–
2001	22	18	58	44	–	1	0	–	–
2002	43	12	1	29	–	0	0	–	–
2003	61	38	0	27	–	0	0	–	–
2004	6	131	9	14	–	0	0	–	–
2005	35	30	1	10	–	1	0	–	–
2006	2	36	0	2	–	0	0	–	–
2007	57	20	0	2	–	0	0	–	–
2008	1	23	0	2	–	0	0	–	–
2009	7	51	0	0	–	0	0	–	–
2010	15	55	7	2	–	0	0	–	–
2011	15	95	66	0	–	0	0	–	–
2012	15	95	1	2	–	0	0	–	–
2013	15	95	1	3	–	0	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	3	11	2	1	–	–	–	–	–
1992	59	11	2	1	–	–	–	–	–
1993	159	47	2	2	–	–	–	–	–
1994	414	6	0	2	–	–	–	–	–
1995	215	8	2	2	–	–	–	–	–
1996	507	1	1	2	–	–	–	–	–
1997	638	16	1	3	–	–	–	–	–
1998	338	62	2	8	–	–	–	–	–
1999	507	18	2	4	–	–	–	–	–
2000	486	13	19	9	–	–	–	–	–
2001	336	5	0	17	–	–	–	–	–
2002	424	21	0	8	–	–	–	–	–
2003	460	244	0	7	–	–	–	–	–
2004	67	17	4	4	–	–	–	–	–
2005	418	78	0	3	–	–	–	–	–
2006	111	66	0	1	–	–	–	–	–
2007	421	125	0	1	–	–	–	–	–
2008	268	47	0	0	–	–	–	–	–
2009	338	50	0	0	–	–	–	–	–
2010	516	25	5	0	–	–	–	–	–
2011	516	121	0	0	–	–	–	–	–
2012	516	121	4	1	–	–	–	–	–
2013	516	121	4	1	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	52	0	1	–	–	–	–	–
1992	8	4	0	0	–	–	–	–	–
1993	102	5	0	1	–	–	–	–	–
1994	51	0	0	1	–	–	–	–	–
1995	232	8	0	1	–	–	–	–	–
1996	136	53	0	1	–	–	–	–	–
1997	496	116	0	2	–	–	–	–	–
1998	128	229	0	4	–	–	–	–	–
1999	85	16	0	2	–	–	–	–	–
2000	178	36	0	5	–	–	–	–	–
2001	64	92	0	8	–	–	–	–	–

2002	142	159	0	4	–	–	–	–	–
2003	226	389	0	4	–	–	–	–	–
2004	56	814	0	2	–	–	–	–	–
2005	168	296	0	1	–	–	–	–	–
2006	257	824	0	0	–	–	–	–	–
2007	150	400	0	0	–	–	–	–	–
2008	101	127	0	1	–	–	–	–	–
2009	7	569	0	0	–	–	–	–	–
2010	44	506	0	0	–	–	–	–	–
2011	44	421	0	0	–	–	–	–	–
2012	44	421	0	0	–	–	–	–	–
2013	44	421	0	0	–	–	–	–	–

CHATHAM RISE									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	154	241	605	3239	861	454	2419	0	7973
1992	1364	303	605	6387	100	201	1053	0	10015
1993	2314	610	605	2028	360	240	1186	0	7344
1994	1402	1718	862	1650	48	302	937	0	6919
1995	809	453	1019	2817	278	184	946	0	6505
1996	4126	110	1107	3737	24	423	671	0	10199
1997	783	889	765	3066	68	372	720	0	6662
1998	657	1436	1661	8244	1845	364	840	0	15046
1999	361	990	587	5314	110	272	1020	0	8654
2000	271	825	690	9829	125	297	787	0	12825
2001	1366	2721	874	6981	18	151	1012	0	13123
2002	1303	1698	1709	9545	77	125	687	0	15144
2003	758	523	1027	8566	150	112	983	0	12119
2004	731	382	806	3181	3	190	793	0	6086
2005	1884	2596	1080	870	0	260	902	0	7592
2006	572	786	955	963	0	176	859	0	4312
2007	1423	2449	546	1814	0	191	393	0	6815
2008	1615	315	1016	1562	0	168	470	0	5146
2009	1326	105	875	2610	0	176	190	0	5283
2010	1470	236	950	6548	0	176	190	0	9571
2011	1470	326	879	2685	0	176	190	0	5726
2012	1470	326	517	1293	0	176	190	0	3972
2013	1470	326	517	2628	0	176	190	0	5307
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	23	187	349	352	–	6	10	–	–
1992	20	169	349	457	–	3	5	–	–
1993	340	492	349	393	–	5	10	–	–
1994	504	1688	693	254	–	5	30	–	–
1995	0	335	799	169	–	4	4	–	–
1996	444	67	913	534	–	6	18	–	–
1997	176	782	619	136	–	6	18	–	–
1998	127	1000	1476	992	–	7	7	–	–
1999	16	735	560	1955	–	9	3	–	–
2000	168	646	690	2135	–	10	13	–	–
2001	179	1965	791	1142	–	1	2	–	–
2002	167	1174	1497	1341	–	3	2	–	–
2003	289	138	920	834	–	5	0	–	–
2004	353	322	727	781	–	0	0	–	–
2005	390	1542	902	341	–	1	7	–	–
2006	20	549	889	267	–	5	0	–	–

2007	283	1398	417	201	–	0	0	–	–
2008	364	220	884	122	–	4	0	–	–
2009	382	73	803	159	–	0	0	–	–
2010	188	168	793	226	–	0	0	–	–
2011	188	223	399	81	–	0	0	–	–
2012	188	223	313	320	–	0	0	–	–
2013	188	223	313	120	–	0	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	131	50	257	2147	–	–	–	–	–
1992	1345	126	257	4954	–	–	–	–	–
1993	1957	113	257	331	–	–	–	–	–
1994	865	30	169	989	–	–	–	–	–
1995	809	108	220	964	–	–	–	–	–
1996	3309	28	194	2736	–	–	–	–	–
1997	550	92	145	2610	–	–	–	–	–
1998	502	424	185	6288	–	–	–	–	–
1999	345	242	24	2706	–	–	–	–	–
2000	91	173	0	6124	–	–	–	–	–
2001	1178	727	83	5199	–	–	–	–	–
2002	1117	516	192	7153	–	–	–	–	–
2003	450	366	87	6336	–	–	–	–	–
2004	367	56	71	2205	–	–	–	–	–
2005	1448	1035	179	402	–	–	–	–	–
2006	492	224	65	555	–	–	–	–	–
2007	1050	964	126	1484	–	–	–	–	–
2008	1169	91	131	1330	–	–	–	–	–
2009	876	30	71	2389	–	–	–	–	–
2010	1258	66	156	5600	–	–	–	–	–
2011	1258	100	479	2268	–	–	–	–	–
2012	1258	100	202	899	–	–	–	–	–
2013	1258	100	202	2388	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	4	0	16	–	–	–	–	–
1992	0	8	0	256	–	–	–	–	–
1993	18	6	0	26	–	–	–	–	–
1994	32	0	0	76	–	–	–	–	–
1995	0	10	0	139	–	–	–	–	–
1996	373	16	0	17	–	–	–	–	–
1997	57	15	0	105	–	–	–	–	–
1998	28	11	0	362	–	–	–	–	–
1999	0	13	4	472	–	–	–	–	–
2000	12	6	0	1545	–	–	–	–	–
2001	9	29	0	586	–	–	–	–	–
2002	19	8	20	1031	–	–	–	–	–
2003	20	18	20	252	–	–	–	–	–
2004	10	5	8	85	–	–	–	–	–
2005	46	19	0	127	–	–	–	–	–
2006	59	13	2	139	–	–	–	–	–
2007	89	87	3	43	–	–	–	–	–
2008	82	4	2	52	–	–	–	–	–
2009	69	1	1	19	–	–	–	–	–
2010	24	2	2	70	–	–	–	–	–
2011	24	3	1	37	–	–	–	–	–
2012	24	3	2	7	–	–	–	–	–
2013	24	3	2	41	–	–	–	–	–

COOK STRAIT									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	3	1081	0	3	76	0	1164
1992	0	0	3	769	0	1	84	0	857
1993	0	4	3	786	0	2	56	0	852
1994	0	0	2	917	0	1	71	0	991
1995	9	0	3	1729	0	2	84	0	1826
1996	0	0	2	3896	0	1	24	0	3923
1997	0	0	1	3259	0	6	32	0	3299
1998	0	0	6	2033	0	3	15	0	2057
1999	3	9	16	1871	31	4	35	0	1968
2000	1	0	21	2724	16	3	16	0	2780
2001	0	7	65	1312	18	6	6	0	1414
2002	36	0	13	718	0	6	7	0	780
2003	4	2	4	2570	0	3	3	0	2587
2004	0	0	15	977	0	1	4	0	996
2005	18	0	31	593	0	1	5	0	648
2006	0	0	36	206	0	2	0	0	244
2007	0	0	48	851	0	0	3	0	902
2008	0	0	35	576	0	0	13	0	624
2009	0	0	8	510	0	0	4	0	522
2010	0	0	7	367	0	0	4	0	378
2011	0	0	8	747	0	0	4	0	759
2012	0	0	5	340	0	0	4	0	348
2013	0	0	5	178	0	0	4	0	186
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	2	843	–	0	0	–	–
1992	0	0	2	600	–	0	0	–	–
1993	0	4	2	613	–	0	0	–	–
1994	0	0	1	118	–	0	0	–	–
1995	0	0	1	1348	–	0	0	–	–
1996	0	0	1	3026	–	0	0	–	–
1997	0	0	0	2542	–	0	0	–	–
1998	0	0	2	1586	–	0	0	–	–
1999	0	7	10	1543	–	0	0	–	–
2000	0	0	8	2702	–	0	0	–	–
2001	0	5	17	1245	–	1	0	–	–
2002	3	0	5	728	–	0	0	–	–
2003	1	1	2	2552	–	0	0	–	–
2004	0	0	7	938	–	0	0	–	–
2005	3	0	11	488	–	1	0	–	–
2006	0	0	12	204	–	0	0	–	–
2007	0	0	27	760	–	0	0	–	–
2008	0	0	27	404	–	0	0	–	–
2009	0	0	3	284	–	0	0	–	–
2010	0	0	2	163	–	0	0	–	–
2011	0	0	3	242	–	0	0	–	–
2012	0	0	0	266	–	0	0	–	–
2013	0	0	0	78	–	0	0	–	–

Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	2	151	–	–	–	–	–
1992	0	0	2	108	–	–	–	–	–
1993	0	0	2	110	–	–	–	–	–
1994	0	0	1	693	–	–	–	–	–
1995	9	0	2	242	–	–	–	–	–
1996	0	0	1	129	–	–	–	–	–
1997	0	0	1	456	–	–	–	–	–
1998	0	0	4	284	–	–	–	–	–
1999	3	2	7	36	–	–	–	–	–
2000	1	0	12	12	–	–	–	–	–
2001	0	1	44	37	–	–	–	–	–
2002	29	0	8	2	–	–	–	–	–
2003	3	1	2	15	–	–	–	–	–
2004	0	0	8	27	–	–	–	–	–
2005	14	0	20	105	–	–	–	–	–
2006	0	0	25	2	–	–	–	–	–
2007	0	0	21	83	–	–	–	–	–
2008	0	0	8	170	–	–	–	–	–
2009	0	0	5	154	–	–	–	–	–
2010	0	0	5	156	–	–	–	–	–
2011	0	0	5	19	–	–	–	–	–
2012	0	0	4	75	–	–	–	–	–
2013	0	0	4	99	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	1	–	–	–	–	–
1992	0	0	0	1	–	–	–	–	–
1993	0	0	0	1	–	–	–	–	–
1994	0	0	0	15	–	–	–	–	–
1995	0	0	0	2	–	–	–	–	–
1996	0	0	0	0	–	–	–	–	–
1997	0	0	0	4	–	–	–	–	–
1998	0	0	0	2	–	–	–	–	–
1999	0	0	0	1	–	–	–	–	–
2000	0	0	1	0	–	–	–	–	–
2001	0	1	4	0	–	–	–	–	–
2002	4	0	0	0	–	–	–	–	–
2003	0	0	0	0	–	–	–	–	–
2004	0	0	0	0	–	–	–	–	–
2005	1	0	0	0	–	–	–	–	–
2006	0	0	0	0	–	–	–	–	–
2007	0	0	0	1	–	–	–	–	–
2008	0	0	0	1	–	–	–	–	–
2009	0	0	0	2	–	–	–	–	–
2010	0	0	0	1	–	–	–	–	–
2011	0	0	0	0	–	–	–	–	–
2012	0	0	0	0	–	–	–	–	–
2013	0	0	0	1	–	–	–	–	–

EAST COAST NORTH ISLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1535	0	24	178	0	9	664	0	2411
1992	696	0	24	131	0	4	692	0	1548

1993	579	0	24	130	0	7	555	0	1295
1994	540	0	41	351	3	1	689	0	1625
1995	418	0	27	316	0	13	893	0	1666
1996	1083	0	30	582	0	13	969	0	2677
1997	405	0	31	726	0	57	873	0	2092
1998	624	0	42	3	0	32	669	0	1369
1999	1240	0	24	218	0	36	627	0	2145
2000	348	0	43	181	0	20	275	0	866
2001	702	0	114	228	3	23	1093	0	2163
2002	2284	0	59	174	6	17	82	0	2622
2003	767	1	23	223	0	22	210	0	1247
2004	494	0	58	116	0	7	706	0	1380
2005	368	0	64	41	0	5	283	0	762
2006	292	0	96	51	0	3	7	0	449
2007	437	0	66	60	0	2	53	0	618
2008	391	0	84	38	0	0	94	0	607
2009	219	0	78	48	0	0	51	0	396
2010	420	0	81	89	0	0	51	0	640
2011	420	0	73	147	0	0	51	0	691
2012	420	0	79	56	0	0	51	0	606
2013	420	0	79	104	0	0	51	0	654
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	24	0	11	24	–	0	3	–	–
1992	142	0	11	24	–	0	3	–	–
1993	158	0	11	21	–	0	2	–	–
1994	278	0	7	92	–	0	2	–	–
1995	43	0	10	77	–	0	18	–	–
1996	57	0	8	279	–	0	5	–	–
1997	194	0	7	206	–	1	2	–	–
1998	110	0	11	3	–	0	5	–	–
1999	50	0	11	94	–	0	3	–	–
2000	84	0	12	74	–	0	0	–	–
2001	145	0	22	58	–	1	2	–	–
2002	456	0	14	35	–	0	0	–	–
2003	153	1	9	59	–	0	0	–	–
2004	129	0	18	36	–	0	0	–	–
2005	39	0	16	16	–	1	7	–	–
2006	30	0	17	12	–	0	0	–	–
2007	68	0	24	22	–	0	3	–	–
2008	60	0	56	6	–	0	0	–	–
2009	26	0	19	8	–	0	2	–	–
2010	93	0	16	10	–	0	2	–	–
2011	93	0	19	14	–	0	2	–	–
2012	93	0	6	20	–	0	2	–	–
2013	93	0	6	23	–	0	2	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1512	0	13	67	–	–	–	–	–
1992	524	0	13	51	–	–	–	–	–
1993	329	0	13	11	–	–	–	–	–
1994	221	0	34	58	–	–	–	–	–
1995	367	0	17	56	–	–	–	–	–
1996	1026	0	22	95	–	–	–	–	–
1997	201	0	23	205	–	–	–	–	–
1998	468	0	31	0	–	–	–	–	–
1999	1159	0	13	84	–	–	–	–	–
2000	236	0	30	77	–	–	–	–	–

2001	482	0	84	134	–	–	–	–	–
2002	1536	0	44	118	–	–	–	–	–
2003	577	0	14	110	–	–	–	–	–
2004	342	0	39	60	–	–	–	–	–
2005	298	0	48	19	–	–	–	–	–
2006	225	0	78	36	–	–	–	–	–
2007	345	0	41	30	–	–	–	–	–
2008	312	0	28	29	–	–	–	–	–
2009	165	0	59	36	–	–	–	–	–
2010	303	0	64	68	–	–	–	–	–
2011	303	0	54	99	–	–	–	–	–
2012	303	0	73	26	–	–	–	–	–
2013	303	0	73	67	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	3	–	–	–	–	–
1992	31	0	0	2	–	–	–	–	–
1993	93	0	0	1	–	–	–	–	–
1994	42	0	0	7	–	–	–	–	–
1995	8	0	0	4	–	–	–	–	–
1996	0	0	0	1	–	–	–	–	–
1997	10	0	0	10	–	–	–	–	–
1998	46	0	0	0	–	–	–	–	–
1999	31	0	0	11	–	–	–	–	–
2000	29	0	1	15	–	–	–	–	–
2001	74	0	8	14	–	–	–	–	–
2002	293	0	0	14	–	–	–	–	–
2003	38	0	1	6	–	–	–	–	–
2004	23	0	0	2	–	–	–	–	–
2005	31	0	0	3	–	–	–	–	–
2006	38	0	0	2	–	–	–	–	–
2007	25	0	0	1	–	–	–	–	–
2008	19	0	0	2	–	–	–	–	–
2009	29	0	0	1	–	–	–	–	–
2010	25	0	0	2	–	–	–	–	–
2011	25	0	0	5	–	–	–	–	–
2012	25	0	0	1	–	–	–	–	–
2013	25	0	0	2	–	–	–	–	–

NORTHLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	615	0	23	13	0	0	5	0	657
1992	405	0	23	91	0	0	1	0	520
1993	303	1	23	127	0	0	2	0	457
1994	231	0	44	53	0	0	4	0	332
1995	386	0	23	191	0	0	3	0	604
1996	732	0	18	215	0	0	8	0	973
1997	431	1	22	520	0	0	40	0	1015
1998	214	0	33	2	0	0	37	0	286
1999	137	0	7	144	0	1	118	0	406
2000	262	0	8	117	0	0	16	0	404
2001	383	1	17	70	9	0	2	0	482
2002	832	0	4	124	0	0	8	0	969
2003	466	7	9	81	0	0	17	0	580
2004	482	2	5	49	0	0	8	0	546
2005	169	0	12	15	0	1	10	0	207

2006	196	2	13	60	0	2	3	0	276
2007	472	4	12	43	0	0	2	0	534
2008	444	0	24	32	0	0	8	0	508
2009	332	2	11	34	0	0	3	0	383
2010	332	0	13	141	0	0	3	0	490
2011	332	0	19	93	0	0	3	0	448
2012	332	0	23	61	0	0	3	0	420
2013	332	0	23	134	0	0	3	0	493
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	13	0	9	2	–	0	0	–	–
1992	115	0	9	17	–	0	0	–	–
1993	60	1	9	20	–	0	0	–	–
1994	39	0	7	14	–	0	0	–	–
1995	57	0	8	47	–	0	0	–	–
1996	120	0	4	103	–	0	0	–	–
1997	83	1	5	148	–	0	2	–	–
1998	26	0	8	2	–	0	5	–	–
1999	2	0	3	62	–	0	29	–	–
2000	6	0	2	48	–	0	1	–	–
2001	52	1	6	18	–	1	0	–	–
2002	164	0	1	25	–	0	1	–	–
2003	69	4	2	21	–	0	0	–	–
2004	90	1	1	15	–	0	3	–	–
2005	10	0	5	6	–	1	7	–	–
2006	8	1	3	15	–	0	0	–	–
2007	52	1	1	16	–	0	0	–	–
2008	75	0	17	6	–	0	10	–	–
2009	55	1	3	6	–	0	0	–	–
2010	84	0	3	15	–	0	0	–	–
2011	84	0	5	9	–	0	0	–	–
2012	84	0	2	22	–	0	0	–	–
2013	84	0	2	29	–	0	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	602	0	14	5	–	–	–	–	–
1992	288	0	14	36	–	–	–	–	–
1993	189	0	14	11	–	–	–	–	–
1994	170	0	37	9	–	–	–	–	–
1995	330	0	15	34	–	–	–	–	–
1996	566	0	14	35	–	–	–	–	–
1997	338	0	17	147	–	–	–	–	–
1998	171	0	25	0	–	–	–	–	–
1999	131	0	4	55	–	–	–	–	–
2000	248	0	6	50	–	–	–	–	–
2001	294	0	11	41	–	–	–	–	–
2002	502	0	3	84	–	–	–	–	–
2003	355	2	7	40	–	–	–	–	–
2004	366	0	4	25	–	–	–	–	–
2005	136	0	7	7	–	–	–	–	–
2006	172	1	10	42	–	–	–	–	–
2007	314	1	11	21	–	–	–	–	–
2008	351	0	7	25	–	–	–	–	–
2009	231	0	9	26	–	–	–	–	–
2010	221	0	11	108	–	–	–	–	–
2011	221	0	14	63	–	–	–	–	–
2012	221	0	21	28	–	–	–	–	–
2013	221	0	21	86	–	–	–	–	–

Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	0	–	–	–	–	–
1992	2	0	0	1	–	–	–	–	–
1993	54	0	0	1	–	–	–	–	–
1994	23	0	0	1	–	–	–	–	–
1995	0	0	0	2	–	–	–	–	–
1996	47	0	0	0	–	–	–	–	–
1997	10	0	0	7	–	–	–	–	–
1998	17	0	0	0	–	–	–	–	–
1999	4	0	0	8	–	–	–	–	–
2000	8	0	0	10	–	–	–	–	–
2001	37	0	0	4	–	–	–	–	–
2002	167	0	0	10	–	–	–	–	–
2003	42	1	0	2	–	–	–	–	–
2004	26	1	0	1	–	–	–	–	–
2005	23	0	0	1	–	–	–	–	–
2006	16	1	0	2	–	–	–	–	–
2007	106	2	0	1	–	–	–	–	–
2008	18	0	0	2	–	–	–	–	–
2009	46	1	0	1	–	–	–	–	–
2010	27	0	0	3	–	–	–	–	–
2011	27	0	0	3	–	–	–	–	–
2012	27	0	0	1	–	–	–	–	–
2013	27	0	0	2	–	–	–	–	–

PUYSEGUR									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	1	21	225	0	26	34	0	306
1992	1	17	21	512	0	34	139	0	724
1993	13	31	21	208	0	115	118	0	505
1994	0	5	27	248	3	32	268	0	582
1995	2	5	22	227	0	63	38	0	358
1996	0	1	34	567	0	75	117	0	794
1997	21	25	60	429	0	100	34	0	669
1998	27	24	122	293	0	90	8	0	564
1999	196	16	66	270	0	130	5	0	683
2000	15	12	42	307	0	109	3	0	488
2001	84	162	106	253	0	167	76	0	848
2002	0	282	60	297	0	129	21	0	788
2003	96	366	45	196	0	215	32	0	950
2004	28	75	34	38	0	98	16	0	290
2005	5	912	39	295	0	107	31	0	1390
2006	0	70	54	188	0	45	3	0	360
2007	0	10	45	129	0	31	0	0	215
2008	0	5	116	113	0	153	2	0	389
2009	0	3	14	88	0	30	3	0	138
2010	0	16	4	66	0	30	3	0	118
2011	0	29	57	151	0	30	3	0	269
2012	0	29	16	132	0	30	3	0	209
2013	0	29	16	216	0	30	3	0	293

QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	11	30	–	0	0	–	–
1992	0	4	11	61	–	0	1	–	–
1993	1	15	11	8	–	0	0	–	–
1994	0	2	16	29	–	0	2	–	–
1995	0	2	10	27	–	0	0	–	–
1996	0	0	11	16	–	0	1	–	–
1997	6	16	17	51	–	0	1	–	–
1998	4	8	39	35	–	0	0	–	–
1999	7	7	36	32	–	0	0	–	–
2000	3	5	11	167	–	0	0	–	–
2001	12	70	41	66	–	1	2	–	–
2002	0	160	18	35	–	0	0	–	–
2003	29	120	14	24	–	0	0	–	–
2004	13	41	23	14	–	0	0	–	–
2005	1	250	10	35	–	1	0	–	–
2006	0	24	15	22	–	0	0	–	–
2007	0	3	9	15	–	0	0	–	–
2008	0	2	52	13	–	0	0	–	–
2009	0	1	5	10	–	0	0	–	–
2010	0	6	1	8	–	0	0	–	–
2011	0	10	0	18	–	0	0	–	–
2012	0	10	1	3	–	0	0	–	–
2013	0	10	1	19	–	0	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	1	10	108	–	–	–	–	–
1992	1	12	10	282	–	–	–	–	–
1993	10	16	10	108	–	–	–	–	–
1994	0	2	11	137	–	–	–	–	–
1995	2	3	12	125	–	–	–	–	–
1996	0	1	23	16	–	–	–	–	–
1997	9	9	43	236	–	–	–	–	–
1998	21	16	82	162	–	–	–	–	–
1999	184	9	30	149	–	–	–	–	–
2000	10	7	30	139	–	–	–	–	–
2001	66	89	63	181	–	–	–	–	–
2002	0	118	42	164	–	–	–	–	–
2003	58	237	31	8	–	–	–	–	–
2004	14	33	11	24	–	–	–	–	–
2005	4	661	29	162	–	–	–	–	–
2006	0	45	38	104	–	–	–	–	–
2007	0	7	37	71	–	–	–	–	–
2008	0	4	64	62	–	–	–	–	–
2009	0	2	10	48	–	–	–	–	–
2010	0	10	3	36	–	–	–	–	–
2011	0	19	57	83	–	–	–	–	–
2012	0	19	15	104	–	–	–	–	–
2013	0	19	15	148	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	7	–	–	–	–	–
1992	0	1	0	4	–	–	–	–	–
1993	2	1	0	0	–	–	–	–	–
1994	0	0	0	2	–	–	–	–	–
1995	0	0	0	2	–	–	–	–	–
1996	0	0	0	2	–	–	–	–	–

1997	6	1	0	4	–	–	–	–	–
1998	2	0	1	3	–	–	–	–	–
1999	5	0	0	2	–	–	–	–	–
2000	2	0	1	0	–	–	–	–	–
2001	6	2	2	1	–	–	–	–	–
2002	0	3	0	3	–	–	–	–	–
2003	9	9	0	0	–	–	–	–	–
2004	1	1	0	0	–	–	–	–	–
2005	0	1	0	3	–	–	–	–	–
2006	0	1	0	2	–	–	–	–	–
2007	0	0	0	1	–	–	–	–	–
2008	0	0	0	1	–	–	–	–	–
2009	0	0	0	1	–	–	–	–	–
2010	0	0	0	1	–	–	–	–	–
2011	0	0	0	1	–	–	–	–	–
2012	0	0	0	2	–	–	–	–	–
2013	0	0	0	2	–	–	–	–	–

STEWART-SNARES SHELF									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	144	15	1471	0	14	1	0	1645
1992	0	83	15	1531	1405	21	2	0	3056
1993	3	1344	15	1942	105	11	2	0	3423
1994	0	99	39	585	13	7	3	0	745
1995	1	79	171	211	64	16	0	0	542
1996	3	4	15	459	503	28	4	0	1014
1997	6	1659	55	1017	51	91	57	0	2936
1998	14	1826	96	1167	0	50	10	0	3163
1999	64	1335	132	1430	40	174	6	0	3180
2000	2	162	55	1114	612	140	2	0	2088
2001	2	928	58	1852	39	69	3	0	2950
2002	0	3145	46	2221	277	170	1	0	5860
2003	25	2663	34	1035	13	96	0	0	3865
2004	17	1001	58	499	0	79	0	0	1654
2005	4	1153	70	388	4	64	0	0	1683
2006	0	800	18	1299	4	55	0	0	2176
2007	0	478	218	434	4	43	0	0	1178
2008	0	333	74	82	4	14	1	0	508
2009	0	1050	34	136	4	71	0	0	1295
2010	0	956	23	277	4	71	0	0	1332
2011	0	1206	23	807	4	71	0	0	2112
2012	0	1206	252	589	4	71	0	0	2123
2013	0	1206	252	615	4	71	0	0	2149
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	132	11	74	–	0	0	–	–
1992	0	35	11	18	–	0	0	–	–
1993	0	1281	11	560	–	0	0	–	–
1994	0	97	26	204	–	0	0	–	–
1995	0	66	155	39	–	0	0	–	–
1996	0	2	14	258	–	0	0	–	–
1997	1	1518	29	42	–	1	0	–	–
1998	2	1519	96	320	–	0	0	–	–
1999	2	1118	55	161	–	0	0	–	–
2000	1	146	21	307	–	0	0	–	–
2001	0	838	36	289	–	1	0	–	–

2002	0	3038	20	721	–	3	0	–	–
2003	7	2261	25	611	–	0	0	–	–
2004	7	969	35	259	–	0	0	–	–
2005	1	890	65	87	–	1	0	–	–
2006	0	596	4	736	–	0	0	–	–
2007	0	354	146	172	–	0	0	–	–
2008	0	266	27	8	–	0	0	–	–
2009	0	803	18	47	–	0	0	–	–
2010	0	738	9	117	–	0	0	–	–
2011	0	821	13	152	–	0	0	–	–
2012	0	821	190	154	–	0	0	–	–
2013	0	821	190	233	–	0	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	9	4	1150	–	–	–	–	–
1992	0	41	4	1288	–	–	–	–	–
1993	3	35	4	1292	–	–	–	–	–
1994	0	2	13	209	–	–	–	–	–
1995	1	11	16	94	–	–	–	–	–
1996	3	1	1	201	–	–	–	–	–
1997	3	3	25	832	–	–	–	–	–
1998	11	278	0	601	–	–	–	–	–
1999	60	176	77	954	–	–	–	–	–
2000	2	13	33	590	–	–	–	–	–
2001	2	55	21	1450	–	–	–	–	–
2002	0	90	25	1298	–	–	–	–	–
2003	15	352	8	354	–	–	–	–	–
2004	9	22	23	201	–	–	–	–	–
2005	3	244	6	261	–	–	–	–	–
2006	0	182	14	517	–	–	–	–	–
2007	0	112	73	114	–	–	–	–	–
2008	0	59	47	68	–	–	–	–	–
2009	0	238	15	49	–	–	–	–	–
2010	0	207	15	83	–	–	–	–	–
2011	0	370	10	387	–	–	–	–	–
2012	0	370	62	188	–	–	–	–	–
2013	0	370	62	266	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	3	0	109	–	–	–	–	–
1992	0	7	0	8	–	–	–	–	–
1993	0	29	0	88	–	–	–	–	–
1994	0	0	0	83	–	–	–	–	–
1995	0	1	0	75	–	–	–	–	–
1996	0	1	0	0	–	–	–	–	–
1997	2	138	0	65	–	–	–	–	–
1998	1	30	0	79	–	–	–	–	–
1999	2	40	0	103	–	–	–	–	–
2000	0	3	2	170	–	–	–	–	–
2001	0	34	1	97	–	–	–	–	–
2002	0	17	0	201	–	–	–	–	–
2003	3	50	0	68	–	–	–	–	–
2004	1	10	0	39	–	–	–	–	–
2005	0	19	0	41	–	–	–	–	–
2006	0	22	0	42	–	–	–	–	–
2007	0	12	0	8	–	–	–	–	–
2008	0	9	0	7	–	–	–	–	–
2009	0	9	0	10	–	–	–	–	–

2010	0	11	0	25	–	–	–	–	–
2011	0	15	0	61	–	–	–	–	–
2012	0	15	0	33	–	–	–	–	–
2013	0	15	0	24	–	–	–	–	–

SUB-ANTARCTIC									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	0	317	364	0	1	3	746	1431
1992	2	0	317	114	0	1	3	1218	1656
1993	47	0	317	40	0	2	5	537	948
1994	34	1	235	33	0	4	3	483	793
1995	1	0	318	22	0	38	7	303	689
1996	16	0	346	26	0	20	40	406	854
1997	125	0	427	17	0	22	97	270	958
1998	38	0	10	73	0	55	34	392	602
1999	19	0	471	54	0	46	25	471	1086
2000	2	0	537	278	0	155	10	471	1454
2001	2	2	557	147	0	230	10	137	1085
2002	37	3	296	655	0	94	6	159	1250
2003	32	129	267	524	0	49	16	250	1266
2004	50	97	329	209	0	86	18	90	879
2005	0	19	136	107	0	51	35	160	508
2006	0	12	66	21	0	150	21	240	510
2007	0	34	53	47	0	152	7	120	413
2008	0	0	62	122	0	114	8	120	426
2009	0	0	151	11	0	107	8	120	397
2010	1	4	115	20	0	107	8	120	375
2011	1	1	20	15	0	107	8	120	272
2012	1	1	86	1	0	107	8	120	324
2013	1	1	86	12	0	107	8	120	335
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	113	14	–	0	0	–	–
1992	0	0	113	18	–	0	0	–	–
1993	6	0	113	6	–	0	0	–	–
1994	14	1	77	5	–	0	0	–	–
1995	0	0	268	3	–	0	0	–	–
1996	1	0	170	4	–	0	0	–	–
1997	80	0	421	3	–	0	0	–	–
1998	6	0	10	11	–	0	0	–	–
1999	1	0	237	0	–	0	0	–	–
2000	1	0	269	43	–	0	0	–	–
2001	0	2	417	24	–	1	0	–	–
2002	5	3	109	42	–	0	0	–	–
2003	10	73	73	117	–	0	0	–	–
2004	22	51	94	32	–	0	0	–	–
2005	0	10	80	16	–	1	0	–	–
2006	0	3	27	3	–	0	0	–	–
2007	0	11	28	7	–	0	0	–	–
2008	0	0	58	24	–	0	0	–	–
2009	0	0	72	3	–	0	0	–	–
2010	0	2	81	3	–	0	0	–	–
2011	0	1	6	3	–	0	0	–	–
2012	0	1	22	0	–	0	0	–	–
2013	0	1	22	5	–	0	0	–	–

Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	0	204	294	–	–	–	–	–
1992	2	0	204	71	–	–	–	–	–
1993	36	0	204	25	–	–	–	–	–
1994	18	0	159	21	–	–	–	–	–
1995	1	0	51	14	–	–	–	–	–
1996	14	0	176	16	–	–	–	–	–
1997	18	0	6	11	–	–	–	–	–
1998	28	0	0	46	–	–	–	–	–
1999	18	0	231	19	–	–	–	–	–
2000	2	0	267	174	–	–	–	–	–
2001	2	0	138	62	–	–	–	–	–
2002	28	0	180	384	–	–	–	–	–
2003	19	34	184	348	–	–	–	–	–
2004	25	2	219	131	–	–	–	–	–
2005	0	6	56	67	–	–	–	–	–
2006	0	1	38	13	–	–	–	–	–
2007	0	9	25	29	–	–	–	–	–
2008	0	0	4	84	–	–	–	–	–
2009	0	0	78	7	–	–	–	–	–
2010	1	1	35	12	–	–	–	–	–
2011	1	0	13	10	–	–	–	–	–
2012	1	0	64	0	–	–	–	–	–
2013	1	0	64	6	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	26	–	–	–	–	–
1992	0	0	0	23	–	–	–	–	–
1993	5	0	0	8	–	–	–	–	–
1994	2	0	0	7	–	–	–	–	–
1995	0	0	0	4	–	–	–	–	–
1996	1	0	0	5	–	–	–	–	–
1997	26	0	0	3	–	–	–	–	–
1998	3	0	0	15	–	–	–	–	–
1999	1	0	2	34	–	–	–	–	–
2000	0	0	1	55	–	–	–	–	–
2001	0	0	2	61	–	–	–	–	–
2002	4	0	7	224	–	–	–	–	–
2003	3	22	10	57	–	–	–	–	–
2004	2	44	16	42	–	–	–	–	–
2005	0	3	0	21	–	–	–	–	–
2006	0	8	1	4	–	–	–	–	–
2007	0	14	1	9	–	–	–	–	–
2008	0	0	0	20	–	–	–	–	–
2009	0	0	1	0	–	–	–	–	–
2010	0	1	0	4	–	–	–	–	–
2011	0	0	0	2	–	–	–	–	–
2012	0	0	0	1	–	–	–	–	–
2013	0	0	0	2	–	–	–	–	–

WEST COAST NORTH ISLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	14	0	0	5	0	19
1992	1	0	0	22	100	0	27	0	150
1993	24	1	0	18	915	0	333	0	1291

1994	0	4	1	9	1285	0	141	0	1439
1995	1	0	0	14	317	4	161	0	497
1996	0	0	10	55	109	0	45	0	220
1997	0	1	32	14	0	2	106	0	155
1998	8	0	1	0	0	0	43	0	53
1999	10	18	17	9	837	0	62	0	953
2000	1	26	2	22	16	0	129	0	196
2001	0	148	6	31	51	1	246	0	483
2002	7	181	3	22	230	0	1070	0	1513
2003	0	79	0	47	124	0	229	0	479
2004	0	3	0	9	85	4	100	0	201
2005	5	0	1	2	84	0	157	0	248
2006	0	0	2	13	84	0	45	0	143
2007	0	0	19	6	84	0	32	0	141
2008	0	0	15	14	84	0	57	0	169
2009	0	0	17	14	84	0	19	0	133
2010	1	0	11	8	84	0	19	0	123
2011	1	0	23	9	84	0	19	0	136
2012	1	0	9	10	84	0	19	0	122
2013	1	0	9	18	84	0	19	0	130
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	2	–	0	0	–	–
1992	0	0	0	4	–	0	1	–	–
1993	3	1	0	3	–	0	13	–	–
1994	0	4	1	2	–	0	4	–	–
1995	0	0	0	3	–	0	3	–	–
1996	0	0	6	26	–	0	2	–	–
1997	0	1	27	4	–	0	3	–	–
1998	1	0	1	0	–	0	2	–	–
1999	0	14	1	4	–	0	2	–	–
2000	0	17	1	9	–	0	16	–	–
2001	0	116	4	8	–	1	8	–	–
2002	1	152	3	5	–	0	25	–	–
2003	0	45	0	12	–	0	20	–	–
2004	0	2	0	3	–	0	13	–	–
2005	1	0	1	1	–	1	0	–	–
2006	0	0	2	3	–	0	17	–	–
2007	0	0	0	2	–	0	0	–	–
2008	0	0	12	2	–	0	0	–	–
2009	0	0	14	2	–	0	8	–	–
2010	0	0	6	1	–	0	8	–	–
2011	0	0	10	1	–	0	8	–	–
2012	0	0	2	3	–	0	8	–	–
2013	0	0	2	4	–	0	8	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	5	–	–	–	–	–
1992	1	0	0	9	–	–	–	–	–
1993	18	0	0	2	–	–	–	–	–
1994	0	0	0	2	–	–	–	–	–
1995	1	0	0	2	–	–	–	–	–
1996	0	0	4	9	–	–	–	–	–
1997	0	0	6	4	–	–	–	–	–
1998	6	0	0	0	–	–	–	–	–
1999	10	3	16	4	–	–	–	–	–
2000	1	4	1	9	–	–	–	–	–
2001	0	12	3	18	–	–	–	–	–

2002	5	16	0	15	–	–	–	–	–
2003	0	21	0	23	–	–	–	–	–
2004	0	0	0	4	–	–	–	–	–
2005	4	0	0	1	–	–	–	–	–
2006	0	0	0	9	–	–	–	–	–
2007	0	0	19	3	–	–	–	–	–
2008	0	0	3	11	–	–	–	–	–
2009	0	0	3	11	–	–	–	–	–
2010	1	0	5	6	–	–	–	–	–
2011	1	0	13	6	–	–	–	–	–
2012	1	0	6	4	–	–	–	–	–
2013	1	0	6	12	–	–	–	–	–
Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	0	–	–	–	–	–
1992	0	0	0	0	–	–	–	–	–
1993	4	0	0	0	–	–	–	–	–
1994	0	0	0	0	–	–	–	–	–
1995	0	0	0	0	–	–	–	–	–
1996	0	0	0	0	–	–	–	–	–
1997	0	0	0	0	–	–	–	–	–
1998	1	0	0	0	–	–	–	–	–
1999	0	1	0	0	–	–	–	–	–
2000	0	5	0	2	–	–	–	–	–
2001	0	20	0	2	–	–	–	–	–
2002	1	13	0	2	–	–	–	–	–
2003	0	13	0	1	–	–	–	–	–
2004	0	1	0	0	–	–	–	–	–
2005	0	0	0	0	–	–	–	–	–
2006	0	0	0	1	–	–	–	–	–
2007	0	0	0	0	–	–	–	–	–
2008	0	0	0	1	–	–	–	–	–
2009	0	0	0	0	–	–	–	–	–
2010	0	0	0	0	–	–	–	–	–
2011	0	0	0	0	–	–	–	–	–
2012	0	0	0	0	–	–	–	–	–
2013	0	0	0	0	–	–	–	–	–

WEST COAST SOUTH ISLAND									
Total	Fishery								
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	0	115	5904	76	0	195	0	6291
1992	0	0	115	3382	201	0	223	0	3921
1993	36	0	115	4889	495	0	192	0	5727
1994	1	1	139	6671	118	1	422	0	7353
1995	18	0	127	8327	461	4	147	0	9084
1996	12	0	220	7314	363	1	102	0	8013
1997	5	1	270	7520	964	3	181	0	8945
1998	19	1	219	3587	0	7	145	0	3979
1999	35	1	223	3177	520	8	290	0	4254
2000	6	0	155	2035	16	4	301	0	2517
2001	0	6	231	2421	482	1	71	0	3211
2002	9	1	128	2926	100	0	37	0	3201
2003	4	50	172	2762	13	0	57	0	3059
2004	0	7	107	1655	12	0	42	0	1822
2005	7	15	165	465	2	0	32	0	686
2006	0	2	153	1414	2	1	25	0	1598

2007	0	9	157	524	2	0	10	0	702
2008	0	0	236	626	2	0	0	0	864
2009	0	0	204	479	2	0	2	0	687
2010	0	1	234	480	2	0	2	0	719
2011	0	0	183	1045	2	0	2	0	1232
2012	0	0	209	1029	2	0	2	0	1243
2013	0	0	209	2082	2	0	2	0	2296
QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	71	1080	–	0	8	–	–
1992	0	0	71	952	–	0	10	–	–
1993	5	0	71	738	–	0	5	–	–
1994	0	1	43	1948	–	0	3	–	–
1995	0	0	70	2143	–	0	15	–	–
1996	1	0	96	4402	–	0	5	–	–
1997	1	1	109	2932	–	0	4	–	–
1998	3	1	95	1074	–	0	12	–	–
1999	1	1	1	1525	–	0	3	–	–
2000	2	0	72	927	–	0	0	–	–
2001	0	4	129	780	–	1	7	–	–
2002	1	1	52	648	–	0	3	–	–
2003	1	29	124	814	–	0	10	–	–
2004	0	3	56	443	–	0	5	–	–
2005	1	8	70	130	–	1	0	–	–
2006	0	1	61	150	–	0	3	–	–
2007	0	3	80	149	–	0	7	–	–
2008	0	0	88	66	–	0	0	–	–
2009	0	0	84	85	–	0	0	–	–
2010	0	1	83	52	–	0	0	–	–
2011	0	0	79	49	–	0	0	–	–
2012	0	0	42	541	–	0	0	–	–
2013	0	0	42	624	–	0	0	–	–
Non-QMS									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	1	0	44	156	–	–	–	–	–
1992	0	0	44	183	–	–	–	–	–
1993	27	0	44	75	–	–	–	–	–
1994	1	0	96	190	–	–	–	–	–
1995	18	0	57	1316	–	–	–	–	–
1996	10	0	124	186	–	–	–	–	–
1997	2	0	161	261	–	–	–	–	–
1998	14	0	124	1076	–	–	–	–	–
1999	33	0	222	894	–	–	–	–	–
2000	4	0	83	625	–	–	–	–	–
2001	0	1	102	372	–	–	–	–	–
2002	8	0	75	1860	–	–	–	–	–
2003	3	13	48	740	–	–	–	–	–
2004	0	0	51	769	–	–	–	–	–
2005	5	5	96	188	–	–	–	–	–
2006	0	1	92	1236	–	–	–	–	–
2007	0	2	77	210	–	–	–	–	–
2008	0	0	148	520	–	–	–	–	–
2009	0	0	120	358	–	–	–	–	–
2010	0	0	151	381	–	–	–	–	–
2011	0	0	104	748	–	–	–	–	–
2012	0	0	167	366	–	–	–	–	–
2013	0	0	167	1046	–	–	–	–	–

Invertebrate									
Fyr	SCI	SQU	LLL	HHL	JMA	OEO	ORH	SBW	ALL
1991	0	0	0	17	–	–	–	–	–
1992	0	0	0	5	–	–	–	–	–
1993	4	0	0	4	–	–	–	–	–
1994	0	0	0	50	–	–	–	–	–
1995	0	0	0	17	–	–	–	–	–
1996	1	0	0	11	–	–	–	–	–
1997	2	0	0	14	–	–	–	–	–
1998	2	0	0	39	–	–	–	–	–
1999	1	0	0	16	–	–	–	–	–
2000	1	0	0	11	–	–	–	–	–
2001	0	1	0	6	–	–	–	–	–
2002	1	0	0	73	–	–	–	–	–
2003	0	8	0	45	–	–	–	–	–
2004	0	3	0	9	–	–	–	–	–
2005	0	2	0	3	–	–	–	–	–
2006	0	1	0	15	–	–	–	–	–
2007	0	4	0	5	–	–	–	–	–
2008	0	0	0	29	–	–	–	–	–
2009	0	0	0	21	–	–	–	–	–
2010	0	0	0	8	–	–	–	–	–
2011	0	0	0	41	–	–	–	–	–
2012	0	0	0	21	–	–	–	–	–
2013	0	0	0	31	–	–	–	–	–

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