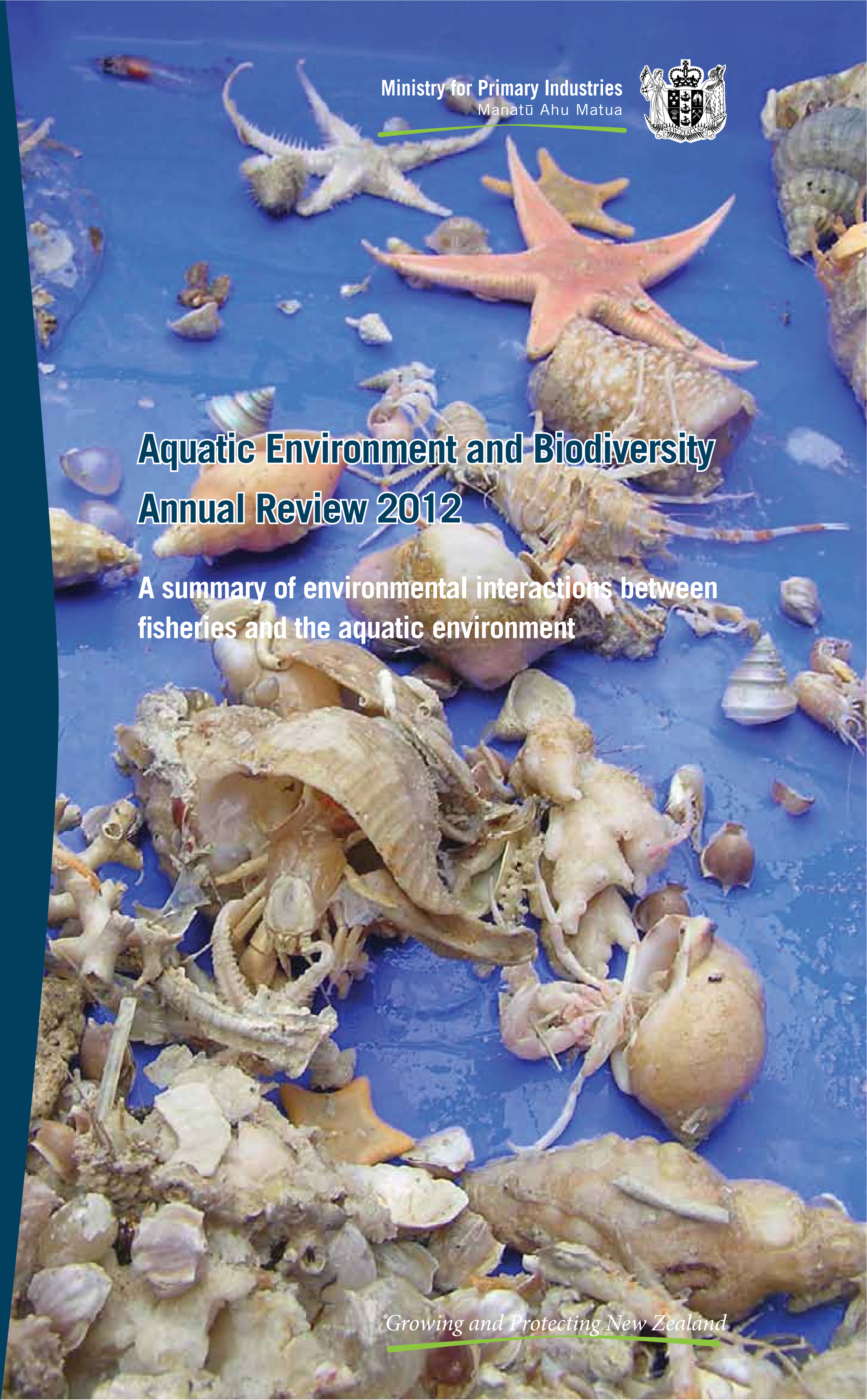
Ministry for Primary Industries
Manatū Ahu Matua

Aquatic Environment and Biodiversity Annual Review 2012

A summary of environmental interactions between fisheries and the aquatic environment



Growing and Protecting New Zealand

MINISTRY FOR PRIMARY INDUSTRIES

AQUATIC ENVIRONMENT AND BIODIVERSITY ANNUAL REVIEW (2012)

Fisheries Management Science Team

Acknowledgements

In addition to the thanks due to members of AEWG and BRAG working groups, special acknowledgement is due to Owen Anderson (NIWA) for his contribution to the new chapter on Non-protected Bycatch; Igor Debski (DOC) on the new seabirds chapter, and Ian Tuck (NIWA) on the benthic chapter. Notwithstanding these contributions, any errors or omissions are the Ministry's.

Image on cover

Chatham-Challenger Ocean Survey 20/20

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Fisheries Management Science Team
Ministry for Primary Industries
Pastoral House, 25 The Terrace
PO Box 2526, Wellington 6140
New Zealand
www.mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: +64 4 894 0300
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PREFACE

This, the 2012 edition of the Aquatic Environment and Biodiversity Review, expands and updates the first edition published in 2011. It summarises information on a range of issues related to the environmental effects of fishing and aspects of marine biodiversity and productivity relevant to fish and fisheries. This review is a conceptual analogue of the Ministry's annual Reports from the Fisheries Assessment Plenary. It summarises the most recent data and analyses on particular aquatic environment issues and, where appropriate, assesses current status against any specified targets or limits. Whereas the Reports from the Fisheries Assessment Plenary are organised by fishstock, however, the Aquatic Environment and Biodiversity Review is organised by issue (for example, protected species bycatch, benthic impacts), and almost all issues involve more than one fishstock or fishery.

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

As has happened with the Reports from the Fisheries Assessment Plenary, continual future expansion and improvement of the Aquatic Environment and Biodiversity Review is anticipated and additional chapters will be developed to provide increasingly comprehensive coverage of the issues. New chapters are included this year for seabirds (Chapter 5) and the bycatch and discards of fish and invertebrates (Chapter 6), and a new appendix summarising aquatic environment and marine biodiversity research since 1998 has now been developed (Appendix 12.9). A chapter on Hector's/Maui's dolphins has been identified as a priority for development in 2013. Data acquisition, modelling, and assessment techniques will also progressively improve, and it is expected that reference points to guide fisheries management decisions will be developed. Both will lead to changes to the current chapters. We hope the condensation in this review of the information from previously scattered reports will assist fisheries managers, stakeholders and other interested parties to understand the issues, locate relevant documents, track research progress and make informed decisions.

This revision has been led by the Science Team within the Directorate of Fisheries Management of the Ministry for Primary Industries (primarily Martin Cryer, Rohan Currey, Rich Ford, and Mary Livingston) but has relied critically on the input of members of the Ministry's Aquatic Environment Working Group (AEWG) and Biodiversity Research Advisory Group (BRAG) and the Department of Conservation's Conservation Services Technical Working Group (DOC-CSTWG). I would especially like to recognise and thank the large number of research providers and scientists from research organisations, academia, the seafood industry, environmental NGOs, Māori customary, DOC, and 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 the aspects of the environmental effects of fishing and marine biodiversity covered as at December 2012.

Pamela Mace
Principal Adviser Fisheries Science
Ministry for Primary Industries

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 and expands and updates the first version published in 2011 (MAF 2011). It is designed to complement the Ministry's annual Reports from Fisheries Assessment Plenaries (e.g., MPI 2012a & b) and emulate those documents' dual role in providing an authoritative summary of current understanding and an assessment of status relative to any overall targets and limits. However, whereas the Reports from Fisheries Assessment Plenaries have a focus on individual fishstocks, this report has a focus on aquatic environment fisheries management issues and biodiversity responsibilities that often cut across many fishstocks, fisheries, or activities, and sometimes across the responsibilities of multiple agencies.

This update has been developed by the Science Team within the Fisheries Management Directorate of the Resource Management and Programmes branch, Ministry for Primary Industries (MPI). It does not cover all issues but, as anticipated, includes more chapters than the first edition in 2011. As with the Reports from Fisheries Assessment Plenaries, it is expected to change and grow as new information becomes available, more issues are considered, and as feedback and ideas are received. This synopsis has a broad, national focus on each issue and the general approach has been to avoid too much detail at a fishery or fishstock level. For instance, the benthic (seabed) effects of mobile bottom-fishing methods are dealt with at the level of all bottom trawl and dredge fisheries combined rather than at the level of a target fishery that might contribute only a small proportion of the total impact. The details of benthic impacts by individual fisheries will be documented in the respective chapters in the May or November Report from the Fisheries Assessment Plenary, and linked there to the fine detail and analysis in Aquatic Environment and Biodiversity Reports (AEBRs), Fisheries Assessment Reports (FARs), and Final Research Reports (FRRs). Such sections have already been developed for several species in both 2012 Fishery Assessment Plenary Reports, and others will follow.

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

1.2. *Legislation*

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

2000; the Resource Management Act 1991 for issues in coastal marine areas that could affect fisheries interests or be the subject of sustainability measures under section 11 of the Fisheries Act; and the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 for issues outside the Territorial Sea. These Acts are administered by other agencies and this leads to a requirement for the Ministry for Primary Industries to work with other government departments (especially the Department of Conservation and through the Natural Resource Sector[1]) and with various territorial authorities (especially Regional Councils) to a greater extent than is required for most fisheries stock assessment issues.

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

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

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

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

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

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

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

1.3. *Policy Setting*

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

The Ministry for Primary Industries' Statement of Intent, SOI, is an important guiding document for the short to medium term. That for 2012–15 is available on the Ministry's website at:

http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1341

The SOI sets out the Ministry's strategic direction for the coming three years, primarily through implementation of Our Strategy 2030 (Appendix 12.7). This strategy was agreed by Cabinet in August 2011and sets out MPI's vision of "growing and protecting New Zealand" and defines the focus and approach of the organisation. The strategy includes four focus areas and outcomes: maximising export opportunities; improving sector productivity; increasing sustainable resource use; and protecting from biological risk.

MPI is the single key adviser to the Government across all aspects of the primary industries, food production and related trade issues. MPI is the principal adviser to the Government on agriculture, horticulture, aquaculture, fisheries, forestry, and food industries, animal welfare, and the protection of New Zealand's primary industries from biological risk. Aspects of the role specific to fisheries itemized in the SOI include supporting the development of sustainable limits to natural resource use. To that end, MPI contracts the following types of research (relevant to this document):

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

1.3.2. Fisheries 2030

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

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

(noting that the Ministry of Fisheries merged with the Ministry of Agriculture and Forestry on 1 July 2011 and became the Ministry for Primary Industries on 30 April 2012. This URL and subsequent links in this document will eventually change as the new Ministry's systems are progressively merged).

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

- Biodiversity and the function of ecological systems, including trophic linkages, are conserved
- Habitats of special significance to fisheries are protected
- Adverse effects on protected species are reduced or avoided

- Impacts, including cumulative impacts, of activities on land, air or water on aquatic ecosystems are addressed.

1.3.3. Fisheries Plans

Fisheries planning processes for deepwater, highly migratory species, inshore finfish, inshore shellfish and freshwater fisheries use objective-based management to drive the delivery of services, as described in Fisheries 2030 and affirmed in the 2012/15 SOI and Our Strategy 2030. The planning processes are guided by five National Fisheries Plans, which recognise the distinctive characteristics of these fisheries. Plans for Deepwater and Highly Migratory species have been approved by the Minister and a suite of three plans for inshore species has been released in prototype form. These plans establish management objectives for each fishery, including those related to the environmental effects of fishing. All are available on the Ministry's websites.

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

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

Certain research areas (aquatic environment, recreational and biodiversity) are not entirely covered by fish plans, as many of these issues span multiple fisheries and plans. Antarctic research is also excluded from fish plans as it is beyond their spatial scope. These areas are administered by the science team and subject to the drivers in Tables 1.1, 1.2 and Fisheries 2030.

1.3.4. Other strategic documents

A number of strategies or reviews have been published that potentially affect fisheries values and research. These include: the New Zealand Biodiversity Strategy (2000); 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); 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, soon to be revised); and the New Zealand National Plan of Action for the Conservation and Management of Sharks (2008). Links to these documents are provided in Appendix 12.8 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 12.5. 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 for 2011/12 and 2012/13 (other than aspects driven by deepwater and HMS plans or the specific needs of inshore fishery managers) followed essentially these same steps.

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

1.4.2. Contributing Working Groups

The main contributing working groups for this document are the Ministry's Aquatic Environment Working Group (AEWG) and Biodiversity Research Advisory Group (BRAG). The Department of Conservation's Conservation Services Programme and National Plan of Action Seabirds Technical Working Group (CSP/NPOA-TWG, see http://www.doc.govt.nz/conservation/marine-and-coastal/commercial-fishing/marine-conservation-services/meetings-and-project-updates/) also considers a wide range of DOC-funded projects related to protected species, sometimes in joint meetings with the AEWG. The Ministry's Fishery Assessment Working Groups occasionally consider research relevant to this synopsis. Terms of reference for AEWG and BRAG are periodically revised and updated (see Appendix 12.1 and 12.3 for the 2012 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 2012 are listed in Appendix 12.2).

The two main responsibilities of BRAG are: to review, discuss, and convey views on the results of marine biodiversity research projects contracted by the Ministry; and to discuss, evaluate, make recommendations and convey views on Medium Term Biodiversity Research Plans and constituent individual projects. Both tasks have hitherto been undertaken in the context the strategic goals in the New Zealand Biodiversity Strategy (2000) and the Strategy for New Zealand Science in Antarctica and the Southern Ocean (2010), but the focus of the programme is currently being reviewed to align it with more recent strategic documents. BRAG also administers some large cross-government projects such as NORFANZ, BIOROSS, Fisheries and Biodiversity Ocean Survey 20/20; and International Polar Year (IPY) Census of Antarctic Marine Life (IPY-CAML). Membership of BRAG is also open (attendees for 2011 and 2012 are listed in Appendix 12.4).

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 at:
http://fs.fish.govt.nz/Page.aspx?pk=61&tk=209.
Increasingly, reports will be available from the MPI website at: http://www.mpi.govt.nz/news-resources/publications.

1.5. *References*

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

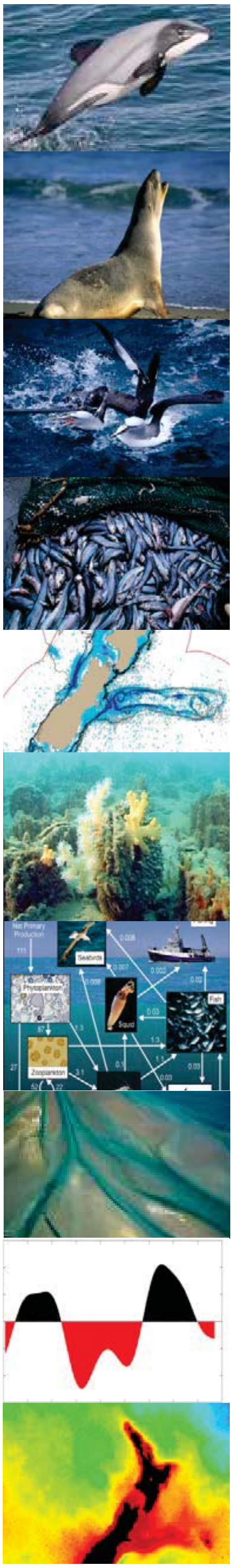
Ministry for Primary Industries (2012a). Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1194 p.

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

2. Research themes covered in this document

The Ministry has identified four broad categories of research on the environmental effects of fishing (Figure 2.1): bycatch and fishing-related mortality of protected species; bycatch of non-protected species, primarily non-QMS fish; modification of benthic habitats (including seamounts); and various ecosystem effects (including fishing and non-fishing effects on habitats of particular significance for fisheries management and trophic relationships). Other emerging issues (such as the genetic consequences of selective fishing and the impacts of aquaculture) are not dealt with in detail in this synopsis but it is anticipated that those that turn out to be important will be dealt with in future iterations. A fifth theme for this document is 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, and Final Research Reports, and the Annual Report from the Fishery Assessment Plenary. Collectively, these provide a rich and well-understood resource for fisheries managers and stakeholders. In 2005, an environmental section was included in the hoki plenary report as part of the characterisation of that fishery and to highlight any particular environmental issues associated with the fishery. Similar, fishery-specific sections have since been developed for other working group reports and the plenary, including many fisheries for highly migratory species and the trawl fisheries for scampi and squid, but work on environmental issues has otherwise been more difficult to access for fisheries managers and stakeholders. The Ministry is, therefore, looking at improving ways to document, review, publicise, and integrate information from environmental assessments with traditional fishery assessments. This will rely heavily on studies that are published in Aquatic Environment and Biodiversity Reports and Final Research Reports but, given the overlapping mandates and broader scope of work in this area, also on results published by other organisations. The integration of all this work into a single source document analogous to the Report from the Fishery Assessment Plenary will take time and not all issues will be covered for some years.



THEME	RESEARCH QUESTIONS	CURRENT WORK
1.PROTECTED SPECIES • Marine mammals • Seabirds • Turtles • Protected fish • Corals	• How many of each NZ-breeding protected species are caught and killed in our fisheries (and out of zone)? • How many unobserved deaths are caused? • What is the likely effect of fishing-related mortality on protected species populations? • Which species or populations are most at risk? • Which fisheries cause the most risk and where are the most cost-effective gains to be made? • What mitigation approaches are most successful and in what circumstances? • What levels of bycatch would lead to different population outcomes?	• Estimation of annual bycatch of protected species by fishery • Abundance and productivity of key seabird populations • Abundance and productivity of Hector's & Maui's dolphins • Semi-quantitative risk assessment for all seabirds • Semi-quantitative risk assessment for other protected species • Full quantitative risk assessment for selected seabird populations • Modelling to assess robust links between observed ycatch 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 bycatch species
3. BENTHIC EFFECTS • Distribution of habitats & trawling • Effects of trawling on each	• What seabed habitats occur where in our TS/EEZ and how much of each is affected by trawling or shellfish dredging? • How sensitive is each habitat to disturbance and what do we lose when each is disturbed? • What are the consequences of different management approaches?	• Testing of habitat classifications • Assessment of recovery rate of some key inshore habitats • Assessment of relative sensitivity of habitats • Mapping of sensitive biogenic habitats, and deepwater and inshore trawl footprints
4. ECOSYSTEM EFFECTS • Trophic studies • Habitats of significance • Ecosystem indicators • Land-use effects • Climate variability • Climate Change • System productivity	• How do the ecosystems that support our fisheries function? • What are the key predator-prey or synergistic relationships in these systems? • Are our fisheries affecting food webs or ecosystem services? • What changes are occurring in the ecosystems that support our fisheries? • What is "habitat of particular significance for fisheries management"? • How do fisheries and/or land management affect fish habitat and fisheries production? • What are the major risks and opportunities from ocean-climate variability and trends?	• Habitat of significance: Kaipara Harbour fish habitats (SNA) • Habitat of significance: review of information for inshore finfish • Habitat of significance: coastal shark nursery areas (starting with rig) • Multi-impact risk assessment • Monitoring and indicators of environmental change for deepwater fisheries • Ecotrophic factors affecting highly migratory species
5. MARINE BIODIVERSITY • Characterising NZ biodiversity • Functional ecology • Genetic diversity • Ocean climate • Metrics & indicators • Threats & impacts • Ross Sea & IPY	• What are the key drivers of pattern in New Zealand's marine biodiversity? • How does biodiversity contribute to the resilience of ecosystems to perturbation and climate change? • What drives genetic connectivity within species? • What do we need to measure and monitor to assess risks and change? • How are biota adapted to polar conditions and what is their sensitivity to perturbation?	• Mapping key biogenic habitats • SPRFMO benthic habitats • Modelling seabed response and recovery from disturbance • Ocean acidification in fish habitat • Experimental response of shellfish to warming and acidification • Monitoring surface plankton • Implications of ocean acidification for plankton productivity • Marine environmental monitoirng

Figure 2.1: Summary of themes in the Aquatic Environment and Biodiversity Annual Review 2011.

CURRENT STATE OF KNOWLEDGE

- Aggregate "on deck" bycatch of seabirds (and approximate species composition), marine mammals, and large sharks known reasonably well for offshore trawl and longline fisheries, but less well for inshore fisheries (where observer coverage has historically been low).
- Incidental, cryptic, or unobserved mortality very poorly known (and difficult to assess).
- Factors affecting fishing related mortality are well known for most seabirds and marine mammals.
- Knowledge of population abundance is increasing for some key seabird species and well known for sea lions, but poorly known or dated for other seabirds, some species of dolphins, fur seals, and most sharks.
- Qualitative or semi-quantitative risk assessments have been completed for almost all seabirds and marine mammals.
- Fully quantitative risk assessments have been completed for two seabird populations, Hector's / Maui's dolphins, and sea lions.
- Impact of fishing-related mortality on most protected species remains uncertain because of some key knowledge gaps.
- Some methods of mitigating bycatch have been formally tested.

- Bycatch and discards are monitored 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 (that have been tested in deepwater) are available of the distribution of seabed habitats at a broad scale using classifications (BOMEC) and at finer scale for seamounts and some biogenic habitats.
- Excellent understanding of the distribution of bottom trawling in offshore waters (but not in coastal waters, especially for most shellfish dredge fisheries).
- Good understanding of the effects of trawling on some nearshore habitats.
- General understanding of the effects of trawling on biogeochemical processes.
- General understanding of the relative sensitivity of different habitats.

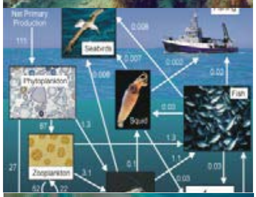
- Variability in the diets of key commercial species in the Chatham Rise ecosystem have been described as part of a wider biodiversity and MSI programme.
- A preliminary trophic model of the Subantarctic ecosystem suggests a low productivity system supporting a simple food chain with high transfer efficiencies.
- Atlases have been developed showing the distribution of spawning, pupping, egg-laying, and juveniles of key species (this needs finalising for inshore species).
- A review of land-based effects on fish habitat and coastal biodiversity has been completed.
- A start has been made on assessing ecosystem change over time (through fish-based indicators calculated from trawl survey data and acoustic time series of mesopelagic biomass)
- A summary of ocean climate variability and change has been produced.
- Broad reviews have been completed of the impacts of climate variability on fisheries (especially recruitment), but the likely impacts of ocean climate change or acidification remain poorly known.
- This theme has links and synergies with MBIE, DOC, universities and the MPI biodiversity programme.s

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









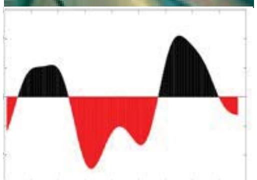
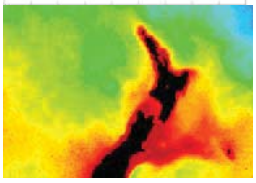



Figure 2.1 *continued*: Summary of Themes in the Aquatic Environment & Biodiversity Review 2011

THEME 1: PROTECTED SPECIES

3. New Zealand sea lions (*Phocarctos hookeri*)

Scope of chapter	This chapter outlines the biology of New Zealand (or Hooker's) sea lions (*Phocarctos hookeri*), the nature of fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
Area	Southern parts of the New Zealand EEZ and Territorial Sea.
Focal localities	Areas with significant fisheries interactions include the Auckland Islands Shelf, the Stewart/Snares Shelf and Campbell Plateau.
Key issues	Improving estimates of incidental bycatch in some trawl fisheries (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 ongoing declines in population size. Estimation of interactions given low numbers of observed captures.
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; External review of the Breen-Fu-Gilbert model* (SRP2011-04).
Other Govt Research (current)	DOC Marine Conservation Services Programme (CSP): INT2012-01 *To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities*; POP2012-01 *To provide information on the population level and dynamics of the New Zealand sea lion at the Auckland Islands relevant to assessing the impacts of commercial fishing impacts on this population*; POP2012-02 *To determine the key demographic factors driving the observed population decline of New Zealand sea lions at the Auckland Islands*. NIWA Research: SA123098 *Multispecies modelling to evaluate the potential drivers of decline in New Zealand sea lions*; TMMA103 *Conservation of New Zealand's threatened iconic marine megafauna*.
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts.
Related issues/chapters	See the New Zealand fur seal chapter.

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 (formerly the Minister of Fisheries), may approve a population management plan (PMP). Although a NZ sea lion PMP was proposed by the Department of Conservation (DOC) in 2007 (DOC 2007), following consultation DOC decided not to proceed with the PMP.

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

The Minister of Conservation gazetted the NZ sea lion as a threatened species in 1997. In 2009, DOC approved the *New Zealand sea lion species management plan*[2]*: 2009–2014* (DOC 2009). It aims*: "To make significant progress in facilitating an increase in the New Zealand sea lion population size and distribution."* The plan specifies a number of goals, of which the following are most relevant for fisheries interactions:

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

In the absence of a PMP, the Ministry for Primary Industries (MPI, formerly the Ministry of Fisheries, MFish) 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 NZ sea lion bycatch aligns with Fisheries 2030 Objective 6: *Manage impacts of fishing and aquaculture*. Further, the management actions follow Strategic Action 6.2: *Set and monitor environmental standards, including for threatened and protected species and seabed impacts.*

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

Specific objectives for the management of NZ sea lion bycatch will be outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ sea lions are most likely to interact. These fisheries include trawl fisheries for arrow squid (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 the Campbell Islands (SBW6I), do not impact the long term viability of the sea lion population and captures are minimised through good operational practices.* Chapters in the National Deepwater Plan for arrow squid and scampi are under development.

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

a. A rule should provide for an increase in the sea lion population to more than 90% of carrying capacity[3], or to within 10% of the population size that would have been attained in the

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

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

absence of fishing, and that these levels must be attained with 90% certainty, over 20-year and 100-year projections.

b. A rule should attain a mean number of mature mammals that exceeded 90% of carrying capacity in the second 50 years of 100-year projection runs.

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

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

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

3.2. *Biology*

3.2.1. Taxonomy

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

3.2.2. Distribution

Before human habitation, NZ sea lions ranged around the North and South Islands of New Zealand. Pre-European remains of NZ sea lions have been identified from at least 47 archaeological sites, ranging from Stewart Island to North Cape, with most occurring in the southern half of the South Island (Smith 1989, 2011, Childerhouse and Gales 1998, Gill 1998). Subsistence hunting on the mainland and subsequent commercial harvest from outlying islands of NZ sea lions for skins and oil resulted in population decline and contraction of the species' range (Gales 1995, Childerhouse and Gales 1998, Nagaoka 2001, 2006). Currently, most NZ sea lions are found in the New Zealand Sub-Antarctic, with individuals ranging to the NZ mainland and Macquarie Island.

NZ sea lion breeding colonies[4] are highly localized, with most pups being born at two main breeding areas, the Auckland Islands and Campbell Island (Wilkinson *et al.* 2003, Chilvers 2008). At the Auckland Islands, there are three breeding colonies: Enderby Island (mainly at Sandy Bay and South East Point); Dundas Island; and Figure of Eight Island. On Campbell Island there is one breeding colony at Davis Point, another colony at Paradise Point, plus a small number of non-colonial breeders (Wilkinson *et al.* 2003, Chilvers 2008, Maloney *et al.* 2009, Maloney *et al.* 2012). Twenty-five sea lion pups were captured and tagged around Stewart Island during a DOC recreational hut and track maintance trip in March 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).

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

Although breeding is concentrated on the Auckland Islands and Campbell Island, occasional births have been reported from the Snares and Stewart Islands (Wilkinson *et al.* 2003, Chilvers *et al.* 2007). Breeding is also taking place on the New Zealand mainland at the Otago peninsula, mainly the result of a single female arriving in 1992 and giving birth in 1993 (McConkey *et al.*, 2002).

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

3.2.3. Foraging ecology

Most foraging studies have been conducted on lactating female NZ sea lions from Enderby Island (Chilvers *et al.* 2005a, 2006, Chilvers and Wilkinson 2009, although work is underway at Campbell Island under NIWA project TMMA103, *Conservation of New Zealand's threatened iconic marine megafauna*). These show that females from this place forage primarily within the Auckland Islands continental shelf and its northern edge, and that individuals show strong foraging site fidelity both within and across years. Satellite tagging data from lactating females showed that the mean return distance travelled per foraging trip is 423 ± 43 km (n = 26), which is greater than that recorded for any other sea lion species (Chilvers *et al.* 2005a). While foraging, about half of the time is spent submerged, with a mean dive depth of 130 ± 5 m (max. 597 m) and a mean dive duration of 4 ± 1 minutes (max. 14.5 minutes; Chilvers *et al.* 2006). NZ sea lions, like most pinnipeds, may use their whiskers to help them capture prey at depths where light does not penetrate (Marshall 2008, Hanke *et al.* 2010).

Studies conducted on female NZ sea lions suggest that the foraging behaviour of each individual falls into one of two distinct categories, benthic or meso-pelagic (Chilvers and Wilkinson 2009). Benthic divers have fairly consistent dive profiles, reaching similar depths (120 m on average) on consecutive dives in relatively shallow water to presumably feed on benthic prey. Meso-pelagic divers, by contrast, exhibit more varied dive profiles, undertaking both deep (> 200 m) and shallow (< 50 m) dives over deeper water. Benthic divers tend to forage further from their breeding colonies, making their way to the north-eastern limits of Auckland Islands' shelf, whereas meso-pelagic divers tend to forage along the north-western edge of the shelf over depths of approximately 3000 m (Chilvers and Wilkinson 2009).

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

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

Adult females at Otago are generally heavier for a given age, breed earlier, undertake shorter foraging trips, and have shallower dive profiles compared with females from the Auckland Islands (Table 3.1). Any observed differences may reflect differences in environment between the Auckland Islands and the Otago peninsula, a founder effect, or a combination of these or other factors.

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

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

NZ sea lions are generalist predators with a varied diet that includes fish (rattail, red cod, opalfish, hoki), cephalopods (octopus, squid), crustaceans (lobster krill, scampi), and salps (Cawthorn *et al.* 1985; Childerhouse *et al.* 2001; Meynier *et al.* 2009). The three main methods used to assess NZ sea lion diets involve analyses of stomach contents, scats and regurgitate, and the fatty acid composition of blubber (Meynier *et al.* 2008). Stomach contents of by-caught animals tend to be biased towards the target species of the fishery concerned (e.g. squid in the SQU6T fishery), whereas scats and regurgitates are biased towards less digestible prey (Meynier *et al.* 2008). Stomach, scat and regurgitate approaches tend to reflect only recent prey (Meynier *et al.* 2008). By contrast, analysis of the fatty acid composition of blubber provides a longer-term perspective on diets ranging from weeks to months (although individual prey species are not identifiable). This approach suggests that the diet of female NZ sea lions tends to include proportionally more arrow squid (*Nototodarus sloanii*) and proportionally less red cod (*Pseudophycis bachus*) and scampi (*Metanephrops challengeri*) than for male NZ sea lions, while lactating and non-lactating females do not differ in their diet (Meynier *et al.* 2008; Meynier 2010).

3.2.4. Reproductive biology

NZ sea lions exhibit marked sexual dimorphism, with adult males being larger and darker in colour than adult females (Walker and Ling 1981, Cawthorn *et al.* 1985). Cawthorn *et al.* (1985) and Dickie (1999) estimated the maximum age of males and females to be 21 and 23 years, respectively, but Childerhouse *et al.* (2010a) recently reported a maximum estimated age for females of 28 years (although the AEWG had some concerns about the methods used and this estimate may not be reliable). Although females can become sexually mature as early as age 2 and give birth the following year, most do not breed until they are 6 years old (Childerhouse *et al.* 2010a). Males generally reach sexual maturity at 4 years of age, but because of their polygynous colonial breeding strategy (i.e., males actively defend territories and mate with multiple females within a harem) they are only able to successfully breed at 7–9 years old, once they have attained sufficient physical size (Marlow 1975, Cawthorn *et al.* 1985). Reproductive rate in females increases rapidly between the ages of 3 and 7, reaching a plateau until the age of approximately 15 and declining rapidly thereafter, with the maximum recorded age at reproduction being 26 years (Breen *et al.* 2010, Childerhouse *et al.* 2010b, Chilvers *et al.* 2010). Chilvers *et al.* (2010) estimated from tagged sea lions that the median lifetime reproductive output of a female NZ sea lion was 4.4 pups, 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 average annual breeding probability 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 for their harems (Robertson *et al.* 2006, Chilvers and Wilkinson 2008). Pregnant and non-pregnant females appear at the breeding colonies in December and early January, with pregnant females giving birth to a single pup in late December before entering oestrus 7–10 days later and mating again (Marlow 1975). Twin births and the fostering of pups in NZ sea lions are rare (Childerhouse and Gales 2001). Shortly after the breeding season ends in mid-January, the harems break up with the males dispersing offshore and females often moving away from the rookeries with their pups (Marlow 1975, Cawthorn *et al.* 1985).

Pups at birth weigh 8–12 kg with parental care restricted to females (Walker and Ling 1981, Cawthorn *et al.* 1985, Chilvers *et al.* 2006). Females remain ashore for about 10 days after giving birth before alternating between foraging trips lasting approximately two days out at sea and returning for about one day to suckle their pups (Gales and Mattlin 1997, Chilvers *et al.* 2005). New Zealand pup growth rates are lower than those reported for other sea lion species, and may be linked to a relatively low concentration of lipids in the females' milk during early lactation (Riet-Sapriza *et al.* 2012, Chilvers 2008). Pups are weaned after about 10–12 months (Marlow 1975, Gales and Mattlin 1997).

3.2.5. Population biology

For NZ sea lions, the overall size of the population is indexed using estimates of the number of pups that are born each year (Chilvers *et al.* 2007). Since 1995, the Department of Conservation (DOC) has conducted mark-recapture counts at each of the main breeding colonies at the Auckland Islands to estimate annual pup production (i.e., the total number of pups born each year, including dead and live animals; Robertson and Chilvers 2011). The data show a decline in pup production from a peak of 3021 in 1997/98 to a low of 1501 ± 16 pups in 2008/09 (Chilvers and Wilkinson 2011, Robertson and Chilvers 2011; Table 3.2), with the largest single-year decline (31%) occurring between the 2007/08 and 2008/09 counts. The most recent estimate of pup production for the Auckland Islands population was 1683 ± 16 pups in 2011/12 (Chilvers 2012a) and a project is underway to obtain a comparable estimate for 2012/13 (POP2012-01).

Total NZ sea lion abundance (including pups) at the Auckland Islands has been estimated using Bayesian population models (Breen *et al.* 2003, Breen and Kim 2006a, Breen and Kim 2006b, Breen *et al.* 2010). Although other abundance estimates are available (e.g. Gales and Fletcher 1999), the integrated models are preferred because they take into account a variety of age-specific factors (breeding, survival, maturity, vulnerability to fishing, and the proportion incidentally captured by fishing), as well as data on the re-sighting of tagged animals and pup production estimates, to generate estimates of the overall size of the NZ sea lion population inhabiting the Auckland Islands (Table 3.2). The most recent estimate of NZ sea lion abundance for the Auckland Islands population was 12 065 animals (90% CI: 11 160–13 061) in 2009. The integrated model suggested a net decline at the Auckland Islands of 23% between 1995 and 2009, or 29% between the maximum estimated population size in 1998 and 2009.

Table 3.2: Pup production and population estimates of NZ sea lions from the Auckland Islands from 1995 to 2010. Pup production data are direct counts or mark-recapture estimates from Chilvers *et al.* (2007), Robertson and Chilvers (2011) and Chilvers (2012a). Standard errors only apply to the portion of pup production estimated using mark-recapture methods. Population estimates from P. Breen, estimated in the model by Breen *et al.* 2010. Year refers to the second year of a breeding season (e.g., 2010 refers to the 2009-10 season).

Year	Pup production estimate		Population size estimate	
	Mean	Standard error (for mark recapture estimates)	Median	90% confidence interval
1995	2 518	21	15 675	14 732–16 757
1996	2 685	22	16 226	15 238–17 318
1997	2 975	26	16 693	15 656–17 829
1998	3 021	94	16 911	15 786–18 128
1999	2 867	33	15 091	13 932–16 456
2000	2 856	43	15 248	14 078–16 586
2001	2 859	24	15 005	13 870–16 282
2002	2 282	34	13 890	12 856–15 079
2003	2 518	38	14 141	13 107–15 295
2004	2 515	40	14 096	13 057–15 278
2005	2 148	34	13 369	12 383–14 518
2006	2 089	30	13 110	12 150–14 156
2007	2 224	38	13 199	12 231–14 215
2008	2 175	44	12 733	11 786–13 757
2009	1 501	16	12 065	11 160–13 061
2010	1 814	36		
2011	1 550[5]	41		
2012	1 683	16		

For the Campbell Island population, pup production was estimated at 681–726 pups in 2010 (Robertson and Chilvers 2011, Maloney *et al.* 2012). Pup production estimates at Campbell Island are increasing over time, although there have been changes to the methodology (Maloney *et al.* 2009). Previous estimates of total pup production were: 150 in 1992/93; 385 in 2003; and 583 in 2007-08 (Cawthorn 1993, Childerhouse *et al.* 2005, Maloney *et al.* 2009). There were also minimum pup counts of 51 in 1987/88, 122 in 1991/92 and 78 (from a partial count) in 1997/98 (Moore and Moffat 1990, McNally *et al.* 2001, M. Fraser, unpubl. data cited in Maloney *et al.* 2009).

For the Otago sub-population, annual pup production has ranged from 0 to 7 pups since the 1994/95 breeding season, with five pups recorded in 2010/11 (McConkey *et al.* 2002, Augé 2011). A modelling exercise suggested that this population can expand to 9–22 adult females by 2018 (Lalas and Bradshaw 2003). The sub-population at Otago is of special interest because it highlights the potential for establishing new breeding colonies, in this case from a single pregnant female (McConkey *et al.* 2002).

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

In addition to the established effects, there are a number of other anthropogenic effects that may also influence NZ sea lion mortality. However their role, if any, is presently unclear. These include: possible competition for resources between NZ sea lions and the various fisheries (Robertson and

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

Chilvers 2011, Bowen 2012); effects of organic and inorganic pollutants, including polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and heavy metals such as mercury and cadmium (Baker 1999, Robertson and Chilvers 2011); and impacts of eco-tourism.

Other sources of mortality include epizootics, particularly *Campylobacter* which killed 1600 pups (53% of pup production) and at least 74 adult females on the Auckland Islands in 1997/98 (Wilkinson *et al.* 2003, Robertson and Chilvers 2011) and *Klebsiella pneumoniae* which killed 33% and 21% of pups on the Auckland Islands in 2001/02 and 2002/03 respectively (Wilkinson *et al.* 2006). The 1998 epizootic event may have affected the fecundity of the surviving pups; reducing their breeding rate relative to other cohorts (Gilbert and Chilvers 2008). There are also occurrences of predation by sharks (Cawthorn *et al.* 1985, Robertson and Chilvers 2011), starvation of pups if they become separated from their mothers (Walker and Ling 1981, Castinel *et al.* 2007), drowning in wallows and male aggression towards females and pups (Wilkinson *et al.* 2000, Chilvers *et al.* 2005b).

Analysis of tag-resight data on Enderby Island yielded estimates of average annual survival for prime-age females of 0.90 for females that did not breed and 0.95 for females that did breed, with no indication of a systematic change in survival during the period 1997/98 to 2010/11 (MacKenzie 2011). Further analysis of tag-resight data is planned under DOC project POP2012-02 to determine the key demographic factors driving the observed population decline of New Zealand sea lions at the Auckland Islands.

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

3.2.6. Conservation biology and threat classification

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

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

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

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

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

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

3.3. *Global understanding of fisheries interactions*

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

3.4. *State of knowledge in New Zealand*

NZ sea lions interact with trawl fisheries resulting in incidental bycatch, specifically from animals being caught and drowned in the trawl nets. These interactions are largely confined to trawl fisheries in Sub-Antarctic waters (Figure 3.1); particularly the Auckland Islands arrow squid fishery (SQU6T), but also the Auckland Islands scampi fishery (SCI6A), other Auckland Islands trawl fisheries, the Campbell Island southern blue whiting (*Micromesistius australis*) fishery (SBW6I) and the Stewart-Snares shelf fisheries targeting mainly arrow squid (SQU1T; Thompson and Abraham 2010, Thompson *et al.* 2011, Thompson *et al.* 2012).[9]

NZ sea lions forage to depths of up to 600 m (Table 3.1), within the habitat where depth ranges for prey species range from 0–500 m for arrow squid, 250–600 m for spawning southern blue whiting and 350–550 m 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, breeding 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, the level of NZ sea lion bycatch has been monitored by government observers aboard a proportion of the fishing fleet in the SQU6T fishery (Wilkinson *et al.* 2003), generally amounting to around 20–40% observer coverage between 1995 and 2010 but reaching almost 100% during the 2001/02 season (see Table 3.4). Over the same period, there has also been 1–15% observer coverage for non-squid trawl fisheries operating around the Auckland Islands (primarily targeting scampi, but also jack mackerel, orange roughy and hoki), 20–60% observer coverage in the Campbell Island southern blue whiting fishery, and 8–43% observer coverage for the Stewart-Snares shelf trawl fisheries (primarily targeting squid, but also hoki, jack mackerel and barracouta; Table 3.4). Unobserved trips have tended to report NZ sea lion captures at a lower rate than observed trips across all observed fisheries. Fishers reported 177 NZ sea lion captures between 1998–99 and 2008–09, while observers reported 196 captures over the same period (Abraham and Thompson 2011). Observers observed an overall average of 4.7–11.2% of trawl tows each year over this time period, but fisheries where most sea lions are caught had higher observer coverage.

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

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

NZ sea lions	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Breeding males	Dispersed at sea or at haulouts		At breeding colony			Dispersed at sea or at haulouts						
Breeding females	At sea			At breeding colony		At breeding colony and at-sea foraging and suckling						
Pups	At sea			At breeding colony								
Non-breeders	Dispersed at sea, at haulouts, or breeding colony periphery											
Major fisheries	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Squid				Stewart-Snares Shelf		Auckland Islands and Stewart-Snares Shelf				Auckland Islands		
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 incorporated in increasingly sophisticated models to estimate the total number of captures across the entire fishing fleet in each fishing year (Smith and Baird 2007b, Thompson and Abraham 2010, Abraham and Thompson 2011). This approach is currently applied using information collected under DOC project INT2012-01 and analysed under MPI project PRO2010-01 (Thompson *et al.* 2011, Thompson *et al.* 2012). Estimates in Table 3.4 for the SQU6T and Campbell Island fisheries were generated using Bayesian models, whereas those for the Stewart-Snares and the Auckland Islands scampi and Auckland Islands other fisheries were generated using ratio estimates (Thompson *et al.* 2012). Captures comprise the number of NZ sea lions brought on deck (both dead and alive), and necessarily exclude the unknown fraction of animals that exit trawls through Sea Lion Exclusion Devices (SLEDs) as well as those that were decomposed upon capture or that climbed aboard vessels (Smith and Baird 2007b, Thompson and Abraham 2010 Thompson *et al.* 2011). Only 8 of the 248 captures from 1995/96 to 2008/09 were released alive (Thompson and Abraham 2010). Interactions are defined as the number of sea lion that would have been caught if no SLEDs were used (Thompson *et al.* 2012).

In the years since SLEDs were introduced in the SQU6T fishery, both the observed and estimated numbers of NZ sea lion captures have declined overall, except for a slight increase in 2009/10 (Table 3.4). Conversely, for those other fisheries where SLEDs are not deployed, observed and estimated numbers of NZ sea lion captures increased in the Campbell Island southern blue whiting fishery to a peak in 2010 (Table 3.4). For the Stewart-Snares and the Auckland Islands non-squid fisheries, the observed and estimated numbers of NZ sea lion captures have fluctuated without trend (Table 3.4).

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

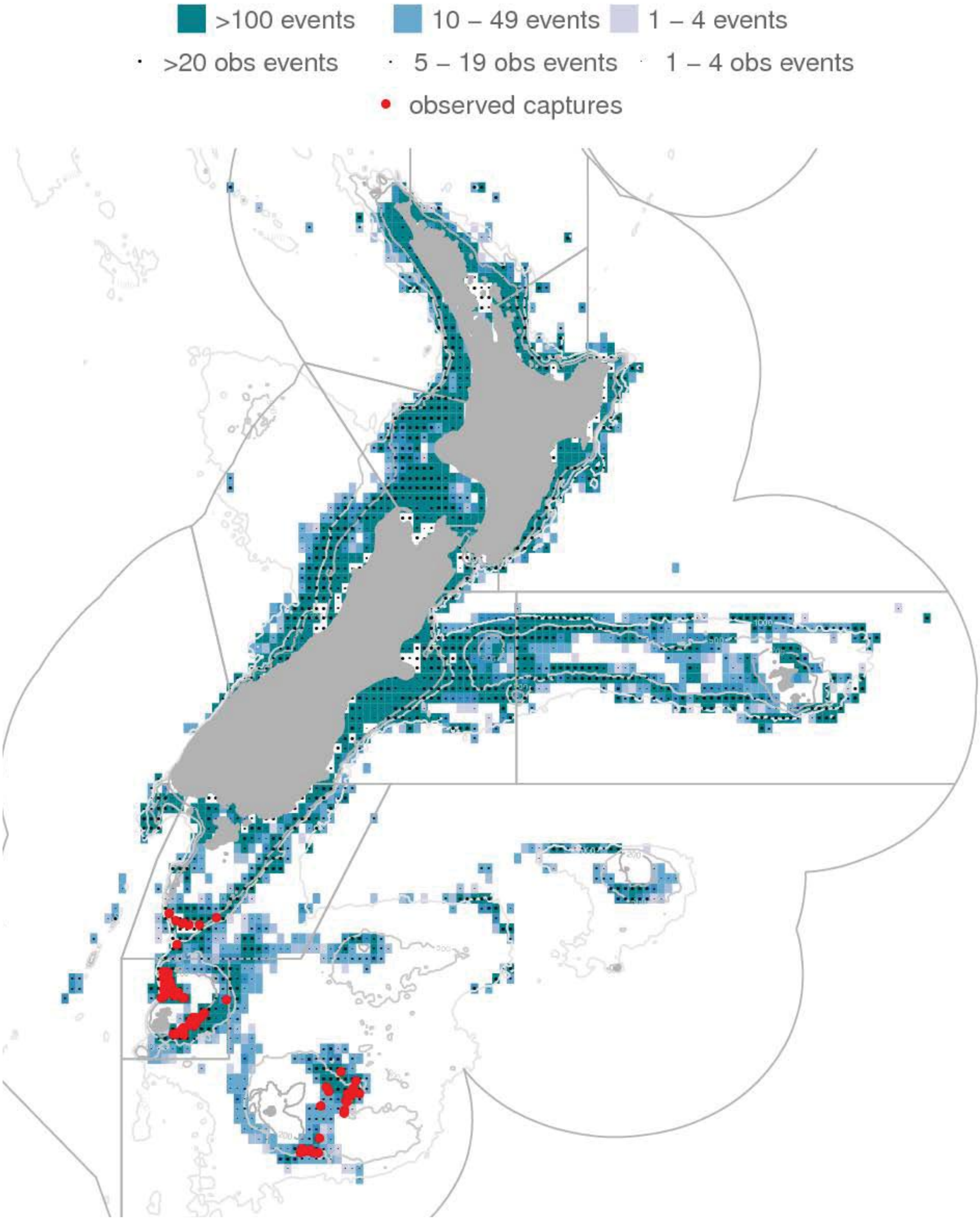


Figure 3.1: Distribution of trawl fishing effort and observed NZ sea lion captures, 2002-03 to 2010-11 (http://data.dragonfly.co.nz/psc/). Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 96.0% of the effort is shown.

Table 3.4a: Effort, observed and estimated NZ sea lion captures in trawl fisheries by fishing year in the New Zealand EEZ (http://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the the total number of tows; the observer coverage (the percentage of tows that were observed); the number of observed captures (both dead and alive); the capture rate (captures per hundred tows); the estimation method used (model, ratio or both combined); the mean number of estimated total captures (with 95% confidence interval); the mean number of estimated total interactions (with 95% confidence interval), and the stike rate (interactions per hundred tows). For more information on the methods used to prepare the data, see Thompson *et al.* (2012).

Fishing year	Fishing effort		Observed captures			Estimated captures		Estimated interations		Estimatedstrike rate	
	All effort	% obs	Number	Rate	Method	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Trawl fisheries											
1995–96	10 081	10	16	1.5	Both	148	85–242	148	85–243	1.5	0.8–2.4
1996–97	10 941	15	28	1.7	Both	155	104–221	155	102–225	1.4	0.9–2.1
1997–98	9 964	14	14	1.0	Both	76	47–119	76	45–121	0.8	0.5–1.2
1998–99	10 551	16	6	0.4	Both	33	20–49	33	19–50	0.3	0.2–0.5
1999–00	9 043	22	28	1.4	Both	88	63–129	89	59–130	1.0	0.7–1.4
2000–01	8 910	40	46	1.3	Both	61	52–72	83	59–111	0.9	0.7–1.2
2001–02	9 945	19	23	1.2	Both	64	46–88	94	61–139	0.9	0.6–1.4
2002–03	8 308	19	11	0.7	Both	34	22–48	62	37–97	0.7	0.4–1.2
2003–04	10 033	23	21	0.9	Both	61	43–85	214	120–376	2.1	1.2–3.7
2004–05	11 109	23	14	0.5	Both	53	36–77	181	94–325	1.6	0.8–2.9
2005–06	9 316	21	14	0.7	Both	52	35–75	174	86–334	1.9	0.9–3.6
2006–07	6 728	24	15	0.9	Both	47	32–66	118	59–235	1.8	0.9–3.5
2007–08	6 545	33	8	0.4	Both	29	18–42	118	35–418	1.8	0.5–6.4
2008–09	6 677	27	3	0.2	Both	22	12–36	103	25–383	1.5	0.4–5.7
2009–10	5 541	34	15	0.8	Both	46	32–66	141	51–439	2.5	0.9–7.9
2010–11	6 389	31	6	0.3	Both	29	17–43	81	26–259	1.3	0.4–4.1
Auckland Islands squid											
1995–96	4 467	12	13	2.4	Model	131	69–226	131	67–224	2.9	1.6–5.0
1996–97	3 716	19	28	3.9	Model	142	91–208	142	89–210	3.8	2.6–5.5
1997–98	1 441	22	13	4.2	Model	60	33–102	60	31–104	4.2	2.5–6.9
1998–99	402	38	5	3.2	Model	14	5–27	15	5–29	3.6	2.1–5.9
1999–00	1 206	36	25	5.7	Model	69	45–107	69	42–108	5.8	4.0–8.6
2000–01	583	99	39	6.7	Model	39	39–40	61	39–87	10.4	8.6–13.1
2001–02*	1 648	34	21	3.7	Model	43	30–64	73	43–116	4.4	3.0–6.6
2002–03	1 470	29	11	2.6	Model	19	13–29	48	24–81	3.2	2.0–5.1
2003–04	2 594	30	16	2.0	Model	41	26–62	194	100–356	7.5	4.0–13.5
2004–05^	2 706	30	9	1.1	Model	31	17–51	159	73–303	5.9	2.7–11.1
2005–06	2 462	28	9	1.3	Model	28	15–45	149	62–308	6.0	2.7–12.5
2006–07	1 320	41	7	1.3	Model	16	9–27	87	29–201	6.6	2.3–14.8
2007–08	1 265	46	5	0.9	Model	12	6–21	101	19–396	8.0	1.6–30.9
2008–09	1 925	40	2	0.3	Model	8	3–17	89	12–365	4.6	0.7–18.4
2009–10	1 190	25	3	1.0	Model	13	5–27	107	18–402	9.0	1.7–33.6
2010–11	1 586	34	0	–	Model	4	0–11	56	4–233	3.5	0.4–14.9

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

Table 3.4b: Effort, observed and estimated NZ sea lion captures in trawl fisheries by fishing year in the New Zealand EEZ (http://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the the total number of tows; the observer coverage (the percentage of tows 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, ratio or both combined); 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.* (2012).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% obs	Number	Rate	Method	Mean	95% c.i.
Auckland Islands scampi							
1995-96	1 303	5	2	3.2	Ratio	11	4–19
1996-97	1 222	15	0	-	Ratio	7	2–15
1997-98	1 107	11	0	-	Ratio	7	1–15
1998-99	1 254	2	0	-	Ratio	9	2–18
1999-00	1 383	5	0	-	Ratio	9	3–18
2000-01	1 417	6	4	4.8	Ratio	14	7–23
2001-02	1 604	9	0	-	Ratio	10	3–20
2002-03	1 351	11	0	-	Ratio	9	2–17
2003-04	1 363	12	3	1.8	Ratio	12	5–20
2004-05	1 275	0	NA	NA	Ratio	9	3–18
2005-06	1 331	9	1	0.9	Ratio	10	3–18
2006-07	1 328	7	1	1.1	Ratio	10	4–19
2007-08	1 327	7	0	-	Ratio	9	2–18
2008-09	1 457	4	1	1.6	Ratio	11	4–21
2009-10	940	10	0	-	Ratio	6	1–13
2010-11	1 401	15	0	-	Ratio	9	2–17
Auckland Islands other							
1995-96	405	6	1	4.0	Ratio	3	1–6
1996-97	296	4	0	-	Ratio	1	0–4
1997-98	684	17	1	0.9	Ratio	3	1–8
1998-99	525	10	1	1.8	Ratio	3	1–7
1999-00	750	13	0	-	Ratio	3	0–8
2000-01	577	7	0	-	Ratio	2	0–7
2001-02	589	4	0	-	Ratio	2	0–7
2002-03	543	13	0	-	Ratio	2	0–7
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

Table 3.4c: Effort, observed and estimated NZ sea lion captures in trawl fisheries by fishing year (calendar year for SBW) in the New Zealand EEZ (http://data.dragonfly.co.nz/psc/). For each fishing year, the table gives the the total number of tows; the observer coverage (the percentage of tows 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, ratio or both combined); 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.* (2012).

Fishing year	Fishing effort		Observed captures		Estimated captures		
	All effort	% observed	Number	Rate	Type	Mean	95% c.i.
Campbell Island SBW							
1996	474	27	0	-	Model	0	0–4
1997	641	34	0	-	Model	1	0–3
1998	963	28	0	-	Model	1	0–5
1999	788	28	0	-	Model	1	0–5
2000	447	52	0	-	Model	0	0–3
2001	672	60	0	-	Model	0	0–2
2002	980	28	1	0.4	Model	4	1–11
2003	599	43	0	-	Model	1	0–3
2004	690	34	1	0.4	Model	3	1–9
2005	726	37	2	0.7	Model	5	2–12
2006	521	28	3	2.1	Model	10	3–21
2007	544	32	6	3.5	Model	15	6–29
2008	557	41	2	0.9	Model	8	5–14
2009	627	20	0	-	Model	1	0–7
2010	550	43	11	4.7	Model	24	15–36
2011	815	40	6	1.8	Model	15	8–25
Stewart-Snares (mainly squid)							
1995-96	3432	8	0	-	Ratio	3	0–7
1996-97	5066	10	0	-	Ratio	4	0–9
1997-98	5769	10	0	-	Ratio	5	1–10
1998-99	7582	16	0	-	Ratio	6	1–13
1999-00	5257	23	3	0.3	Ratio	7	3–12
2000-01	5661	43	3	0.1	Ratio	6	3–10
2001-02	5124	18	1	0.1	Ratio	5	1–10
2002-03	4345	16	0	-	Ratio	3	0–8
2003-04	5097	21	1	0.1	Ratio	5	1–10
2004-05	6232	24	3	0.2	Ratio	7	4–13
2005-06	4963	19	1	0.1	Ratio	5	1–10
2006-07	3498	24	1	0.1	Ratio	4	1–7
2007-08	3249	36	1	0.1	Ratio	3	1–7
2008-09	2547	31	0	-	Ratio	2	0–5
2009-10	2784	43	1	0.1	Ratio	3	1–6
2010-11	2456	36	0	-	Ratio	1	0–4

3.4.2. Managing fisheries interactions

For NZ sea lions, efforts to mitigate fisheries bycatch have focused on the SQU6T fishery. Spatial and/or temporal closures have been put in place, SLEDs were developed by industry, codes of practice were introduced, and mortality limits imposed. In 1982 the Minister of Fisheries established a 12 nautical mile exclusion zone around the Auckland Islands from which all fishing activities were excluded (Wilkinson *et al.* 2003). In 1995, the exclusion zone was replaced with a Marine Mammal Sanctuary with the same controls on fishing (Chilvers 2008). The area was subsequently also designated as a Marine Reserve in 2003. In addition to these area-based measures, mitigation devices in the form of SLEDs were introduced in the SQU6T fishing fleet in 2001/02 (Figure 3.2), with widespread and standardised use by all the fleet since 2004/05. The use of SLEDs is not mandatory, but is required by the current industry body (the Deepwater Group), fleet wide in application and monitored by 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. This has happened seven times (1996 to1998, 2000, and 2002 to 2004) since this plan was first adopted in 1993 (Table 3.5; Robertson and Chilvers 2011).

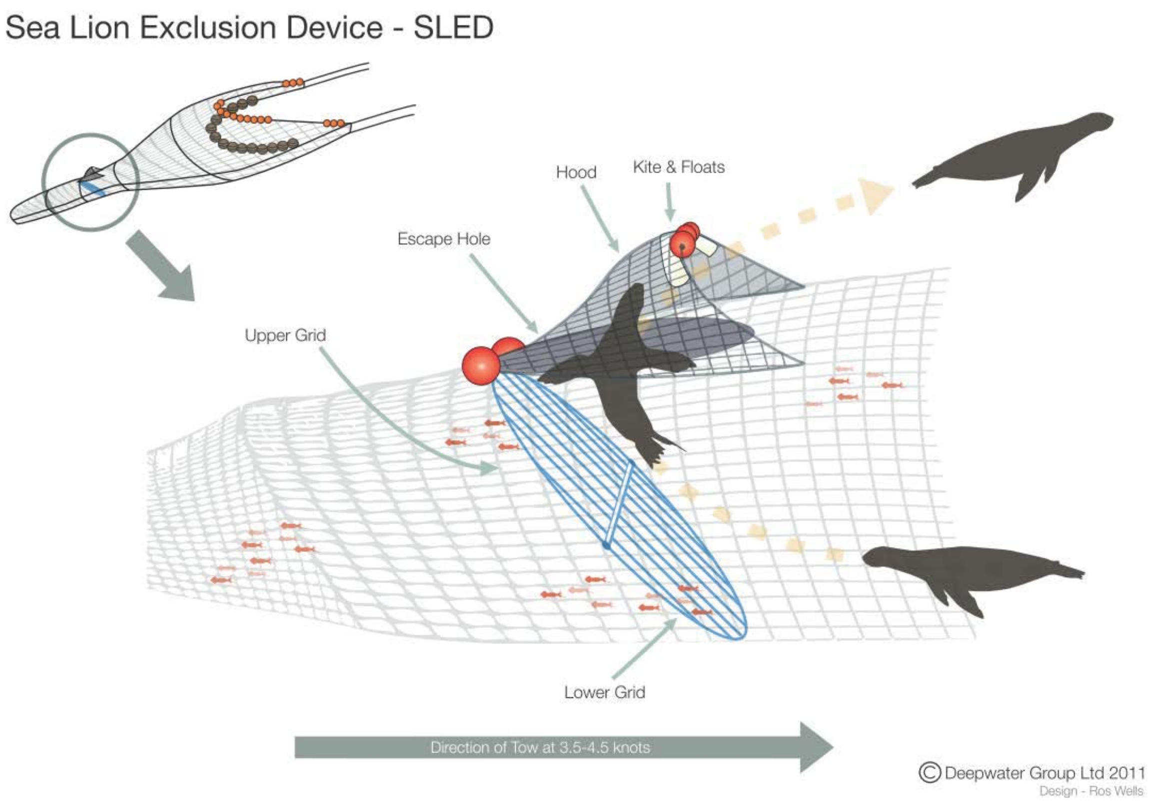


Figure 3.2: Diagram of a NZ sea lion exclusion device (SLED) inside a trawl net. Image courtesy of the Deepwater Group.

Before the widespread use of SLEDs, NZ sea lions incidentally caught during fishing were usually retained in trawl nets and hauled on board, allowing observers to gain an accurate assessment of the number of NZ sea lions being captured on observed tows in a given fishery. This enabled a relatively simple estimation of the total number of NZ sea lions killed. However, following the introduction of SLEDs, the number of NZ sea lions interacting with SLEDs and the proportion of those surviving are much more difficult to estimate. Since the introduction of SLEDs, therefore, it has become necessary to estimate the number of NZ sea lions interacting with trawls using a predetermined strike rate to monitor performance against any bycatch limits set. Using a predetermined strike rate enables the FRML to be converted into a number of tows for management purposes. The rate of 5.65% assumed by MPI for the SQU6T fishery is based on rates observed on vessels without SLEDs from 2003/04 to 2005/06 and is also assumed as part of the fishery implementation within an integrated management procedure evaluation model (named the BFG model after its authors, see section 3.3.3). A strike rate of 5.89 will be assumed for the 2012-13 season, reflecting a slight increase in the long-term average. The most recent strike rates are given in Table 3.4 (Thompson *et al*. 2012).

The current management regime for the SQU6T fishery provides for a “discounted” strike rate to apply to all tows when an approved SLED is used (because SLEDs allow some NZ sea lions to escape and survive their encounters with trawl nets; Thompson and Abraham 2010, see Table 3.5). The SLED discount rate is a fisheries management setting and should not be confused with the actual survival of NZ sea lions that encounter a trawl equipped with a SLED, but the discount mechanism is duplicated in the BFG simulations. The current discount rate of 82% means that the strike rate is reduced from 5.89% to 1.06% so that, for every 100 tows using an approved SLED, 1.06 NZ sea lions are presumed killed. Ideally, the discount rate would be equal to the survival rate of NZ sea lions that encounter a trawl in circumstances that would be fatal if no SLED were fitted. This survival rate is the product of the proportion of animals that exit a trawl with a SLED and their post-exit survival.

Table 3.5: Maximum allowable level of fisheries-related mortality (MALFiRM) or fisheries-related mortality limit (FRML) from 1991 to 2013. Note, however, that direct comparisons among years of the limits in Table 3.5 are not possible because the assumptions underlying the MALFiRM or FRML changed over time.

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

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

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

3.4.3. Modelling population-level impacts of fisheries interactions

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

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

The BFG model incorporates various population dynamics observations (tag re-sighting observations, pup births and mortality, age at maturity) as well as bycatch counts and catch-at-age data from the SQU6T trawl fishery. The model was projected into the future by applying the observed dynamics and a virtual fishery model that is managed in roughly the same way as the real SQU6T fishery. A large number of projections were run and used to assess the likely performance of a wide range of different management control rules against the four performance criteria described in Context (two MFish criteria and two DOC criteria). For each set of runs the population indicators were summarised and the rules compared in tables. The BFG model is sensitive to several key parameters (see Sources of uncertainty, below) and is scheduled to be reviewed in 2013.

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

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

Notwithstanding the limitations of the necropsy data in assessing trauma for previously frozen animals, it was possible to determine that none of the necropsied animals sustained sufficient injuries to the body (excluding the head) to compromise survival (Roe and Meynier 2010, Roe 2010). Head trauma, most likely due to impacts with the SLED grid, could not be ruled out as a potential contributing factor (Roe and Meynier 2010, Roe 2010). In order to quantify the likelihood of a NZ sea lion experiencing physical trauma sufficient to render the animal insensible (and therefore likely to drown) after a colliosion 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 derived from a number of sources, including necropsies (for head mass), video footage of Australian fur seals interacting with Seal Exclusion Devices (SEDs) (for impact speed, location and body orientation) and biomechanical modelling of impacts on the SLED grid (for the risk of brain injury).

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

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

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

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

For the base case, the simulation results indicated there was a 3.3% chance of a single head-first collision resulting in MTBI with a 95 percentile of 15.7% risk of MTBI (Abraham 2011). Sensitivities 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, some additional assumptions were made based on the Australian observations. Using these data, Abraham (2011) estimated the number of head-first collisions per interaction as 0.74, leading to an estimated probability of MTBI for a NZ sea lion interacting with a trawl of 2.7%. Single parameter sensitivity runs increased this to up to 4.6% and the multiple parameter sensitivity using the scenario described above increased it to 8.2% (Abraham 2011). Assuming synergistic interaction between successive head-first strikes (each collision carrying 5 times more risk than previous ones) did not appreciably increase the overall risk because few fur seals had multiple head-first collisions. These results indicate that the risk of mortality for NZ sea lions interacting with the SLED grid is probably low, although some remaining areas of uncertainty were identified (see below).

3.4.4. Sources of uncertainty

There are several outstanding sources of uncertainty in modelling the effects of fisheries interactions on NZ sea lions at the Auckland Islands, including uncertainty relating to the Bayesian management procedure evaluation model (the BFG model, Breen *et al.* 2010), uncertainty in the modelling of stike rate (Thompson *et al.* 2011) 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, potentially as a consequence of attempting to estimate λ for a declining population. This is a very low maximum growth rate for a pinniped (some suggest a default value of 12% per year, Wade 1998), so a prior of 8% was applied to the base model. In a sensitivity run, the model was fitted using a prior of 5% per year, and the results were more consistent with the observed data than when 8% was used.

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

The density dependent response for this population of NZ sea lions is largely unknown, although there is presently no evidence of a density dependent response in life-history traits such as pup mass, pup survival or female fecundity (Chilvers 2012b). Ecological principles suggest that, as numbers in a population decline, individuals compete less with one another for resources. Less competition may result in NZ sea lions growing faster as well as having lower mortality rates and higher rates of pup production and survival. The effect of this type of response is that populations tend to recover from events that reduce their numbers, and populations with strong density dependence recover more strongly than those with weak density dependence. In the BFG model, the shape of the density dependent response was "hard wired" in the model and assumed to occur entirely in the mortality rate of pups. The strength of this response is unknown, and there was no information to support a strong preference for any of the assumed values used in sensitivity runs. This means the base model results may be either conservative or optimistic.

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

In addition to sources of uncertainty for inputs in the BFG model, there are other sources of uncertainty relevant to the management of fisheries interactions. For example, the estimated strike rate has varied considerably over time, and the model estimates of strike rates for recent years are very imprecise (Thompson *et al.* 2011, Table 3.4). Although year on year variation in strike rate is unlikely to appreciably affect the conclusions from the simulations, if the long-term average strike rate is higher or lower than that assumed within the fishery component of the simulations, or if the strike rate or catchability has increased since the introduction of SLEDs, then there may be some bias. If NZ sea lion catchability has increased, as a result of the increased average tow duration in the SQU6T fishery since the introduction of SLEDs (Table 3.6), or by some other factor, then this would make the simulations optimistic.

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

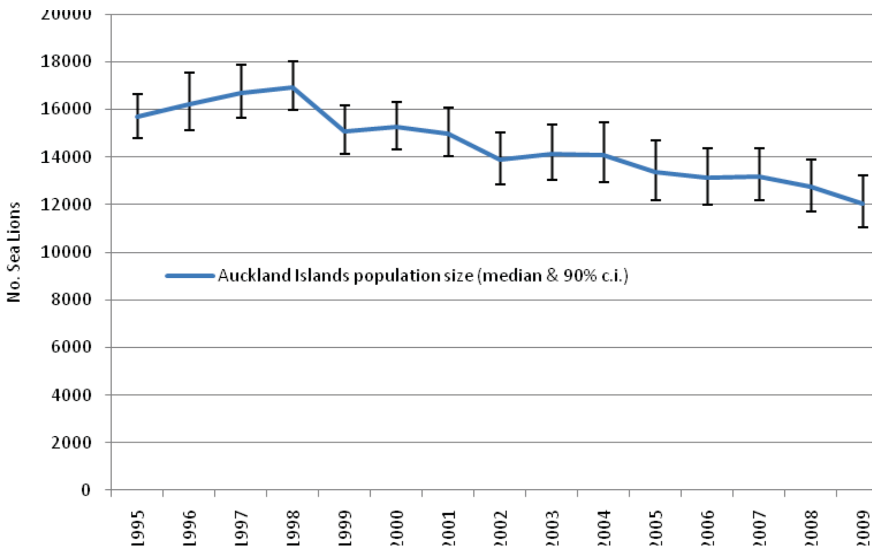
* Includes data up to November 30, 2012.

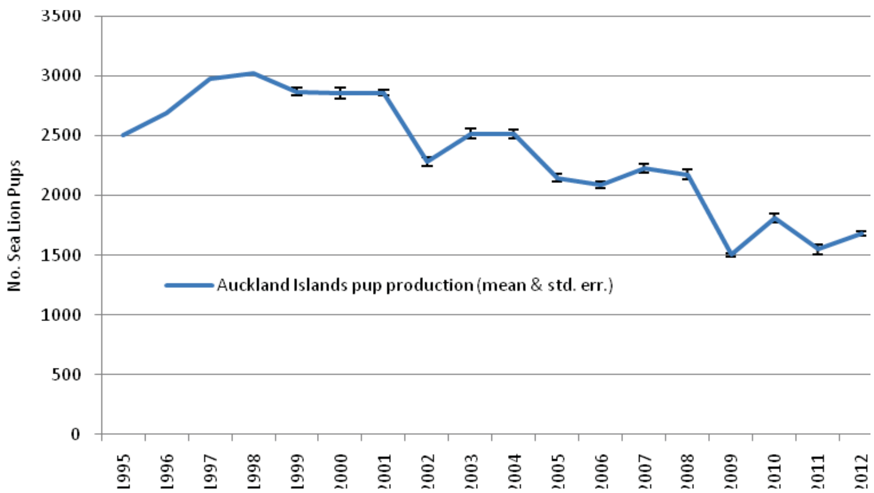
There are a number of possible sources of uncertainty relating to the biomechanical modelling (Ponte *et al.* 2010, 2011, Abraham 2011, Lyle 2011). The use of linear acceleration, as opposed to rotational (angular) acceleration, in the biomechanical modelling may underestimate the risk of MTBI, although 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.

3.4.5. Potential indirect threats

In addition to sources of uncertainty associated with direct fisheries interactions, there is the possibility that indirect fisheries effects may have population-level consequences for NZ sea lions. Such indirect effects may include competition for food resources between various fisheries and NZ sea lions (Robertson and Chilvers 2011). In order to determine whether resource competition is present and is having a population-level effect on NZ sea lions, research must identify if there are resources in common for NZ sea lions and the various fisheries within the range of NZ sea lions, and if those resources are limiting. Diet studies have demonstrated overlap in the species consumed by NZ sea lions and those caught in fisheries within the range of NZ sea lions, particularly hoki and arrow squid (Cawthorn *et al.* 1985, Childerhouse *et al.* 2001, Meynier *et al.* 2009). A recent study focused on energy and amino acid content of prey determined that the selected prey species contained all essential amino acids and were of low to medium energy levels (Meynier 2010). This may indicate that the nutritional content of prey species is not limiting the metabolic activity of NZ sea lions, although vitamin and mineral content were not considered. Meynier (2010) also developed a bio-energetic model and used it to estimate the amount of prey consumed by NZ sea lions at 17 871 tonnes (95% CI 17 738–18 000 t) per year. This is equivalent to ~30% of the tonnage of arrow squid, and ~15% of the hoki harvested annually by the fisheries in the Sub-Antarctic between 2000 and 2006 (Meynier 2010). Comparison of the temporal and spatial distributions of sea lion prey, sea lion foraging and of historical fishing extractions may help to identify the mechanisms whereby resource competition might occur (Bowen 2012). The effects of fishing on sea lion prey species are likely to be complicated by food web interactions and multispecies models may help to assess the extent to which resource competition can impact on sea lion populations, such as those currently being developed by NIWA (Project SA123098). In addition, multispecies models may provide a means for simultaneously assessing multiple drivers of sea lion population change (a review of potential causes is given in Robertson & Chilvers 2011) which may be a more effective approach than focussing on single factor explanations for the recent observed decline in NZ sea lions (Bowen 2012).

3.5. *Indicators and trends*

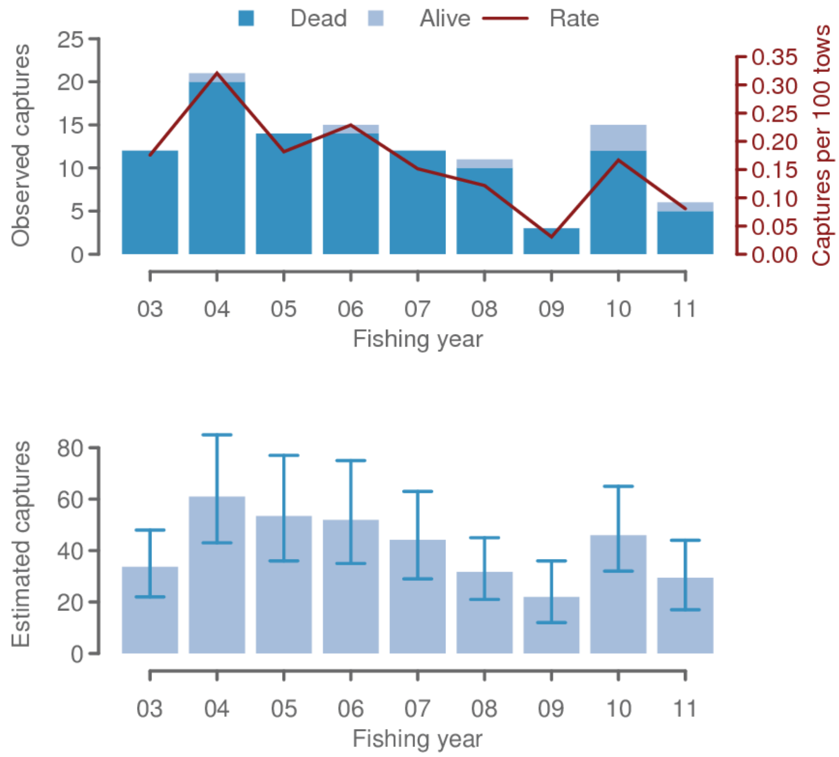
<table>
<tr><td>Population size</td><td>
• 12 065 animals (including pups < 1 yr old) at the Auckland Islands (90% CI: 11 160–13 061) in 2009 (most recent model estimate)[10]
• 1 683 pups at the Auckland Islands (SE = 16) in 2011/12[11]
• 681–726 pups at Campbell Island in 2010[12]
• 25 pups tagged at Stewart Island during a DOC recreational hut and track maintance trip in March 2012
• 5 pups at the Otago Peninsula in 2011/12[13]
</td></tr>
<tr><td>Population trend</td><td>
• Estimated abundance at the Auckland Islands:


• Pup production at the Auckland Islands:


• The population is probably increasing at Campbell Island based on substantial increases in pup counts (although methodology has changed over time).
• The population is increasing at the Otago Peninsula through a combination of reproduction and immigration.
</td></tr>
</table>

[10] Breen *et al*. (2010).
[11] Chilvers (2012).
[12] Robertson and Chilvers (2011), Maloney *et al*. (2012).
[13] For more information, see: http://www.sealiontrust.org.nz/otago-sea-lion-family-tree/.

<table>
<tr><td>Threat status</td><td>• NZ: Nationally Critical, Criterion C[14], Range Restricted[15], in 2010[16]
• IUCN: Vulnerable, A3b[17], in 2008[18]</td></tr>
<tr><td>Number of interactions[19]</td><td>• 81 estimated interactions (95% CI: 26-259) in trawl fisheries in 2010-11
• 29 estimated captures (95% CI: 17-43) in trawl fisheries in 2010-11
• 6 observed captures in trawl fisheries in 2010-11</td></tr>
<tr><td>Trend in interactions</td><td>Trawl fisheries:



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

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[14] 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).

[15] 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).

[16] Baker *et al*. (2010).

[17] 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).

[18] Gales (2008).

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

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

Scope of chapter	This chapter outlines the biology New Zealand fur seals (*Arctocephalus forsteri*), the nature of any fishing interactions, the management approach, trends in key indicators of fishing effects and major sources of uncertainty.
Area	All of the New Zealand EEZ and territorial sea.
Focal localities	Areas with significant fisheries interactions include waters over or close to the continental shelf surrounding the South Island and southern offshore islands, notably Cook Strait, West Coast South Island, Banks Peninsula and the Bounty Islands, plus offshore of Bay of Plenty-East Cape.
Key issues	Improving estimates of incidental bycatch in some fisheries, and assessing the potential for 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*.
Other Govt Research (current)	DOC Marine Conservation Services Programme (CSP): INT2012-01 *To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities.*
Links to 2030 objectives	Objective 6: Manage impacts of fishing and aquaculture. Strategic Action 6.2: Set and monitor environmental standards, including for threatened and protected species and seabed impacts
Related issues/chapters	See the New Zealand sea lion chapter.

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.

In 2004, DOC approved the *Department of Conservation Marine Mammal Action Plan for 2005–2010*[20] (Suisted and Neale 2009). The plan specifies a number of species-specific key objectives for NZ fur seals, of which the following is most relevant for fisheries interactions: *"To control/mitigate fishing-related mortality of NZ fur seals in trawl fisheries (including the WCSI hoki and Bounty Island southern blue whiting fisheries)."*

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

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

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

Specific objectives for the management of NZ fur seals bycatch are to be outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ fur seals are most likely to interact. These fisheries include hoki (HOK), southern blue whiting (SBW), hake (HAK) and jack mackerel (JMA). The HOK chapter of the National Deepwater Plan is complete and includes Operational Objective 2.11: *Ensure that incidental marine mammal captures in the hoki fishery are avoided and minimised to acceptable levels (which may include standards) by 2012*. The SBW chapter is nearing completion while the timeframes for the HAK and JMA chapters are yet to be confirmed.

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

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 one of only two species of otariid (eared seals, includes fur seals and sea lions) native to New Zealand, the other being the New Zealand sea lion (*Phocarctos hookeri* (Gray, 1844)).

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