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Review of research and monitoring studies on New Zealand sharks, skates, rays and chimaeras, 2008−2012

New Zealand Aquatic Environment and Biodiversity Report No. 102.

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W. S. Lyon

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Francis, M.P.; Lyon, W.S. (2012). Review of research and monitoring studies on New Zealand sharks, skates, rays and chimaeras, 2008−2012.

New Zealand Aquatic Environment and Biodiversity Report No. 102. **70 p.**

The New Zealand National Plan of Action for the Conservation and Management of Sharks (NPOA) came into effect in October 2008. It contains a suite of planned actions in the areas of research, compliance and management that aim "to ensure the conservation and management of sharks and their long-term sustainable use". The NPOA contains a requirement to conduct a review of its achievements in 2012. To inform that review, there is a need to identify, collate, analyse and summarise the actions carried out under the umbrella of the NPOA since 2008. The purpose of the present review is to complete that task for actions relevant to research and monitoring (this report does not cover actions related to compliance and management). The study reviewed existing research and monitoring, and did not carry out any new research or data analyses.

Published and unpublished literature sources were searched for research and monitoring studies carried out on chondrichthyans in New Zealand waters since 2008. One hundred and seven sources were reviewed. Each source was classified into one of 10 categories:

- taxonomy;
- identification guides;
- genetics;
- distribution and movement;
- feeding;
- growth and reproduction;
- fisheries catches and catch per unit effort (CPUE);
- trawl surveys;
- stock assessment; and
- mitigation of human impacts.

For each source, the species covered, methods, results, conclusions and limitations (where appropriate) were summarised. More than two-thirds (71%) of the studies fell into four categories: genetics, distribution and movement, fisheries catches and CPUE, and trawl surveys. There were few studies covering the other six categories. A list of the 119 known species of New Zealand chondrichthyans is provided, along with an indication of their occurrence in each of the 10 information categories. Twenty-seven species (nine Quota Management System and 18 non-QMS) occurred in four or more categories. Eighty-three species (70%) occurred in at least one study, although that number dropped to 64 (54%) when those species included only in an identification guide were excluded. Thirty-six species (30%) occurred in none of the studies.

The achievements of the NPOA were assessed in relation to the actions specified in the plan. The recent production of a comprehensive species guide should improve fisher and observer catch reporting (NPOA Sections 4.1 and 4.2). Research and monitoring (NPOA Section 4.3) have been strengthened in a number of areas. Genetic studies have contributed to species identification, knowledge of population structure and identifying the source of food products such as shark fin soup. A number of surveys have been carried out in the previously little-studied Kermadec and Norfolk Ridge regions, highlighting new chondrichthyan biodiversity. Tagging technology continues to reveal individual movement patterns of both oceanic and coastal shark species. Long-running trawl surveys in certain regions have provided data for a wide variety of biological studies including diet, age, growth and reproductive biology, and provide the only estimates of biomass for some species. Both target and non-target catch rates and the fate of different species are monitored in a wide variety of fisheries, although observer coverage is sometimes insufficient to provide reliable information.

Research and monitoring actions that were not completely addressed were summarised, and recommendations were made for additional research during the next five years to fill these gaps. The lack of recent biomass or biological data for northern New Zealand was highlighted, and given the value of the existing time series surveys in other areas, re-instatement, in some form, of trawl surveys around the North Island is suggested. The relatively low number of species for which CPUE analyses and/or stock assessment have been carried out during the term of the NPOA was noted. It is recommended that a review be conducted to determine which species have sufficient information available for such studies, and which species could reach that stage if efforts are made to gather the required data, during the next five years. For those species where sufficient data is unlikely ever to be available, productivity and vulnerability should be assessed using a suitable risk assessment approach. Identification of specific habitats of significance, such as nursery grounds, for key inshore species is recommended, given their likely vulnerability to human impacts.

1. INTRODUCTION

The New Zealand National Plan of Action for the Conservation and Management of Sharks (NPOA) came into effect in October 2008. It contains a suite of planned actions in the areas of research, compliance and management that aim "to ensure the conservation and management of sharks and their long-term sustainable use". The impacts of fishing are likely to constitute the greatest threats to the sustainability of sharks and consequently they form the primary focus of New Zealand's current NPOA. However, it is anticipated that non-fishing related impacts on sharks, such as pollution, coastal development and land use change, and climate change, will be incorporated into later versions (Ministry of Fisheries 2008).

The NPOA contains a requirement to conduct a review of its achievements in 2012. To inform that review, there is a need to identify, collate, analyse and summarise the actions carried out under the umbrella of the NPOA since 2008. The purpose of the present study is to complete that task for actions relevant to research and monitoring (this report does not cover actions related to compliance and management). Specified "actions to improve information" in the NPOA are: strengthen existing research and monitoring programmes; reduce the use of generic shark reporting codes; and produce a field identification guide. This study reviews existing research and monitoring, and does not carry out any new research or data analyses.

In the NPOA, "sharks" are defined to include all chondrichthyans, viz. sharks, rays, skates and chimaeras. The NPOA applies to species that are found within New Zealand's Exclusive Economic Zone (EEZ) and Territorial Sea, migratory species that frequent New Zealand's EEZ and Territorial Sea, and species taken by New Zealand-flagged vessels fishing on the High Seas. The scope of this report follows that of the NPOA in covering all chondrichthyans occurring in or passing through New Zealand waters (including the Ross Sea, Antarctica), and species caught by New Zealand vessels. Only research and monitoring studies that have been completed to final report or In Press stage since the NPOA came into force (2008) are included.

The overall objective of the study is:
"To collate and summarise information in support of a review of the National Plan of Action for the Conservation and Management of Sharks (NPOA – Sharks)".

The Specific objectives of project ENV201101 are:

1. To collate and summarise information in support of a review of the National Plan of Action for the Conservation and Management of Sharks (NPOA – Sharks).
2. To identify research gaps from Objective 1 and suggest cost-effective ways these could be addressed.

2. METHODS

Published and unpublished literature were searched for research and monitoring studies carried out on chondrichthyans in New Zealand waters since 2008. Sources ranged from scientific literature and published Ministry for Primary Industries (MPI; formerly Ministry of Fisheries) documents to unpublished documents produced by various parties for MPI Fishery Assessment Working Group meetings, Department of Conservation Conservation Services Programme meetings and contracts, and other grey literature. Searches were made for published literature using the Proquest and Web of Knowledge bibliographic search engines, which access the following databases: Aquatic Sciences and Fisheries Abstracts, Web of Science, Current Contents, Journal Citation Reports and Zoological Record.

The following main categories of information were sought for this review:

- Taxonomic description of chondrichthyans

- Identification guides to chondrichthyans
- Genetics studies of species and stocks
- Geographical and depth distribution, movements and migrations, and habitat requirements
- Food and feeding
- Age, growth, reproduction and productivity
- Fishery characterisations, trends in catches, conversion factors used to convert processed weight to whole weight, catch per unit effort (CPUE), and catch composition
- Trawl surveys to monitor distribution, abundance and population composition
- Stock assessment and stock status
- Mitigation of human impacts.

The order of the categories reflects a progression from the identification of species and stocks through behaviour and biology to catches, abundance and stock assessment. Information sources were classified into one of the above categories. Some sources covered more than one category, but each source was assigned to the single most appropriate category. Only sources that provided new data or information, or were considered to perform a relevant and useful review of existing information, were included. Reports that simply listed a species by name or gave catches of the species during a survey or fishing event, were not considered significant and were excluded. Within each category, sources were listed in chronological order.

Identified sources were synthesised into concise, informative summaries that included a bibliographic reference, list of the species covered, a description of the methods, the major results and conclusions, and an assessment of the study's limitations (where applicable). This short, simple layout was used to facilitate ease and speed of scanning for relevant information. A full list of the references is provided, and readers are referred to the original sources for further details.

A list of 119 known New Zealand chondrichthyans (including those from the Ross Sea) is provided, detailing scientific family, generic and specific names, and common names. The number of studies that covered each species is tabulated by the 10 information categories listed above.

Identifying research gaps for all chondrichthyans throughout New Zealand would be a very large job that is beyond the scope of this study. Quantitative stock assessments have been completed for only three chondrichthyan stocks (rig in SPO 3 and SPO 7, and elephantfish in ELE 3). Furthermore, much of the research history of chondrichthyans pre-dates the NPOA, and falls outside the somewhat narrow range of actions in the NPOA. Here we focus on the achievements of the NPOA by comparing the action list in Section 4 of the NPOA with our review of research and monitoring studies carried out in the last five years (section 3.1 below). We identify which actions have been partially or fully completed and which gaps still require attention, and make recommendations of cost-effective ways of addressing these gaps.

3. RESULTS

3.1 Review of research and monitoring studies

One hundred and seven New Zealand chondrichthyan studies published or reported during 2008–2012 are summarised below.

3.1.1 Taxonomy

1 Didier, D.A. (2008). Two new species of the genus *Hydrolagus* Gill (Holocephali: Chimaeridae) from Australia. *CSIRO Marine and Atmospheric Research Paper 22*: 349–356.

a) Species: Black ghost shark (*Hydrolagus homonycteris*).

b) Methods

- Taxonomic description of new species of ghost sharks from Australasia.

c) Results and conclusions

- *Hydrolagus homonycteris* is described from specimens collected from the continental slope and seamounts off southeastern Australia and deepwater fishing grounds off New Zealand in depths ranging from 866–1447 m. The species has previously been known as *Hydrolagus* sp. A (HYB).

2 Sasahara, R.; Sato, K.; Nakaya, K. (2008). A new species of deepwater cat shark, *Apristurus ampliceps* sp. nov. (Chondrichthyes: Carcharhiniformes: Scyliorhinidae), from New Zealand and Australia. *CSIRO Marine and Atmospheric Research Paper 22*: 93–104.

a) Species: Roughskin cat shark (*Apristurus ampliceps*).

b) Methods

- Taxonomic description of a new species of cat shark from Australasia.

c) Results and conclusions

- *Apristurus ampliceps* sp. nov. is described from the waters off New Zealand and Australia at depths of 800–1503 m.

3 Seret, B.; Last, P.R. (2009). *Notoraja sapphira* sp. nov. (Rajoidei: Arhynchobatidae), a new deepwater skate from the slopes of the Norfolk Ridge (South-West Pacific). *Zootaxa 2153*: 24–34.

a) Species: Sapphire skate (*Notoraja sapphira*).

b) Methods

- Taxonomic description of a new species of skate from the Norfolk Ridge.

c) Results and conclusions

- *Notoraja sapphira* is described from five specimens collected on the slopes of the Norfolk Ridge between 1195 and 1313 m depth.

4 Straube, N.; Duhamel, G.; Gasco, N.; Kriwet, J.; Schliewen, U.K. (2012). Description of a new deep-sea lantern shark *Etmopterus viator* sp. nov. (Squaliformes: Etmopteridae) from the Southern Hemisphere. *In:* Duhamel, G.; Welsford, D. (eds). The Kerguelen Plateau: marine ecosystem and fisheries, pp. 137–150. Société Française d'Ichtyologie, France.

a) Species: Blue-eye lantern shark (*Etmopterus viator*).

b) Methods

- Taxonomic description of a new species of lantern shark from Kerguelen Islands and New Zealand.

c) Results and conclusions

- *Etmopterus viator* is described from specimens collected from Kerguelen Island and the Chatham Rise between 830 and 1610 m depth. It is also known from South Africa and the Macquarie Ridge, and may have a Southern Hemisphere distribution.
- Brief notes are given on litter size, size at maturity, maximum size, and food.

3.1.2 Identification guides

5 McMillan, P.J.; Marriott, P.; Hanchet, S.M.; Fenaughty, J.M.; Mackay, E.; Sui, H.; Wei, F. (2009). Field identification guide to the main fishes caught in the Ross Sea long-line fishery. Unpublished report for Ministry of Fisheries. 57 p.

a) Species: Antarctic skates.

b) Methods

- Field guide for Antarctic skates, mostly caught as bycatch in the Ross Sea bottom longline fishery.
- Includes photos, distinguishing features, colour, size, distribution, depth, similar species, biological notes.

c) Results and conclusions

- Antarctic fish identification guide.
- Covers four skates.

6 McMillan, P.J.; Francis, M.P.; James, G.D.; Paul, L.J.; Marriott, P.J.; Mackay, E.; Wood, B.A.; Griggs, L.H.; Sui, H.; Wei, F. (2011a). New Zealand fishes. Volume 1: A field guide to common species caught by bottom and midwater fishing. *New Zealand Aquatic Environment and Biodiversity Report No. 68*. 329 p.

a) Species: Multiple.

b) Methods

- This identification guide includes the more commonly caught bottom and midwater New Zealand chondrichthyans.
- It is intended for use in the field.

c) Results and conclusions

- Includes photos, distinguishing features, colour, size, distribution, depth, similar species, biology and ecology, references.
- Covers 33 sharks, 12 skates and rays, and 9 chimaeras.

7 McMillan, P.J.; Francis, M.P.; Paul, L.J.; Marriott, P.J.; Mackay, E.; Baird, S.-J.; Griggs, L.H.; Sui, H.; Wei, F. (2011b). New Zealand fishes. Volume 2: A field guide to less common species caught by bottom and midwater fishing. *New Zealand Aquatic Environment and Biodiversity Report No. 78*. 181 p.

a) Species: Multiple.

b) Methods

- This identification guide includes the less common chondrichthyans caught during bottom and midwater fishing in New Zealand.
- It is intended for use in the field.

c) Results and conclusions

- Includes photos, distinguishing features, colour, size, distribution, depth, similar species, biology and ecology, references.
- Covers 5 sharks and 2 chimaeras.

8 McMillan, P.J.; Griggs, L.H.; Francis, M.P.; Marriott, P.J.; Paul, L.J.; Mackay, E.; Wood, B.A.; Sui, H.; Wei, F. (2011c). New Zealand fishes. Volume 3: A field guide to common species caught by surface fishing. *New Zealand Aquatic Environment and Biodiversity Report No. 69*. 145 p.

a) Species: Multiple.

b) Methods

- This identification guide includes the more common chondrichthyans caught during surface fishing in New Zealand.
- It is intended for use in the field.

c) Results and conclusions

- Includes photos, distinguishing features, colour, size, distribution, depth, similar species, biology and ecology, references.
- Covers 25 sharks and 3 skates and rays.

3.1.3 Genetics

9 Smith, P.J.; Steinke, D.; McVeagh, S.M.; Stewart, A.L.; Struthers, C.D.; Roberts, C.D. (2008b). Molecular analysis of Southern Ocean skates (*Bathyraja*) reveals a new species of Antarctic skate. *Journal of Fish Biology 73(5)*: 1170–1182.

a) Species: Antarctic allometric skate.

b) Methods

- Two regions of mtDNA, cytochrome b and cytochrome c oxidase subunit 1, sequenced in nine species of *Bathyraja* from the Southern Ocean and New Zealand.

c) Results and conclusions

- The species that has been referred to as *Bathyraja eatonii* from the Antarctic is distinct from *B. eatonii* from the Kerguelen Plateau (type locality), and is a new and undescribed species.

10 Smith, P.J.; Steinke, D.; McMillan, P.J.; McVeagh, S.M.; Struthers, C.D. (2008a). DNA database for commercial marine fish. *New Zealand Aquatic Environment and Biodiversity Report No. 22*. 62 p.

a) Species: Multiple.

b) Methods

- Muscle tissue samples were taken for DNA barcoding.
- DNA extraction, amplification and sequencing followed standard procedures for the cytochrome *c* oxidase I gene, the COI barcode region.

c) Results and conclusions

- List of chondrichthyans DNA barcoded in the project.

11 Smith, P.J.; McVeagh, S.M. (2008). DNA identification of suspect shark soup and dried shark fin. NIWA Client Report No. WLG2008-62. 5 p.

a) Species: Not applicable.

b) Methods

- Samples of shark fin soup and shark fin were genetically tested using gene sequences from the barcode region of the mitochondrial DNA cytochrome c oxidase I gene, COI, and also “mini” barcodes based on small fragments of DNA (ca 100 bp) typical of those obtained from processed food products.

c) Results and conclusions

- No sequence matches were found with those stored in gene databases, and the samples were more closely related to teleost sequences than elasmobranch sequences.

d) Study limitations

- Gene databases do not have a comprehensive set of barcode and "mini" barcode sequences from New Zealand elasmobranchs for comparison with sequences obtained from fish products.

12 Smith, P.J. (2009). Review of genetic studies of rig and school shark. Final Research Report for Ministry of Fisheries Project INS200803. 16 p.

a) Species: Rig, school shark.

b) Methods

- A desktop review of molecular genetic studies on rig and school shark.

c) Results and conclusions

- Low genetic variation of allozymes and mitochondrial (mt) DNA RFLPs has been reported in rig and school shark.
- The mtDNA control region has higher levels of genetic diversity in several shark species, including school shark, and genetic divergence across ocean basins.
- For many coastal sharks, genetic subdivisions within oceans are associated with oceanic barriers, with little differentiation along continental margins.
- Microsatellite markers applied to population studies of shark species worldwide have high genetic diversity, but little evidence for differentiation within ocean basins.
- Neutral genetic markers are unlikely to be a useful tool for distinguishing fishery management units within the New Zealand EEZ.
- If genetic differentiation is found among populations, it can be interpreted as evidence for discrete stocks. However, a lack of genetic differentiation, does not preclude the existence of discrete stocks since even large populations separated for thousands of generations may not have had sufficient time for genetic differences to accumulate.
- DNA markers that are under selection may provide finer spatial patterns of genetic differentiation.

13 Chabot, C.; Allen, L.G. (2009). Global population structure of the tope (*Galeorhinus galeus*) inferred by mitochondrial control region sequence data. *Molecular Ecology 18*: 545–552.

a) Species: School shark.

b) Methods

- Analysed control region mtDNA from worldwide school shark samples, but no samples from New Zealand included.

c) Results and conclusions

- Regional populations appear to be isolated with little to no gene flow occurring among them.

d) Study limitations

- Does not include New Zealand school shark.

14 Benavides, M.T.; Feldheim, K.A.; Duffy, C.A.; Wintner, S.; Braccini, J.M.; Boomer, J.; Huveneers, C.; Rogers, P.; Mangel, J.C.; Alfaro-Shigueto, J.; Cartamil, D.P.; Chapman, D.D. (2011). Phylogeography of the copper shark (*Carcharhinus brachyurus*) in the southern

hemisphere: implications for the conservation of a coastal apex predator. *Marine and Freshwater Research 62*: 861–869.

a) Species: Bronze whaler shark.

b) Methods

- Analysed part of the mitochondrial control region (mtCR) in 120 individuals from eight sampling areas, defining 20 mtCR haplotypes.

c) Results and conclusions

- Significant genetic structure was detected among the following three major coastal regions separated by oceanic habitat: Australia–New Zealand, South Africa–Namibia and Peru. A major phylogeographic discontinuity exists across the Indian Ocean.
- Oceanic expanses appear to be traversed over evolutionary but not ecological timescales, which means that regional copper-shark populations should be assessed and managed independently.

15 Straube, N.; Kriwet, J.; Schliewen, U.K. (2011). Cryptic diversity and species assignment of large lantern sharks of the *Etmopterus spinax* clade from the Southern Hemisphere (Squaliformes, Etmopteridae). *Zoologica Scripta 40(1)*: 61–75.

a) Species: Baxter's dogfish.

b) Methods

- Molecular approach to illuminate the taxonomy and distribution of *Etmopterus granulosus* and *E. baxteri* by using sequence data from the mitochondrial DNA cytochrome oxidase I gene and amplified fragment length polymorphisms.

c) Results and conclusions

- There is a high level of cryptic diversity within this group, indicating that there is not just one circum-Southern Hemisphere species.
- *Etmopterus granulosus* is not endemic to Chile, but instead has a widespread distribution in the Southern Hemisphere. *Etmopterus baxteri* from New Zealand is a synonym of *E. granulosus*.
- Specimens previously assigned to *E. baxteri* from South Africa now represent a distinct species.

16 Verissimo, A.; McDowell, J.R.; Graves, J.E. (2012). Genetic population structure and connectivity in a commercially exploited and wide-ranging deepwater shark, the leafscale gulper (*Centrophorus squamosus*). *Marine and Freshwater Research 63(6)*: 505–512.

a) Species: Leafscale gulper shark.

b) Methods

- To investigate the pattern of population structure and connectivity in leafscale gulper sharks using nuclear microsatellite loci and nucleotide sequences of the mitochondrial DNA ND2 gene. Sample collections from Ireland, Portugal, the Azores, South Africa and New Zealand.
- The data were also used to assess migration rates of leafscale gulper shark among regions by comparing the patterns of genetic diversity exhibited by nuclear (biparentally inherited) and mitochondrial markers (maternally inherited).

c) Results and conclusions

- There is genetic homogeneity among sampled sites.

- Despite the overall genetic homogeneity, there was significant genetic divergence between New Zealand and the remaining collections at the mtDNA ND2 suggesting long-term isolation of this population.
- There was evidence for sex-biased dispersal across the Indian Ocean with male migration rate estimates higher than for females. This may indicate long-term female philopatry to Atlantic/Indian oceans and South Pacific Ocean, with more dispersive males maintaining gene flow.
- The results confirm a single genetic stock of leafscale gulper sharks.
- Genetic homogeneity is likely to minimize the loss of unique genetic diversity in the event of localized depletion, but low levels of migration among regions would not compensate localised declines, and high local fishing mortality may have far reaching impacts given the philopatric behaviour of females.

17 Naylor, G.J.P.; Caira, J.N.; Jensen, K.; Rosana, K.A.M.; White, W.T.; Last, P.R. (2012). A DNA sequence-based approach to the identification of shark and ray species and its implications for global elasmobranch diversity and parasitology. *Bulletin of the American Museum of Natural History 367*: 1–262.

a) Species: Multiple.

b) Methods

- A survey of DNA sequences derived from the mitochondrial NADH2 gene was conducted for elasmobranchs from around the world.

c) Results and conclusions

- Neighbour-joining analysis of the data revealed a considerable amount of previously undocumented genetic diversity, suggesting 79 potentially new elasmobranch taxa.

18 Le Port, A.; Lavery, S. (2012). Population structure and phylogeography of the short-tailed stingray, *Dasyatis brevicaudata* (Hutton 1875), in the Southern Hemisphere. *Journal of Heredity 103*: 174–185.

a) Species: Short-tailed stingray.

b) Methods

- Examined mtDNA diversity among South Africa, Australia, and New Zealand. Compared samples from offshore and coastal locations around New Zealand.

c) Results and conclusions

- Stingrays exhibit high genetic divergence across oceanic basins and lower differentiation along continuous coastal habitats.
- Significant population differentiation was found among several coastal New Zealand locations.
- Data did not support the hypothesis of genetic differentiation between individuals from an offshore breeding area and the mainland.

19 Boomer, J.J.; Harcourt, R.G.; Francis, M.P.; Stow, A.J. (2012). Genetic divergence, speciation and biogeography of *Mustelus* (sharks) in the central Indo-Pacific and Australasia. *Molecular Phylogenetics and Evolution 64*: 697–703.

a) Species: Rig.

b) Methods

- A molecular phylogenetic approach to investigate speciation of *Mustelus* in the central Indo-Pacific and Australasia.

- Examined phylogenetic relationships and levels of genetic divergence among species, to identify appropriate thresholds of genetic distance for delineating species.
- Investigates species barriers in taxa showing low levels of sequence divergence.
- Used *M. antarcticus* and *M. lenticulatus* to examine the hypothesis of dispersal as a key driver of speciation.

c) Results and conclusions

- Analysis supports two *Mustelus* clades, one comprising species with no white spots and a placental reproductive mode and a second clade of white spotted, aplacental species.
- Levels of genetic divergence are low in white spotted, aplacental species.
- The data support the hypothesis of a radiation following dispersal from a Northern Hemisphere ancestor.
- Molecular dating suggested that localised speciation in Australasia may have occurred during the Pleistocene.

20 Ritchie, P.; Fleming, A. (2012). Testing for genetic differentiation between two size classes of the starry skate. Final Research Report for Ministry for Primary Industries Research Project SEA2010-19 Objectives 1 & 2. 9 p.

a) Species: Antarctic starry skate.

b) Methods

- DNA was extracted from samples from small and large size classes of skates collected by observers in the Ross Sea. Five mitochondrial DNA genes were sequenced to test whether the two size classes represent genetically differentiated groups.

c) Results and conclusions

- No genetic differences were found among the samples, and the data did not support the hypothesis that the two size classes were reproductively isolated.

d) Study limitations

- The lack of genetic difference within the samples was a limitation, but it was not an unusual finding for an elasmobranch species.
- This study would have benefited from samples collected from other locations in the Southern Ocean.

3.1.4 Distribution, movements and habitat

21 Clark, M.R.; Roberts, C.D. (2008). Fish and invertebrate biodiversity on the Norfolk Ridge and Lord Howe Rise, Tasman Sea (NORFANZ voyage, 2003). *New Zealand Aquatic Environment and Biodiversity Report No. 28.* 131 p.

a) Species: Multiple.

b) Methods

- Biodiversity survey.

c) Results and conclusions

- Shovelnose dogfish (*Deania calcea*) were abundant.
- A species of cat shark (*Gollum attenuatus*) is believed to be endemic to the Norfolk Ridge and adjacent areas around New Zealand and New Caledonia.
- Species with a southern distribution that share affinities with the New Zealand fauna included *Deania* sp., *Chimaera* sp., black ghost shark (*Hydrolagus homonycteris*).

- Species with distributions centred on the Norfolk Ridge included bulldog cat shark *Apristurus* sp. E, bareskin dogfish *Dipturus* sp, Rajiidae new genus new species C, Rajiidae new genus species D.

d) Study limitations

- Limited to those species able to be caught by sampling equipment.
- Many specimens could not be identified confidently to species during the voyage and await taxonomic examination.
- Some species were caught outside the New Zealand EEZ but may be found in New Zealand waters with further sampling.

22 Mormede, S. (2008). Year of the Skate sampling protocol: learning from the 2007–08 season sampling protocol on NZ vessels. *CCAMLR No. WG-FSA 08/49*. 14 p.

a) Species: Antarctic starry skate and Antarctic allometric skate.

b) Methods

- Reviews skate tagging results.
- Describes new skate sampling and tagging protocol.

c) Results and conclusions

- Four New Zealand vessels caught 4618 skates and tagged 1015 of them in the 2007–08 season.
- Numbers of tagged and released skates recorded on C2 forms are summarised. Number of skates caught and their fate, as well as total number of skates tagged up to and including the 2005–06 season are summarised.
- Modified procedures for collecting skate biological data and tag-release data are proposed.

23 Le Port, A.; Sippel, T.; Montgomery, J.C. (2008). Observations of mesoscale movements in the short-tailed stingray, *Dasyatis brevicaudata* from New Zealand using a novel PSAT tag attachment method. *Journal of Experimental Marine Biology and Ecology 359*: 110–117.

a) Species: Short-tailed stingray.

b) Methods

- Attachment method developed for PSAT transmitter to a stingray.
- Preliminary insights into short-tailed stingray movements.
- Collected geolocation, depth and behavioural data for 62 and 151 day tracks.

c) Results and conclusions

- Neither ray moved large distances (no more than 25 km) from tagging location.
- Showed a seasonal shift to deeper water for winter.
- One ray showed strong diel vertical movements.

24 Holdsworth, J.; Saul, P. (2008). New Zealand billfish and gamefish tagging, 2006–07. *New Zealand Fisheries Assessment Report 2008/28*. 27 p.

a) Species: Blue shark, mako shark, bronze whaler shark.

b) Methods

- Seasonal summary of release and recapture data from the cooperative tag recapture programme for gamefish.

c) Results and conclusions

- The numbers of mako and blue sharks tagged in the last four years (150–241 and 95–156 respectively) were significantly lower than the averages for the last 10 years (322 and 222 respectively).
- The modal blue shark weight of 30 kg was the lowest ever recorded from this programme. Two blue sharks were recaptured.

25 Fergusson, I.K.; Graham, K.J.; Compagno, L.J.V. (2008). Distribution, abundance and biology of the smalltooth sandtiger shark *Odontaspis ferox* (Risso, 1810) (Lamniformes: Odontaspididae). *Environmental Biology of Fishes 81*: 207–228.

a) Species: Deepwater nurse shark.

b) Methods

- A review of published information on the deepwater nurse shark. Presents new distributional, abundance and biological data, and discusses its conservation status.

c) Results and conclusions

- Most Southern Hemisphere deepwater nurse sharks have been caught by trawl on the continental slope as deep as 880 m.
- The largest recorded male was 344 cm total length, and female 450 cm. Limited data suggest a size at maturity for males at 200–250 cm, and females 300–350 cm. Size at birth is probably about 100 cm.
- This species is considered ‘‘Vulnerable’’ globally, by the World Conservation Union (IUCN)

26 Francis, M.P.; Gordon, D.P.; Ahyong, S.T.; Griggs, L.H. (2009). Marine biodiversity of the Kermadec region. NIWA Client Report No. WLG 2009-20. NIWA Project PEG09301. 28 p.

a) Species: Blue, mako, porbeagle, thresher, great white, tiger, Galapagos, basking, oceanic whitetip, and whale sharks; Kermadec, Harrisson’s and northern spiny dogfish; Kermadec rig; manta ray and spinetail devilray.

b) Methods

- Reviews the available information on the marine biodiversity of the Kermadec FMA waters between the existing marine reserve and the boundary of the EEZ.

c) Results and conclusions

- A paucity of research on many taxonomic groups in the Kermadec region makes it difficult to make broad-based analyses of marine biodiversity. The study concentrates on four taxonomic groups that are moderately well known: bryozoans, decapod crustaceans, fishes and reptiles.
- Many of the chondrichthyan species listed are open ocean (pelagic) and migratory species that pass through the Kermadec FMA.
- Galapagos sharks are abundant in coastal waters around the Kermadec Islands, and this may be among the last remaining unfished populations of this species worldwide.
- The endemic Kermadec spiny dogfish and Kermadec rig are demersal on the continental shelf and slope around the islands.
- Harrisson’s dogfish, classified as Critically Endangered, is recorded from a single Kermadec specimen (it also occurs in eastern Australia).

27 Holdsworth, J.; Saul, P. (2009). New Zealand billfish and gamefish tagging, 2007–08. *New Zealand Fisheries Assessment Report 2009/26*. 27 p.

a) Species: Blue shark, mako shark.

b) Methods

- Seasonal summary of release and recapture data from the cooperative tag recapture programme for gamefish.

c) Results and conclusions

- The number of mako and blue sharks tagged remained significantly below the long-term average, as was the case for the last five years. Very high percentages of the total recreational catch of mako and blue sharks (88%) were tagged rather than landed.
- Three blue sharks and two mako sharks were recaptured.

28 Riding, T.A.C.; Dennis, T.E.; Stewart, C.L.; Walker, M.M.; Montgomery, J.C. (2009). Tracking fish using 'buoy-based' GPS telemetry. *Marine Ecology-Progress Series 377*: 255–262.

a) Species: Eagle ray.

b) Methods

- Small buoy mounted GPS receiver tested on eagle rays.

c) Results and conclusions

- Highly accurate movement data for eagle rays within a Northland estuary.

29 Francis, M.P. (2010a). Movement of tagged rig and school shark among QMAs, and implications for stock management boundaries. *New Zealand Fisheries Assessment Report 2010/3*. 24 p.

a) Species: Rig and school shark.

b) Methods

- Review the existing QMA boundaries in order to determine whether they are appropriate.
- Re-analyse updated tagging datasets to assess the degree of inter-QMA movement of rig and school shark.
- Review companion studies that might provide information on stock range and boundaries, including length and age at maturity, size composition, sex ratio, spatial variation in CPUE trends, trends in relative biomass as determined from trawl surveys, and population genetic composition.

c) Results and conclusions

- The fundamental principle is that QMAs should be matched to biological stock boundaries as closely as possible
- Male rig rarely moved outside the release QMA, even after more than five years at liberty. Female rig were more mobile than male rig, one-third move beyond their release QMA boundaries within 2–5 years of release. The existing QMAs are probably appropriate for rig stocks.
- One-third of tagged school sharks moved outside the release QMA within one year of release, and this was maintained in the second year after release. After 2–5 years at liberty about 60% of male and female school sharks had moved outside the release QMA. After more than five years at liberty, 8% of males and 19% of females had moved to Australia. There is likely to be a single biological stock of school shark in the New Zealand EEZ.
- Little genetic variation was found that might indicate different stocks of rig or school shark.
- The only persuasive evidence for a mismatch between existing QMA boundaries and biological stocks was the apparent lack of juvenile school shark nursery areas in SCH 4 and SCH 5.

- School shark QMAs are much smaller than the ranges inhabited by the sharks. However, management of school shark in the current small QMAs is unlikely to have a detrimental effect on the stock. Therefore, the current stock management units may be a wise precautionary measure to spread fishing effort.

d) Study limitations

- The relative importance of various nursery areas around New Zealand, and whether females return to the area in which they were born remain unknown.
- Use of tagging data to estimate movement rates is fraught with problems.

30 Blackwell, R.G.; Francis, M.P. (2010). Review of life history and fishery characteristics of New Zealand rig and school shark. *New Zealand Fisheries Assessment Report 2010/2*. 39 p.

a) Species: Rig and school shark.

b) Methods

- Collated data from a variety of sources to provide information on the stock structure of rig and school shark.
- Length and age at maturity, maximum size, sex ratio, spatial variation in CPUE trends, and trawl survey relative biomass trends are all examined as indicators of stock identity.

c) Results and conclusions

- Information available for testing the validity of rig and school shark Fishstock boundaries is limited.
- There is limited evidence for the existence of multiple stocks of rig and school shark in New Zealand waters.
- Length at maturity data suggest that rig in SPO 1 East are a distinct stock from those on east and west coasts of the South Island, but further work is required to confirm this.
- The only persuasive evidence for a mismatch for school shark is the lack of juvenile/nursery areas in SCH 4 and SCH 5.
- Trends in trawl survey relative biomass and CPUE may be more informative than catch composition data.

d) Study limitations

- Information on size composition and sex ratio of commercial and trawl survey catches provided little information on stock identity.
- Caution must be used when comparing length-composition among areas.
- Different trends in CPUE for both species may be caused by processes acting at spatial scales smaller than the stock level.

31 Francis, M.P. (2010b). Review of research and observer data on hammerhead sharks (*Sphyrna zygaena*). Final Research Report for Ministry of Fisheries Research Project IPA200901. 8 p.

a) Species: Hammerhead shark.

b) Methods

- Determine the distribution, abundance and size composition of hammerhead sharks in New Zealand waters.
- Data sources used were MFish research trawl and observer databases.

c) Results and conclusions

- Only one species of hammerhead shark (*Sphyrna zygaena*) has been recorded from New Zealand waters. Tropical and subtropical hammerhead sharks occur in Australia and the South Pacific and may occasionally visit New Zealand.

- Juveniles are common in shallow coastal waters of the northern North Island, but are absent further south.
- Juveniles use coastal waters as nurseries, with the highest concentrations occurring in the Firth of Thames, Hauraki Gulf, eastern Bay of Plenty and 90-Mile Beach.
- Kaipara and Manukau harbours may be important, but data from these harbours are lacking.
- Hammerhead length frequency data showed a summer total length mode around 60 cm, and a spring mode around 70 cm. 150 cm sharks are 1+ and 2+ age classes. Sex ratio is 1:1.
- Aerial surveys indicate juveniles 150–200 cm total length are abundant off the west coast of the North Island.

d) Study limitations

- Assumed that all data refer to *S. zygaena*.
- The habitat of adult hammerheads is unknown. Mature hammerhead sharks, including pregnant females, have occasionally been seen and caught in coastal waters around northern New Zealand, including Hauraki Gulf and Hawke Bay.

32 Duffy, C.; Francis, M. (2010). Sharks and rays of the Kermadec Islands and north Kermadec Ridge: species of interest, conservation, and scientific significance. *In:* Pew Environment Group (comps.). Proceedings of DEEP: Talks and thoughts celebrating diversity in New Zealand's untouched Kermadecs, August 30–31 2010. pp. 76–80. Wellington. New Zealand.

a) Species: Multiple.

b) Methods

- Review existing data on chondrichthyan species. Comment on their science and the conservation significance of the populations.
- Sources included scientific literature, personal observations, unpublished data, underwater photographs, museum specimens, MFish catch effort database.

c) Results and conclusions

- Protected species deepwater nurse and white shark occur there.
- 37 species from 20 families occur on North Kermadec Ridge, but this is likely to increase with further study.
- Tables listing all chondrichthyan species, distribution, habitat range, source.
- *Squalus raoulensis*, *Cephaloscyllium* sp. and *Mustelus* sp. appear to be endemic to the North Kermadec Ridge and possibly Tonga.

d) Study limitations

- Some families were under-represented possibly due to insufficient sampling.

33 Bonfil, R.; Francis, M.P.; Duffy, C.; Manning, M.J.; O'Brien, S. (2010). Large-scale tropical movements and diving behavior of white sharks *Carcharodon carcharias* tagged off New Zealand. *Aquatic Biology 8*: 115–123.

a) Species: White shark.

b) Methods

- Satellite tagging four sharks at Chatham Islands.
- PAT4-tags using ambient light levels for geolocation.

c) Results and conclusions

- Sharks remain at Chatham Islands for several months after tagging, then rapid, directed movements to subtropical and tropical locations.

- Sharks experienced a wide temperature range from 6.4 to 23.8 °C.
- During ocean crossings sharks maintained high swimming speeds of 3.7 to 5.4 km/hr.
- Migration could be related to seasonal aggregations of humpback whales in tropical areas.
- Sharks preferred 2–50 m depths at Chatham Islands. During oceanic movements more than half of the time was spent at 0–1 m depth, this behaviour was punctuated with dives beyond 600 m depth.

34 Holdsworth, J.C.; Saul, P.J. (2010). New Zealand billfish and gamefish tagging, 2008–09. *New Zealand Fisheries Assessment Report 2010/12*. 34 p.

a) Species: Blue shark, mako shark, school shark.

b) Methods

- Seasonal summary of release and recapture data from the cooperative tag recapture programme for gamefish.

c) Results and conclusions

- The numbers of mako and blue sharks tagged (284 and 101 respectively) continued to be below the long-term averages (300 and 160 respectively), as has been the case for the last five years.
- A mako shark recaptured between New Caledonia and Vanuatu after almost 10 years was a 297 cm pregnant female. A blue shark was recaptured in the Coral Sea after 666 days.

35 Holdsworth, J.; Saul, P. (2011a). New Zealand billfish and gamefish tagging, 2009–10. *New Zealand Fisheries Assessment Report 2011/23*. 26 p.

a) Species: Blue shark, mako shark, hammerhead shark.

b) Methods

- Seasonal summary of release and recapture data from the cooperative tag recapture programme for gamefish.

c) Results and conclusions

- Mako shark numbers were up on previous seasons (396 compared with the 10-year average of 253) but blue shark numbers were down (70 compared with the 10-year average of 143). Very high percentages of the total recreational catch of mako (90%) and blue sharks (92%) were tagged rather than landed.
- The average size of makos tagged in the last three seasons has been about 50 kg. This is 20 kg less than in the early 2000s. Most of the fish encountered are juveniles with few large females.
- Two blue sharks, seven mako sharks and one hammerhead shark were recaptured.

36 Holdsworth, J.C.; Saul, P.J. (2011b). New Zealand billfish and gamefish tagging, 2010–11. *New Zealand Fisheries Assessment Report 2011/60*. 26 p.

a) Species: Blue shark, mako shark.

b) Methods

- Seasonal summary of release and recapture data from the cooperative tag recapture programme for gamefish.

c) Results and conclusions

- During the 2010–11 season, 546 mako sharks were tagged and released. This was the fourth consecutive season in which mako releases have increased and the highest seasonal total since 1998–99.

- A total of 125 blue sharks were tagged, well up on the previous year and slightly better than the average of the last ten seasons (119).
- Seven mako sharks and three blue sharks were recaptured. Two of the mako sharks were recaptured near Fiji.

37 Last, P.R.; White, W.T. (2011). Biogeographic patterns in the Australian chondrichthyan fauna. *Journal of Fish Biology 79*: 1193–1213.

a) Species: Multiple.

b) Methods

- Review of biogeographic patterns of Australian chondrichthyans and compares them with patterns in New Zealand.

c) Results and conclusions

- New Zealand has higher proportions of sharks (65%) and chimaeras (12%), and a lower proportion of rays (23%) than does Australia.
- Species richness by family, biogeographic category, and depth biome are tabulated.
- The New Zealand fauna shares less than 10% of its species with Indonesia and New Guinea, and approximately 20% with New Caledonia and Australia.
- Most New Zealand species (65%) are demersal slope inhabitants.

d) Study limitations

- Treatment is at family or genus level. No species-specific data.

38 Duffy, C.A.J.; Francis, M.P.; Manning, M.J.; Bonfil, R. (2012). Regional population connectivity, oceanic habitat, and return migration revealed by satellite tagging of white sharks, *Carcharodon carcharias*, at New Zealand aggregation sites. *In*: Domeier, M.L. (ed.). Global perspectives on the biology and life history of the white shark. pp. 301–318. CRC Press.

a) Species: White shark.

b) Methods

- 25 PAT tags deployed, 19 tracks obtained.
- Light based geolocation, refined with SST data, and unscented Kalman filtering.

c) Results and conclusions

- Three instances of return migration to the tagging location in New Zealand waters.
- Most sharks made rapid directed movements north of New Zealand to subtropical or tropical areas where they stayed for 5–7 months of the year. Most sharks were resident in New Zealand waters for 5 months after tagging.
- No sharks moved between Stewart Island and the Chatham Islands, but mixing may occur outside New Zealand waters.
- Deep-dives during oceanic migrations were interpreted as foraging behaviour
- Spatio-temporal distribution of white sharks in the southwest Pacific overlaps that of many cetaceans; this is understandable as sharks eat small cetaceans and scavenge whale carcasses.
- Populations at Stewart Island and Chatham Islands are not segregated by size or sex.

d) Study limitations

- Smaller sharks were mostly excluded from the tagging boat by larger sharks.
- No young-of-the-year or mature female sharks are included in this analysis.

39 Francis, M.P.; Duffy, C.A.J.; Bonfil, R.; Manning, M.J. (2012b). The third dimension: vertical habitat use by white sharks (*Carcharodon carcharias*) in New Zealand and in oceanic and tropical waters of the South-west Pacific Ocean *In*: Domeier, M. (ed.). Global perspectives on the biology and life history of the great white shark (*Carcharodon carcharias*), pp. 319–342. CRC Press.

a) Species: White shark.

b) Methods

- Investigated how white sharks use the vertical dimension of the ocean, and the thermal environment they encounter.
- Twenty-five sharks tagged with PAT-tags from 2005 to 2009.
- Analysed depth-related behaviour patterns near New Zealand seal colonies, while crossing open oceans, and when in tropical regions.

c) Results and conclusions

- Sharks showed major differences in behaviour in different regions.
- Shelf phase: sharks presumed to have remained in coastal waters showed a modal depth range of 11–25 m.
- Ocean phase: in the open ocean sharks showed a bimodal depth distribution, with two-thirds of their time at the surface (approximately 1 m) punctuated by deep dives (more than 800 m).
- Tropics phase: sharks preferred the upper 75 m of the water column, but continued making deep dives.
- Temperature limits recorded 2.7 to 26.6 °C

40 Francis, M.; Lyon, W.; Jones, E.; Notman, P.; Parkinson, D.; Getzlaff, C. (2012a). Rig nursery grounds in New Zealand: a review and survey *New Zealand Aquatic Environment and Biodiversity Report No. 95*. 50 p.

a) Species: Rig.

b) Methods

- Identify and define important nursery areas for rig.
- Set net survey of 14 harbours targeting 0+ rig.
- Environmental samples collected at each site (depth, temperature, salinity, pH, turbidity, and a sediment sample).

c) Results and conclusions

- List of references 1930–2009 with information about 0+ rig.
- Kaipara and Raglan produced highest catches of 0+ rig.
- Waitemata, Tamaki, and Porirua harbours produced moderate catches of 0+ rig.
- Remaining harbours surveyed produced only small numbers of 0+ rig.
- Turbidity appears to be positively correlated with 0+ rig catch.
- Also includes summaries of snapper, grey mullet, kahawai, school shark, and invertebrate catches.

d) Study limitations

- Juvenile (0+) rig catch rates have shown high variability among months.

41 Le Port, A.; Lavery, S.; Montgomery, J.C. (2012). Conservation of coastal stingrays: seasonal abundance and population structure of the short-tailed stingray *Dasyatis brevicaudata* at a Marine Protected Area. *ICES Journal of Marine Science 69*: 1427–1435.

a) Species: Short-tailed stingray.

b) Methods

- Examined the seasonal abundance and population structure of the short-tailed stingray at the Poor Knights Islands Marine Reserve, and the reported use of this location as a mating ground.
- Dive surveys were conducted from 2004 to 2007. Seasonality, size composition, sex ratios and presence of mating scars on females were assessed.

c) Results and conclusions

- A substantial increase in adult and subadult numbers, particularly females, was seen during the suggested breeding season (summer−autumn), with a corresponding increase in females bearing fresh mating scars. There were also large numbers of smaller (probably immature) rays of both sexes from spring to autumn.
- These results suggest that the area acts as both a mating aggregation location and a nursery for this species.
- For coastal stingrays, small MPAs may be effective at protecting key life-history stages.

d) Study limitations

- Maturity status of observed rays not known.

42 Tracey, D.M.; Clark, M.R.; Anderson, O.F.; Kim, S.W. (2012). Deep-sea fish distribution varies between seamounts: results from a seamount complex off New Zealand. *PLoS One 7*: 1–12.

a) Species: Baxter’s dogfish, Plunket’s shark, lucifer dogfish, Owston’s dogfish, leafscale gulper shark, Portuguese dogfish, seal shark, purple chimaera.

b) Methods

- Fish species data from the Graveyard Seamount Complex were analysed to investigate whether fish species composition varied among seamounts. Five seamount features were included, with summit depths ranging from 748–891 m and elevation from 189–352 m.
- Measures of fish species dominance, rarity, richness, diversity, and similarity were examined. A number of factors were explored to explain variation in species composition, including latitude, water temperature, summit depth, depth at base, elevation, area, slope, and fishing effort.

c) Results and conclusions

- Mean catch rate and percent occurrence are shown for the top 10 species on each seamount (includes 4−6 sharks and chimaeras).
- Relationships with depth at base and slope were significant, shallow seamounts had high total species richness, and seamounts with a more gradual slope had high mean species richness.
- Fish assemblages on seamounts can vary over very small spatial scales, in the order of several kilometres. However, patterns of species similarity and abundance were inconsistent across the seamounts examined, and these results add to a growing literature suggesting that faunal communities on seamounts may be populated from a broad regional species pool, yet show considerable variation on individual seamounts.

d) Study limitations

- Most analyses combine teleosts and chondrichthyans so there is little specific information on the latter.

3.1.5 Feeding

43 Jones, M.R.L. (2008). Biology and diet of *Coryphaenoides subserrulatus* and *Etmopterus baxteri* from the Puysegur region, southern New Zealand. *New Zealand Journal of Marine and Freshwater Research 42(3)*: 333–337.

a) Species: Baxter's dogfish.

b) Methods

- Described the biology and diet of Baxter's dogfish from hill features of the Puysegur Box.
- Fish collected by observers in 2006.

c) Results and conclusions

- Baxter's dogfish fed on fish and squid.

44 Jones, M.R.L. (2009). Diets of eight fish species from the upper slope off the Wairarapa coast, North Island, New Zealand, with notes on the diets of others. *New Zealand Journal of Marine and Freshwater Research 43(4)*: 929–939.

a) Species: Lucifer dogfish, dark ghost shark, Dawson's cat shark, carpet shark.

b) Methods

- Provides information on aspects of the food and feeding for eight species from upper slope fish communities on the Wairarapa coast. Also provides notes on the diets of 18 others.

c) Results and conclusions

- Table with stomach contents of lucifer dogfish, dark ghost shark, Dawson's cat shark, and carpet shark.

45 Dunn, M.R.; Griggs, L.; Forman, J.; Horn, P. (2010a). Feeding habits and niche separation among the deep-sea chimaeroid fishes *Harriotta raleighana*, *Hydrolagus bemisi* and *Hydrolagus novaezealandiae*. *Marine Ecology-Progress Series 407*: 209–225.

a) Species: Dark ghost shark, pale ghost shark and longnose chimaera.

b) Methods

- Examination of gut contents from depths 219–876 m on Chatham Rise.
- Similarity percentages, generalised additive models, multivariate analyses (distance-based linear model), cluster analysis (hierarchical agglomerative clustering), all used in analysis.
- Provides an analysis of the diets and distributions of three chimaeroid species, clarifying their ecological role and providing insight into the possible role of competition in determining the realized niches.

c) Results and conclusions

- All three species fed predominantly on benthic epifauna and infauna.
- The primary factor influencing niche separation between the species appears to be depth and distribution, rather than dietary specialisation.
- Competition between chimaera species may be of lesser importance when determining their population dynamics.

d) Study limitations

- The gut contents included large amounts of fragmented and unidentifiable crustaceans and molluscs, consistent with crushing prey between tooth plates.

46 Dunn, M.R.; Szazbo, A.; McVeigh, M.S.; Smith, P.J. (2010b). The diet of deep sea sharks and the benefits of using DNA identification of prey. *Deep Sea Research I 57*: 923–930.

a) Species: Seal shark, leafscale gulper shark, Owston’s dogfish, longnose velvet dogfish, Plunket’s shark and school shark.

b) Methods

- Stomachs from the six sharks were sampled from three research trawl surveys on the Chatham Rise. Between 14 and 50 stomachs were examined for each species, of which 8–62% were empty.

c) Results and conclusions

- Prey were visually identified in 80 stomachs, and by DNA barcoding in a further 28 stomachs. The use of DNA methods allowed the identification of chunks of flesh in the stomachs of seal shark and Plunket’s shark, and nearly doubled the rate of data accumulation for seal shark, leafscale gulper shark, and Owston’s dogfish.
- The prey of seal shark, leafscale gulper shark, and Plunket’s shark were predominantly benthic or demersal fishes and cephalopods. The prey of Owston’s dogfish and longnose velvet dogfish, were predominantly mesopelagic fishes and squids. School shark foraged throughout the water column.
- Scavenging of discards from commercial fishing vessels was likely in leafscale gulper shark, Plunket’s shark and school shark.
- The diet of all species except longnose velvet dogfish was dominated by hoki.

47 Forman, J.S.; Dunn, M.R. (2012): Diet and scavenging habits of the smooth skate *Dipturus innominatus*. *Journal of Fish Biology 80*: 1546–1562.

a) Species: Smooth skate.

b) Methods

- The diet of smooth skate was determined from examination of stomach contents of 321 specimens sampled from research and commercial trawlers at depths of 231–789 m on Chatham Rise.
- Distance-based linear model analysis was used to identify which of six biological, environmental and temporal predictors explained a significant proportion of the variability in diet. The mass of prey observed was first standardized, then square-root transformed and a dissimilarity matrix calculated using Bray–Curtis distances.

c) Results and conclusions

- The diet was dominated by the benthic and natant decapods and fishes from 17 families, of which hoki, sea perch, various Macrouridae and a variety of discarded fishes were the most important.
- Crustaceans dominated the diet in small skates, with fish and discards increasing in larger skates.
- Scavenged discards (fish heads or tails, or skeletal remains after filleting) were most frequent in areas where commercial fishing was most active. Discarding practices may help support populations through improved scavenging opportunities.
- The best predictors of diet variability were skate length and a spatial model.

48 Getzlaff, C. (2012). Diet and foraging behaviour of juvenile rig (*Mustelus lenticulatus*) from New Zealand harbours and estuaries. M.Sc. thesis. Massey University, Palmerston North. 102 p.

a) Species: Rig.

b) Methods

- A nationwide study of the diet of juvenile (less than one year old) rig was undertaken throughout New Zealand in February–March 2011.
- Diet similarities were detected through pairwise analyses of similarity between sites.
- Index of relative importance was calculated for stomach contents.
- Foraging behaviour in captive (0+) rig was analysed.

c) Results and conclusions

- Juvenile rig fed mostly on benthic crustaceans, such as stalk-eyed mud crabs (*Hemiplax hirtipes*) and snapping shrimp (*Alpheus richardsoni*).

49 Dunn, M.R.; Stevens, D.S.; Forman, J.S.; Connell, A. (2012 in press). Trophic interactions and distribution of Squaliforme sharks, including new diet descriptions for *Deania calcea* and *Squalus acanthias*. *PLoS One*.

a) Species: Shovelnose dogfish, spiny dogfish, Owston's dogfish, leafscale gulper shark, longnose velvet dogfish, seal shark, Baxter's dogfish, lucifer dogfish, prickly dogfish, Plunket's shark, northern spiny dogfish.

b) Methods

- The diets of 133 shovelnose dogfish and 295 spiny dogfish collected on the Chatham Rise were determined from examination of stomach contents.
- The diet of nine other commonly caught squaliforme sharks was reviewed, and the spatial and depth distribution of all species on Chatham Rise described from research bottom trawl surveys.

c) Results and conclusions

- The diet of shovelnose dogfish was characterised by mesopelagic fishes, and spiny dogfish by benthic to pelagic fishes but included likely scavenging.
- The most important predictors of diet variability in spiny dogfish were year, bottom temperature, longitude and fish weight.
- The eleven species had a variety of different diets, and depth and location preferences, consistent with niche separation to reduce interspecific competition.
- Four trophic groups were identified, characterised by a diet of: mesopelagic fishes and invertebrates (longnose velvet dogfish, shovelnose dogfish, and Lucifer dogfish); mesopelagic and benthopelagic fishes and invertebrates (Owston's and Baxter's dogfish); demersal and benthic fishes (leafscale gulper shark, seal shark and Plunket's shark); and a generalist diet of fishes and invertebrates (spiny dogfish).

3.1.6 Age, growth, reproduction and productivity

50 Francis, M.P.; Mormede, S. (2008). Updated biological parameters for the Antarctic starry skate, *Amblyraja georgiana*, from the Ross Sea. *CCAMLR WG-FSA-08/20*. 15 p.

a) Species: Antarctic starry skate.

b) Methods

- An estimate is generated of the ratio of Antarctic starry skate to Antarctic allometric skate caught in the Antarctic toothfish bottom longline fishery in the Ross Sea (CCAMLR areas 88.1 and 88.2).
- Revised estimates of length-weight regression parameters, and length at maturity are provided for the Antarctic starry skate, and the fate and condition of skate bycatch is summarised for the 2007–08 season.

c) Results and conclusions

- Forty-three out of 47 skates (10.75:1) were identified as Antarctic starry skate.
- Length-weight regression parameters for Antarctic starry skate are provided
- An updated staging scheme for Antarctic starry skate is provided.
- The median pelvic length at maturity for both sexes combined was 67.3 cm.
- Nearly all of the skates that were returned to the sea were in good condition (78%).

d) Study limitations

- Improved data recording should provide better estimates of skate fate and condition in the future.
- Pelvic length is the length measurement used on skates by CCAMLR. In some earlier studies total length was used, which limits the comparability between this and some previous studies.
- Tagged skates may be double-counted (i.e. listed on both the L11 and skate tagging logsheets).

51 Francis, M.P.; Natanson, L.J.; Campana, S.E. (2008). The biology and ecology of the porbeagle shark, *Lamna nasus*. *In:* Camhi, M.D.; Pikitch, E.K.; Babcock, E.A. (eds). Sharks of the open ocean: biology, fisheries and conservation, Blackwell Publishing, Oxford, United Kingdom.

a) Species: Porbeagle shark.

b) Methods

- Information on the biology, ecology, and fisheries of porbeagle sharks *(Lamna nasus)* is reviewed to assess biological and population parameters that are relevant to stock assessment, and to identify gaps in our knowledge.

c) Results and conclusions

- Separate porbeagle stocks occur in the Northwest and Northeast Atlantic, but stock identity is poorly understood in the Southern Hemisphere.
- Porbeagles are born at 58–67 cm fork length. Length at maturity is lower for Southwest Pacific males and females (about 140–150 and 170–180 cm, respectively) than for North Atlantic males and females (174 and 218 cm).
- Ages at 50% maturity for North Atlantic males and females are 8 and 13 years, respectively. Porbeagles recruit to commercial fisheries in both hemispheres during their first year. North Atlantic males and females reach at least 262 and 317 cm, respectively, and longevity exceeds 26 years. Age at maturity and longevity in the Southwest Pacific are unknown. Growth is almost linear, and similar for both sexes, for about 8 years, after which females grow faster.
- The rate of natural mortality for the Northwest Atlantic is 0.10 for immature sharks, rising to 0.15–0.20 for mature sharks.
- The gestation period is 8–9 months and the length of the female reproductive cycle may be about 1 year. Mean litter size is 3.7–4.0 embryos, and the embryonic sex ratio is 1:1.
- Porbeagle sharks are vulnerable to overfishing. In the Southern Hemisphere, porbeagles are taken mainly as bycatch in tuna longline fisheries, which are unrestricted and poorly monitored; no biomass estimates or stock assessments are available. The low productivity of porbeagles and their history of overfishing indicate that sustainable yields will be low.

52 Simpfendorfer, C.A.; Kyne, P.M. (2009). Limited potential to recover from overfishing raises concerns for deep-sea sharks, rays and chimaeras. *Environmental Conservation 36(2)*: 97–103.

a) Species: Leafscale gulper shark, shovelnose dogfish, Baxter's dogfish, longnose velvet dogfish, Plunket's shark.

b) Methods

- Determined the intrinsic rebound potential and population doubling times for deep-sea chondrichthyans. Compared results to shallow water continental shelf and pelagic species to consider the implications for management of the deep-sea.

c) Results and conclusions

- Deep-sea chondrichthyans have rates of population increase that are on average less than half those for shelf and pelagic species.
- Population doubling times indicate that once a stock has been depleted, it will take decades to centuries before it will recover.
- Population recovery rates decrease with increased depth, suggesting that species from the deepest waters are most vulnerable to fishing.

53 Francis, M.P.; Gallagher, M.J. (2009). Revised age and growth estimates for Antarctic starry skate (*Amblyraja georgiana*) from the Ross Sea. *CCAMLR Science 16*: 211–220. [Also 2008, *CCAMLR WG-FSA-08/21*. 12 p.]

a) Species: Antarctic starry skate.

b) Methods

- An alternative method of ageing Antarctic starry skate is proposed.
- This method involves counting fine individual growth bands on caudal thorns, instead of grouping them into broad diffuse bands.
- The new method offers new estimates of growth parameters, age at maturity, longevity and natural mortality rate.

c) Results and conclusions

- Growth curves suggest much slower growth, greater ages at maturity (20 years compared to 6–11 years), and greater maximum ages (28–37 years compared to 14 years) than the previous study.
- A list of circumstantial evidence supporting the new age and growth estimates is provided.

d) Study limitations

- A validation study is required to determine which growth scenario is correct

54 Francis, M.P. (2010c). Revised biological parameters for the Antarctic skates *Amblyraja georgiana* and *Bathyraja* cf. *eatonii* from the Ross Sea. *CCAMLR WG-FSA-10/27*. 13 p.

a) Species: Antarctic starry skate and Antarctic allometric skate.

b) Methods

- Revised estimates of weight-length and length-length regression parameters, and length at maturity for the Antarctic starry skate and Antarctic allometric skate from the Ross Sea bottom longline fishery for Antarctic toothfish.
- Linear regressions were fitted to length-length relationships, log-linear regressions were fitted to weight-length relationships, and male and female relationships were tested using homogeneity of slopes models.

c) Results and conclusions`

- Antarctic starry skate median lengths at maturity estimated for both sexes combined with a reasonable overall value of 66 cm pelvic length.

- Approximate median lengths at maturity for Antarctic allometric skate are 70 cm pelvic length for males and 75 cm for females.

d) Study limitations

- The differences between sexes may be spurious, and an artifact of insufficient and inaccurate data.
- Problems still exist with observer maturity staging. Training of observers is recommended to reduce errors in skate maturity staging.
- The estimate of the median length at maturity of Antarctic allometric skate is uncertain because of insufficient data.

55 Lyon, W.S.; Francis, R.I.C.C.; Francis, M.P. (2011). Calculating incubation times and hatching dates for embryonic elephant fish (*Callorhinchus milii*). *New Zealand Journal of Marine and Freshwater Research 45*: 59–72.

a) Species: Elephant fish.

b) Methods

- Laboratory based calculation of embryo incubation times.
- Embryonic stages timed at 10, 15 and 20 ^{o}C.
- Incubation times estimated for Marlborough Sounds, Canterbury Bight, Dunedin and Te Waewae Bay.

c) Results and conclusions

- Marlborough Sounds incubation period estimated to be 32 weeks, Canterbury Bight 25 weeks, Dunedin and Te Waewae Bay 34 weeks.

d) Study limitations

- Using laboratory investigations to model real-world processes.

56 Parker, S.J.; Francis, M.P. (2011). Productivity of two species of deepwater sharks, *Deania calcea* and *Centrophorus squamosus* in New Zealand. Final Research Report for Ministry of Fisheries Research Project ENV2008-04. 39 p.

a) Species: Shovelnose dogfish and leafscale gulper shark.

b) Methods

- Counting internal bands in cross sections of the second dorsal fin spine.
- Estimated age composition, growth functions, maturity ogives, and natural mortality.
- Conducted a demographic analysis to assess productivity, stock status, and to recommend future monitoring and management options.

c) Results and conclusions

- Productivity of these sharks in New Zealand is similar to that estimated in the North Atlantic.
- Biomass trends from the Chatham Rise and Sub-Antarctic trawl surveys suggest a flat or modest increase since the early 1990s for both species.
- Growth, age composition, and natural mortality summarised.
- Length and age at maturity is listed for both species.
- Recommendations are listed for addressing stock monitoring needs and for prioritising research needs.

d) Study limitations

- Age determination had a moderate level of disagreement between readers.
- No feasible method of validating spine ages currently exists, so age-derived biological parameters should be treated with caution.

3.1.7 Fisheries, catches, catch per unit effort, and catch composition

57 Babcock, E.A. (2008). Recreational fishing for pelagic sharks worldwide. *In:* Camhi, M.D.; Pikitch, E.K.; Babcock, E.A. (eds). Sharks of the open ocean: biology, fisheries and conservation, pp. 193–204. Blackwell Publishing, Oxford, United Kingdom.

a) Species: Blue, mako, porbeagle and thresher sharks.

b) Methods

- Summarises published information on recreational fisheries for pelagic sharks in major fishing countries, including New Zealand.

c) Results and conclusions

- In 2000, 25% of the 236 International Game Fish Association world records for pelagic sharks were held by fish caught in New Zealand. The New Zealand records were for blue, mako, porbeagle and thresher sharks.
- Blue and mako sharks comprise most of the pelagic sharks caught by game fishers, and landed in shark fishing tournaments.
- Landings have decreased because of increased tag and release, and minimum weight limits at tournaments.
- Provides numbers of sharks tagged in the Gamefish Tagging Programme up to 2001−02.
- Provides recreational bag limits.

d) Study limitations

- Most data were 5–8 years out of date at the time of publication.

58 Griggs, L.H.; Baird, S.J.; Francis, M.P. (2008). Fish bycatch in New Zealand tuna longline fisheries in 2005–06. *New Zealand Fisheries Assessment Report 2008/27*. 47 p.

a) Species: Blue, porbeagle and mako sharks, plus some rarer species.

b) Methods

- Estimate the catches, catch rates, and discards of non-target fish in tuna longline fisheries from observer and commercial data for 2005–06.
- Describe bycatch trends using this data and earlier results of similar studies.

c) Results and conclusions

- Maximum of 27 million hooks set by fishery in 1980–81, dropping to 4 million in the mid-1990s when foreign licensed vessels ceased fishing in New Zealand. Domestic effort peaked in 2001–02 at 10 million hooks, and has dropped since then to 3.7 million hooks.
- Catch composition varied with fleet and area fished.
- CPUE only reliably calculated for charter fleet, where CPUE increased for blue, mako, and deepwater dogfish and decreased for school shark.
- Deepwater dogfish (species not identified but including *Centroscymnus owstoni*) had large increases in catches from previous years.
- Most blue, porbeagle, and mako sharks observed were immature.

d) Study limitations

- Limited observer coverage in domestic fleet (less than 5%).

59 Anon (2008). Annual report to the Commission. Part 1: Information on fisheries, research, and statistics. *Western and Central Pacific Fisheries Commission Scientific Committee fourth regular session WCPFC-SC4-AR PART 1/WP-19*. 20 p.

a) Species: Blue, mako, porbeagle and school sharks, pelagic stingray.

b) Methods

- Bycatch analysed from New Zealand flagged vessels targeting tuna or swordfish in the western and central Pacific Ocean convention area, (inside and outside the NZ EEZ) from 2001–2007.
- For bycatch species of commercial interest, reasonably good estimates of landings can be obtained from fisher records; for less valuable species, observer data provide the best information.

c) Results and conclusions

- Blue sharks are the most common non-tuna bycatch species in the longline fishery. From 2005–06 to 2006–07 the estimated catch of blue shark dropped by almost 50%, as did mako shark, but porbeagle sharks stayed the same. Deepwater dogfish and school shark estimated catches rose for this period. A recent large reduction in longline effort was the reason given for reductions in landings in some of the major bycatch species.
- Spine-tail devil rays make up 7% of the catch from the purse seine fishery in New Zealand waters.

60 Anderson, O.F. (2008). Fish and invertebrate bycatch and discards in ling longline fisheries, 1998–2006. *New Zealand Aquatic Environment and Biodiversity Report No. 23*. 43 p.

a) Species: Spiny dogfish and numerous other species.

b) Methods

- Commercial catch effort data and observer data were used to estimate bycatch and discards in ling long-line fisheries from 1998–99 to 2005–06.
- Generalised linear models used on observer data to identify factors influencing variability.

c) Results and conclusions

- Main chondrichthyan bycatch from observer records include spiny dogfish (14% of total estimated catch), smooth and rough skates (3.7% of total estimated catch). Other less frequently caught species (at least 0.1% of estimated catch) include *Etmopterus* spp., shovelnose spiny dogfish, school shark, ghost sharks, seal shark, northern spiny dogfish, and chimaeras.
- Annual estimates of spiny dogfish bycatch are currently (2005–06) half the weight of the late 1990s and early 2000 figures.
- Estimated spiny dogfish discards were around 1500 t in the late 1990s, by the mid 2000s discards had dropped to 1000 t.

d) Study limitations

- Low observer coverage in areas where vessels were much smaller than would usually carry observers.
- Observers estimate total catch for all species in each set by scaling up the catch on observed hooks to the total number of hooks. However, the observed fraction of hooks is not recorded.

61 Griggs, L.H.; Francis, M.P. (2009). Fishing activity in the Kermadec Fisheries Management Area (FMA 10). NIWA Client Report No. WLG 2009-15. NIWA Project PEG09301. 52 p.

a) Species: Blue, mako, thresher and bronze whaler sharks, northern spiny dogfish, spiny dogfish, slender smoothhound, Galapagos shark, carpet shark, sharpnose sevengill shark, and pelagic stingray.

b) Methods

- Reviews the nature and extent of commercial fisheries in the Kermadec Fisheries Management Area (FMA 10).

c) Results and conclusions

- Most of the Kermadec region is very deep, with almost 98% exceeding 1000 m depth, and 33% exceeding 5000 m. Only 2% is shallower than 500 m and much of the seabed in shallow water is composed of rough volcanic rock. Thus bottom trawling in the region has been negligible, and other bottom fishing methods have been restricted to localised areas. The main fishing method has been surface longlining, which targets oceanic tunas.
- Catches are reported by method for the species mentioned for the period 1980–2008.
- Fishing effort and its geographical distribution are also reported by method.
- Sharks and rays have not been targeted in FMA 10 but blue and mako sharks and northern spiny dogfish have been significant bycatch in the surface longline and dropline fisheries.

62 Ballara, S.L.; Anderson, O.F. (2009). Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 38*. 102 p.

a) Species: Numerous species.

b) Methods

- Commercial catch effort data and observer records used to estimate the levels of bycatch and discards from 1999–00 to 2005–06.
- Bootstrapping techniques were used to choose the best ratio estimators, for scaling up observed bycatch and discards to the whole fishery.
- Regression analyses were applied to the data to identify key factors influencing bycatch and discard variability.

c) Results and conclusions

- In the arrow squid fishery, dogfish and sharks, often unspecified but including spiny dogfish and basking shark, accounted for much of the non-commercial catch. Spiny dogfish accounted for 2% of the estimated catch and 81% of that was discarded. Fifty-eight tonnes of basking shark were caught over 8 years.
- Ghost sharks accounted for 1.9% of the catch in the scampi fishery, the majority of that was processed. Unspecified skates and spiny dogfish both 1.4% of the catch, 90% of each was discarded. Forty-three tonnes (1.3%) of smooth skate was caught and two-thirds was processed.

d) Study limitations

- Observer coverage in the squid trawl fishery was 20–54% of the catch, which although considered sufficient was misleading as most of the coverage was in two areas.
- Observer coverage of the scampi fishery has been irregular over time and between areas, with less than 10% of the annual target fishery catch observed in three of the seven years.
- Care needs to be taken over interpretation of bycatch and discard estimates for both squid and scampi.

63 Baird, S.J. (2009). Characterisation of pelagic fisheries using observer data. *New Zealand Fisheries Assessment Report 2009/6*. 58 p.

a) Species: Blue, porbeagle, mako and school shark.

b) Methods

- Observers collected shark conversion factor data, and described the observed shark finning practices in the tuna longline fishery.

- Bycatch from two observed trips targeting trevally, 68 tows in TRE 1 and 7.

c) Results and conclusions

- Wet fin conversion factor for blue sharks calculated as 14.53 from a greenweight of 2680 kg (139 blue sharks). Finning practices were described from observer data.
- From 1992–2005 over the observed longline fleet, 87% of blue sharks were landed alive, and 70% of other species of sharks were landed alive.
- At least 26 shark species were observed caught in pelagic fisheries from 1992–2005. Blue sharks made up 75% of all sharks caught, mako sharks, porbeagle sharks, school sharks, and various deepwater dogfish accounted for most of the remaining captures.
- In descending order of heaviest cumulative catch, from 68 observed tows targeting trevally in 2005–06, chondrichthyans caught as bycatch were school shark, spiny dogfish, rig, carpet shark, eagle ray, smooth skate, bronze whaler shark, stingray, softnose skate, electric ray, dark ghost shark, thresher shark, longtailed stingray, northern spiny dogfish.
- Chartered Japanese vessels were more likely than domestic vessels to fin blue sharks. The percentage of blue sharks finned by Japanese pelagic vessels has remained steady from the late 1990s to 2005 at around 80%.
- The domestic pelagic fleet finned around 50% of blue sharks from the late 1990s to 2005, although there was variability among years.

d) Study limitations

- Possible changes in finning practices were described, rather than trends in observed numbers of captures.
- Fleet composition and fishing effort have varied considerably over time.
- Changes over time and among vessels in the way fishers process their catch, and record the data may have affected data comparability and interpretation

64 Manning, M.J. (2009). Updated relative abundance indices and catch-at-length estimates for spiny dogfish (*Squalus acanthias*) in SPD 3 and 5 to the end of the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2009/61*. 90 p.

a) Species: Spiny dogfish.

b) Methods

- Updates relative abundance indices and catch-at-length estimates.
- Commercial catch and effort data are processed using Starr's effort restratification and landed catch allocation algorithm.

c) Results and conclusions

SPD 3

- Most of the catch is caught in statistical areas 018, 020, 022, and 024.
- Bottom-trawl and set net fishing account for most of the catch. However, the target set net catch has decreased over the data series, from 54% of the total catch in 1989–90 to 5% during the 2005–06 fishing year.
- The lack of catch-composition data from the SPD 3 fisheries constrains our ability to interpret these indices.

SPD 5

- This fishery is dominated by bottom-trawl fishing (63%). There was a recent steady increase in the total catch in SPD 5.
- Statistical areas 028 and 30 are the most in SPD 5, with almost half the total catch from these two areas.
- Trends in the scaled length distributions are similar to those identified in earlier studies.

65 Anderson, O.F. (2009a). Fish and invertebrate bycatch and discards in southern blue whiting fisheries, 2002–07 *New Zealand Aquatic Environment and Biodiversity Report No. 43*. 42 p.

a) Species: Porbeagle sharks and numerous other species.

b) Methods

- Commercial catch effort data and observer records were used to estimate the rate and level of bycatch and discards from 2002–03 to 2006–07.
- Linear mixed-effect models were used to identify factors influencing variability. Regression tree methods were used on the main factors influencing variability.

c) Results and conclusions

- Of the total observer estimated catch, 99% was southern blue whiting. Of the remaining 1%, the most frequently caught chondrichthyan was porbeagle shark (0.06% of the total observed catch) then pale ghost shark and spiny dogfish at 0.01% of the observed total catch. More than half of the porbeagle sharks caught were discarded.
- Even with low discard rates in this fishery, porbeagle sharks are the heaviest discarded species by weight. Returning these sharks to the sea using the Sixth Schedule of the 1996 Fisheries Act, would allow some of the porbeagle sharks to survive.

66 Anderson, O.F. (2009b). Fish discards and non-target fish catch in the New Zealand orange roughy trawl fishery, 1999–2000 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 39*. 40 p.

a) Species: Shovelnose dogfish, Baxter's dogfish and numerous other deepwater sharks.

b) Methods

- Commercial catch effort data and observer data were used to estimate the rate and level of bycatch and discards from 1999–2000 to 2004–05.
- Linear regression models were applied to the observer data to identify key factors influencing variability in bycatch and discard levels. Regression tree methods were used to group data into a number of areas and periods

c) Results and conclusions

- Chondrichthyans were caught in low numbers, were usually unspecified, but included shovelnose spiny dogfish, and *Etmopterus* species (most likely Baxter's dogfish).
- The chondrichthyan species most affected by discarding, with only 10–15% being retained, were shovelnose dogfish, unidentified sharks (most likely Baxter's dogfish), *Centroscymnus* species, and seal sharks, which combined made up 2% of the observer estimated catch.

d) Study limitations

- With very high variability in Observer bycatch and discard figures, the precision of estimates was modest.

67 Bremner, G.; Johnstone, P.; Bateson, T.; Clarke, P. (2009). Unreported bycatch in the New Zealand West Coast South Island hoki fishery. *Marine Policy 33(3)*: 504–512.

a) Species: Numerous species.

b) Methods

- Observer collected data from the hoki fishery were compared to vessel logbook data from the same fishery to quantify misreporting.

c) Results and conclusions

- List of chondrichthyan species discarded in hoki fishery.

68 Blackwell, R.G. (2010). Distribution and abundance of deepwater sharks in New Zealand waters, 2000–01 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 57*. 51 p.

a) Species: Shovelnose dogfish, Baxter's dogfish, lucifer dogfish, Owston's dogfish, longnose velvet dogfish, leafscale gulper shark, and seal shark.

b) Methods

- Commercial catch effort data, observer records, and trawl survey data were used to monitor trends and characterise the catch of deepwater sharks in the deepwater and middle depth trawl fisheries.
- Deepwater shark species included shovelnose dogfish, Baxter's dogfish, lucifer dogfish, Owston's dogfish, longnose velvet dogfish, leafscale gulper shark, and seal sharks.

c) Results and conclusions

- The seven shark species are commonly taken as bycatch in the New Zealand middle depths and deepwater fisheries for hoki, orange roughy, and oreos. They are either discarded at sea, or processed for their fins and livers.
- Catches have been consistently reported for only two of the species (seal shark and shovelnose dogfish). Catches increased through the early 1990s, peaked in the early 2000s, and then declined. Analysis of observer data was confined to the Chatham Rise where observer coverage has remained relatively constant. Little change occurred in bycatch in the main target fisheries (hoki, orange roughy, and oreo) between 2001–02 and 2006.
- Available abundance indices for six of the deepwater shark species showed little change, or an increase in relative abundance on the northeast Chatham Rise between 1986 and 2002. The relative abundance indices for Baxter's dogfish were more variable, where indices declined on the northeast Chatham Rise between 1986 and 2002. Only the Chatham Rise middle depths (600–800 m) trawl survey series has continued through to recent years, though a summer survey series has resumed on the Sub-Antarctic shelf.

d) Study limitations

- The continued use of generic species codes by the commercial industry and Observer Programme excluded the identification of trends among these species.
- Scaled length frequencies are too variable to monitor trends in recruitment for shovelnose dogfish, Baxter's dogfish, and longnose velvet dogfish. Insufficient data are available for other species to determine trends.
- The commercial fishery data for deepwater dogfish are unreliable. The Observer Programme data were also unreliable because of poor species identification, misreporting, and between-year variability in observer coverage.
- The trawl survey series cover only a small part of the known distribution of these species, and it is not known how representative the results are.

69 Anon (2010). Annual report to the Commission. Part 1: Information on fisheries, research, and statistics. *Western and Central Pacific Fisheries Commission Scientific Committee sixth regular session WCPFC-SC6-AR/CCM-15*. 28 p.

a) Species: Blue, mako, porbeagle and thresher sharks, pelagic stingray.

b) Methods

- Bycatch analysed from New Zealand flagged vessels targeting tuna in the western and central Pacific Ocean convention area from 2006–2009.

- For bycatch species of commercial interest, reasonably good estimates of landings can be obtained from fisher records; for less valuable species, observer data provide the best information.

c) Results and conclusions

- In 2009 more effort was observed across the tuna fishing fleet: 26% of the longline effort (hooks), 35% of the New Zealand purse seine sets, and 6 troll trips (percentage not stated).
- Blue sharks are the most common non-tuna bycatch species in the longline fishery. The estimated catch of blue shark was stable at more than 50 000 sharks, except for a drop in 2008. The estimated mako shark catch decreased from 2006 to 2008, but rose in 2009 back to 2006 levels. Porbeagle shark catches have increased from 2006 to 2008 and remained unchanged in 2009. Pelagic stingray catch dropped considerably from 2006–2008, then increased in 2009. A large reduction in longline effort was the reason given for reductions in landings in some of the major bycatch species.
- Manta and devil rays made up 0.1% of the observed purse seine catch in 2009.

70 Francis, M.P.; Smith, M.H. (2010). Basking shark (*Cetorhinus maximus*) bycatch in New Zealand fisheries, 1994–95 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 49*. 57 p.

a) Species: Basking shark.

b) Methods

- To analyse the nature and extent of fishing-induced mortality of basking sharks in New Zealand waters, and to recommend methods of reducing the catch.
- Bayesian predictive hierarchical models were used to estimate catches and catch rates.
- Catch and landing data and observer data were used.

c) Results and conclusions

- In New Zealand waters the highest abundance of basking sharks, as indicated by surface sightings and incidental capture in trawl fisheries, are off Banks Peninsula–Canterbury Bight, west coast South Island, the Snares shelf, and Auckland Islands Shelf.
- Most of the recent decline in basking shark bycatch is likely to be attributable to a decline in fishing effort.
- Any reduction in fishing effort in the three main fisheries, particularly during peak capture periods, would reduce basking shark bycatch.
- Commercial data indicated low landings with occasional small peaks during the 1990s, large landings in the early 2000s, and low landings for the three most recent years.
- Observer records were generally similar to the commercial records, apart from under-representation during the landing peaks of the 2000s. In addition, the observer records indicated a peak in catches in 1988–89, before the commercial data series began.
- The Puysegur squid fishery and the north-subarea of the west coast hoki fishery produce the highest bycatch. Effort reductions could be targeted at those subareas.
- Bycatch was much higher in midwater trawl nets than in bottom trawl nets on the west coast. A reduction in use of midwater trawl nets in this area may reduce basking shark bycatch.

d) Study limitations

- It is likely that weights up to 500 kg are mistaken identification or coding errors in all data sets and they were omitted.

71 Mormede, S.; Dunn, A. (2010). Characterisation of skate catches in the Ross Sea Region. *CCAMLR No. WG-FSA-2010/25.* 23 p.

a) Species: Antarctic starry skate and Antarctic allometric skate.

b) Methods

- The available fisheries and biological information for skates in the Ross Sea Region is summarised, including the data collected in the two "Year of the Skate" fishing seasons in 2008–09 and 2009–10.

c) Results and conclusions

- Skates form a small proportion of the total Ross Sea catch (typically 2% or less).
- The composition of the skate catch by species is uncertain. It is estimated that about 33 000 starry skates were landed, and 55 000 released in the Ross Sea region by all vessels to the end of the 2009–10 fishing season, and about 4300 allometric skates were landed and 4600 released in the same region over the same period of time.
- There were differences in the distribution of the two species, starry skates generally being found deeper and more to the west than allometric skates.
- Scaled length frequencies showed no change between 2003 and 2008 for landed starry skates, while tagged starry skates had a lower proportion of large individuals than landed starry skates.
- Allometric skates had a different length frequency, with a narrower distribution centred around a larger average size than starry skates. This larger distribution is consistent with other studies suggesting allometric skates might grow larger than starry skates.
- During the "Years of the Skate", a total of about 3300 starry skates and 700 allometric skates were tagged, and 13 starry skates and 3 allometric skates were recaptured and successfully linked to a tag event. In total there have now been a total of 179 tags recaptured but only 128 have been successfully linked.
- There was no evidence of growth retardation linked with the capture and tagging event.
- Tag loss rates of T-bar tags were similar to those calculated for toothfish.

72 Ballara, S.L.; O'Driscoll, R.L.; Anderson, O.F. (2010). Fish discards and non-target fish catch in the trawl fisheries for hoki, hake, and ling in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 48*. 100 p.

a) Species: Numerous species.

b) Methods

- Observer data were used to estimate bycatch and discard rates in target fisheries for hoki, hake, and ling from 2000–01 to 2006–07. Ratio estimators were calculated for scaling up observed rates to the total fishery. Bootstrapping techniques were used to select the key ratio estimator.
- Regression analyses were used to determine which key factors had the most influence on bycatch and discard ratios.

c) Results and conclusions

- Spiny dogfish make up 1% of the estimated total catch weight from these fisheries; almost 90% of those spiny dogfish are discarded. This level has remained steady for the latter half of the study period. Most spiny dogfish are still discarded, but the proportions processed have increased since 2003–04.
- The pale ghost shark catch was 0.5% of the total estimated catch, 20% of these are discarded. This catch has more than halved from a highpoint in 2002–03.

- Shovelnose dogfish make up 0.2% of the total catch (314 tonnes) with 87% discarded. This catch estimate has remained steady, below 1000 t, since 2002–03.
- One hundred and twenty tonnes of basking sharks were caught in 8 years.
- Trawl duration had the most influence on the discards of shovelnose dogfish, deepwater sharks and skates. Tow type was also important for deepwater sharks and skates.
- Total discards for most species, including deepwater sharks, shovelnose dogfish, skates and other sharks have decreased over the study period. This apparent decrease may be related to vessels processing more of these species to meal.

d) Study limitations

- The precision of the bycatch and discard estimates was strongly linked to the observer coverage (11–21%) of the fishery. This was considered sufficient to be representative of the overall fishery, although coverage was variable by area, month and year.

73 Starr, P.J.; Kendrick, T.H. (2010a). Characterisation and CPUE analysis for SCH 1. Report to the Adaptive Management Programme Fishery Assessment Working Group No. AMP WG 2010/05-v3. 85 p.

a) Species: School shark.

b) Methods

- SCH 1 characterisation and standardised CPUE analysis for the period ending September 2009. The data preparation followed Starr (2007).
- Abundance indices estimated using a GLM model.

c) Results and conclusions

- In recent years landings have been near to the TACC in SCH 1.
- In October 2008, regulations to protect Maui’s and Hector’s dolphins were amended, this extended a set net closure from four to seven nautical miles offshore.
- SCH 1 is fished by a variety of methods. From the last 20 years of data, landings were split evenly between three fishing methods: bottom trawl, bottom longline and set net.
- Relative CPUE abundance indices from west coast set net data show almost no trend since 1989–90. East coast set net data show a decrease to the mid 1990s then an increasing trend.
- Relative CPUE abundance indices from west coast bottom longline data show no trend in the first decade of the series, but decline to a minimum in 2001–02, after which they steadily increase up to 2007–08. The east coast data show a gradual upward trend over the 20-year period, except for four years in the late 1990s and early 2000s.
- None of the four CPUE series selected for detailed analysis showed any long-term systematic decline in abundance.

74 Starr, P.J.; Kendrick, T.H. (2010b). Characterisation and CPUE analysis for SCH 2. Report to the Adaptive Management Programme Fishery Assessment Working Group No. AMP WG 2010/06-v2. 64 p.

a) Species: School shark.

b) Methods

- SCH 2 characterisation and standardised CPUE analysis for the period ending September 2009. The data preparation followed Starr (2007).
- Abundance indices estimated using a GLM model.

c) Results and conclusions

- The SCH 2 fishery is a mixed method fishery, with bottom trawl accounting for half of the landings over the past 20 years, bottom longline 30%, set net 16%, and Dahn line 6%.
- Two CPUE series were evaluated for SCH 2, one based on landings from set net, the other from longline landings (both were from fisheries targeting other species). The two CPUE series showed contradictory trends, the set net series generally increased, the bottom longline series generally declined.
- Due to the contradictory nature of both CPUE series, it is not known if current landings would affect the school shark population in SCH 2.

75 Starr, P.J.; Kendrick, T.H.; Bentley N (2010a). Characterisation, CPUE analysis and logbook data for SCH 3. Report to the Adaptive Management Programme Fishery Assessment Working Group No. AMP WG 2010/07-v2. 62 p.

a) Species: School shark.

b) Methods

- SCH 3 characterisation and standardised CPUE analysis for the period ending September 2009. The data preparation followed Starr (2007).
- Abundance indices estimated using a GLM lognormal model.
- School shark biological data from Industry set net logbook data.

c) Results and conclusions

- Many regulations have affected the SCH 3 fishery: the Banks Peninsula Marine Mammal Sanctuary established in 1988 by the Department of Conservation under the Marine Mammal Protection Act 1978, an industry led voluntary closure by the SEFMC in October 2000, and the October 2008 area closures to protect Hector's dolphins.
- Landings were close to or exceeded the TACC from 1998–99 to 2004–05, when the TACC was increased, since that time landings have been below the TACC.
- From more than 20 years of catch history, over 50% of the SCH 3 fishery landings have been from set nets, a further third by bottom trawl.
- The CPUE indices for SCH 3 showed a generally increasing trend after an initial drop of about 40% between 1989–90 and 1992–93.
- Set net length frequency data appear to be stable up to 2001–02, after which the female mean lengths dropped and the male mean lengths continued to be stable for the next three fishing years.

d) Study limitations

- Participation in the voluntary logbook programme declined considerably in recent years which will limit the representativeness of biological data.

76 Starr, P.J.; Kendrick, T.H.; Bentley N (2010b). Characterisation, CPUE analysis and logbook data for SCH 5. Report to the Adaptive Management Programme Fishery Assessment Working Group No. AMP WG 2010/08-v2. 65 p.

a) Species: School shark.

b) Methods

- SCH 5 characterisation and standardised CPUE analysis for the period ending September 2009. The data preparation followed Starr (2007).
- Biological information and catch and effort data are from the target shark set net fishery.
- Abundance indices estimated using a GLM model.

c) Results and conclusions

- The fishery has not experienced much stability in the way it has been fished.

- Relative CPUE abundance indices show a high level from 1989–90 to 1992–93, followed by a drop to about 75–95% of the peak which was then maintained through to the mid-2000s. The index then declined to 50% of the long-term average between 2005–06 and 2008–09, with a particularly large drop between 2007–08 and 2008–09.
- The GLM analysis may be indicative of a small fishery operating on a reasonably large stock, with annual variations in the indices relating to short term changes in school shark availability, or to variability caused by factors other than abundance.
- It is unknown if these catches are at levels that would allow the stock to move towards a size that would support the maximum sustainable yield.

d) Study limitations

- Participation in the QMA 5 logbook programme declined considerably "in recent years" which will limit the representativeness of biological data.
- In October 2008, regulations to protect Maui's and Hector's dolphins were implemented. There is possible instability in the index due to the small number of vessels that fish in the SCH 5 fishery.

77 Starr, P.J.; Kendrick, T.H.; Bentley N (2010c). Characterisation, CPUE analysis and logbook data for SCH 7 and SCH 8. Report to the Adaptive Management Programme Fishery Assessment Working Group AMP WG 2010/09-v2. 149 p.

a) Species: School shark.

b) Methods

- Characterisation and standardised CPUE analysis for SCH 7 and SCH 8 for the period ending September 2009. The data preparation followed Starr (2007).
- Catch effort and biological data are mostly from the target shark set net fishery.
- Abundance indices estimated using a GLM model.

c) Results and conclusions

- The SCH 7 set net CPUE series shows a declining trend from 1999–2000 to 2007–08, with a strong upturn in the final (2008–09) fishing year.
- The CPUE series evaluated for SCH 8 shows no overall trend, apart from a strong drop from 1995–96 to 2001–02. The level on both sides of the drop is approximately the same, at about 10–15% above the long-term mean of the series.

d) Study limitations

- The CPUE series for SCH 7 and SCH 8 need to be viewed with caution as they may be affected by factors other than abundance or may be monitoring a larger population that is migrating between areas.
- In October 2008, regulations to protect Maui's and Hector's dolphins were implemented. This may have affected the utility of the SCH 8 index.

78 Starr, P.J.; Kendrick, T.H.; Bentley N (2010d). Characterisation, CPUE analysis and logbook data for SPO 7. Report to the Adaptive Management Programme Fishery Assessment Working Group No. AMP WG 2010/10-v2. 93 p.

a) Species: Rig.

b) Methods

- SPO 7 characterisation and standardised CPUE analysis conducted on SPO 7 from 1989–90 to 2008–09. The methodology followed Starr (2007).
- Includes a west coast South Island and Tasman and Golden bay research trawl survey abundance index.

c) Results and conclusions

- Dressed and headed and gutted were the main processed states. Conversion factors for rig have remained unchanged since 1999–2000.
- Set net was the primary fishing method for rig (61% of landings since 1989–90), followed by bottom trawl with 38% of landings. Set net catches were mostly taken in a rig target fishery during spring−summer. Rig caught by bottom trawl were mostly bycatch of fisheries for flatfish, barracouta, red cod and tarakihi.
- Relative CPUE indices for the Tasman and Golden Bay target set net fishery showed a rapid decline in the early 1990s, then a steady slow decline for the remainder of that decade, and a gentle increase from 2005–06. The rapid decline triggered a large reduction in TACC in October 2006. Relative CPUE indices for the west coast South Island set net fishery showed an oscillating rise to a peak in the late 1990s followed by a continued oscillating decline to 2008–09. Relative CPUE indices for the bottom trawl fishery from SPO 7 showed repeated peaks and troughs, more recently the index is about half the peak value of 1999–00.
- Rig biomass estimates from a time series of trawl surveys in Tasman and Golden Bays have remained steady around 100 t from 1992. The South Island west coast rig biomass estimates increased to a peak in 1995 then decreased through to 2005, increasing again with the 2007 and 2009 surveys.

d) Study limitations

- The methodological limitations of Starr (2007) include discarding trips if they fish in 'straddle' statistical areas. The allocation of estimated green weight landed catch to specific statistical areas, methods and target species has been done assuming catches are distributed correctly (even though the discarding of trips will compromise this assumption).
- Trawl surveys are not effective at monitoring adult rig biomass, because larger mature rig can swim faster than the trawl gear.

79 Starr, P.J. (2010). Farewell Spit rig setnet survey: 2005–2007. Analysis of station data and rig biomass indices. Draft report to the Southern Inshore Stock Assessment Working Group No. SINS-WG-2010-32. 23 p.

a) Species: Rig.

b) Methods

- A set net survey was carried out inside and outside Farewell Spit in each of the three years 2005−2007. 15−18 sets were made per survey in each of five strata.
- CPUE was calculated and multiplied by stratum area to provide a relative biomass estimate.

c) Results and conclusions

- Catch weights of rig in all survey years appeared to be greatest on the Golden Bay side of Farewell Spit. There was little evidence that increased soak time resulted in increased catches, with the highest recorded catches taken with less than three hours of soak time.
- There was weak evidence that mean weight increased with increasing mesh size, with the mean weights showing considerable overlap in all three survey years across the mesh size panels used.
- Biomass levels were calculated using two different assumptions regarding the inclusion of set net soak time. Varying the assumption regarding soak time made a large difference to the relative biomass estimates and c.vs.

- Biomass was lower in 2006 than in 2005 and 2007, but the c.v. was larger.
- Most of the rig were measured (2500 females and approximately 100 males). The mean size of both the male and female rig in the 2005 survey were greater than in either the 2006 or the 2007 surveys, possibly because of the earlier timing of the 2005 survey (January versus March).
- It seems unlikely that set nets can be used successfully to track biomass.

d) Study limitations

- Mesh sizes and survey timing varied among years.
- Catch weights were not consistently provided, and were estimated from rig numbers and mean weight.
- Maturity and pupping information collected by observers appears to be unreliable based on clear errors in the data, and the small proportion of some catches examined.

80 Anderson, O.F. (2011). Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990–91 until 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 67*. 61 p.

a) Species: Numerous species.

b) Methods

- Commercial catch effort data and observer data were used to estimate the rate and level of bycatch and discards from 1990–91 to 2008–09.
- Linear mixed-effect models were used to identify factors influencing variability. Regression tree methods were used on the main factors influencing variability.

c) Results and conclusions

- Since 2005–06, in the orange roughy fishery, 1.8% of the observer estimated total catch has been made up of various species of deepwater dogfish. Shovelnose spiny dogfish made up 0.6% of the estimated total catch, from which over 90% was discarded. Other sharks frequently caught and mostly discarded were likely to have been Baxter’s dogfish, and also include longnose velvet dogfish, longnose spookfish and seal sharks.
- Since 2002, in the oreo fishery, 1.2% of the observer estimated total catch has been made up of various species of deepwater dogfish that are mostly discarded. Baxter’s dogfish and seal sharks accounted for most of this discarded catch.
- In the oreo fishery, shovelnose dogfish were considerably less vulnerable than in the orange roughy fishery.

d) Study limitations

- The orange roughy fishery is very widespread. To achieve even coverage across the whole fishery is very difficult.
- Only about 15% of the observed trips examined in this research targeted mostly oreos. To achieve an even spread of observer coverage in this fishery is also very difficult.

81 Francis, M.P.; Sutton, P. (2012). Possible factors affecting bycatch of basking sharks (*Cetorhinus maximus*) in New Zealand trawl fisheries. NIWA Client Report Prepared for Department of Conservation No. WLG2012-48. 23 p.

a) Species: Basking shark.

b) Methods

- Aim was to identify factors related to the apparent decline in bycatch of basking sharks from 1994–95 to 2007–08.

- Two hypotheses are tested to explain the fluctuations seen in basking shark bycatch rates: (a) high catch rates during the late 1980s and late 1990s resulted from increased water temperatures; and (b) catch rates may have been higher in early periods because foreign fishing vessels may have been targeting sharks.

c) Results and conclusions

- A strong and highly significant association was found between the number of sharks caught and vessel nationality in all three fishery areas.
- Other variables examined were not correlated with shark catch rates.

82 Ministry of Fisheries (2011). Report from the mid-year Fisheries Assessment Plenary, November 2011: stock assessments and yield estimates. 355 p.

a) Species: Blue shark, mako shark, porbeagle shark.

b) Methods

- Summarises fisheries, catch histories, quota histories, biology, stocks, estimates of relative abundance (e.g. CPUE, trawl surveys), and status of the stocks. For some species, biomass and yield estimates are provided.

c) Results and conclusions

- The above items are summarised and updated to 2010−11 for three pelagic sharks in the Quota Management System.

83 Ministry for Primary Industries (2012). Report from the Fisheries Assessment Plenary, May 2012: stock assessments and yield estimates. 1194 p.

a) Species: Elephantfish, dark ghost shark, pale ghost shark, rig, school shark, rough skate, smooth skate, spiny dogfish.

b) Methods

- Summarises fisheries, catch histories, quota histories, biology, stocks, estimates of relative abundance (e.g. CPUE, trawl surveys), and status of the stocks. For some species, biomass and yield estimates are provided.

c) Results and conclusions

- The above items are summarised and updated to 2010−11 for eight chondrichthyans in the Quota Management System.

84 Griggs, L.H.; Baird, S.J. (2012 in press). Fish bycatch in New Zealand tuna longline fisheries 2006–07 to 2009–10. *New Zealand Fisheries Assessment Report 2012/xx*. 74 p.

a) Species: Blue, porbeagle, mako and school sharks.

b) Methods

- To estimate the catches, catch rates, and discards of bycatch from tuna longline fisheries using observer and commercial data from 2006–07 to 2009–10.
- Describe bycatch trends using current data and previous similar projects.

c) Results and conclusions

- Maximum of 27 million hooks set by fishery in 1980–81, dropping to 4 million in the mid-1990s when foreign licensed vessels ceased fishing in New Zealand. Domestic effort peaked in 2001–02 at 10 million hooks, and has dropped since then to 2–3 million hooks.
- Blue shark was the most commonly caught species, more than 30% of the catch during the study period. Porbeagle and mako sharks each account for less than 3% of the catch.
- Most blue, porbeagle, and mako sharks observed were immature.

- From 2006–07 to 2009–10, most blue, mako, porbeagle, school sharks, and deepwater dogfish (mostly Owston's dogfish) were alive when recovered.
- Most blue, porbeagle, mako, and school sharks were processed, either just finned or retained for their flesh, and there were significant fleet differences.
- Recommend that observer coverage of the domestic fleet be increased.

d) Study limitations

- Observer domestic coverage has increased over the last four fishing years, although still below 10%.
- Differences in CPUE trends in the charter fleet in the North and South regions may reflect different spatial representation or varying abundance of species in different areas.

85 Kendrick, T.H.; Bentley, N. (2012). Fishery characterisation and setnet catch-per-unit-effort indices for rig in SPO 1 and SPO 8, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/44*. 95 p.

a) Species: Rig.

b) Methods

- This study updates the characterisation of the fishery.
- Rig in SPO 1 and SPO 8 is monitored using standardised CPUE for a core fleet of inshore vessels that target rig using the set net method. This study updates the previously defined series with an additional four years of data.
- An exploration of CPUE indices from bottom trawl was also done for each of SPO 1E, SPO 1W, and SPO 8.

c) Results and conclusions

- The Southern Inshore Working Group was uncertain about adjusting estimated catches on the basis of the annual ratio of landed/estimated catch, and did not accept the set net series for SPO 1. This was largely because the groomed landings were markedly in excess of Quota Management Report totals during the 1990s, and compromise the reliability of the ratio.
- Destination "Q" landings (holding catch ashore) did not affect data for the set net series in SPO 8, and that series, which fluctuated without trend and had recent indices near the long-term average, was accepted.
- The Working Group accepted that the trawl series in SPO 1 E and SPO 1 W are probably monitoring some part of the rig population, but felt that the trawl series for SPO 8 was based on too few data to be reliable.
- The bottom trawl series all show a decline to low points in the mid 2000s, but agree on recent recoveries.

d) Study limitations

- The practise of holding catch ashore for subsequent landing to a LFRR effectively breaks the linkage between effort and landings, and the increasing use of this code may bias contaminates both catch rate and success rate signals.

86 MacGibbon, D.J.; Fu, D. (2012 in press). Fishery characterisation and standardised CPUE analyses for pale ghost shark, *Hydrolagus bemisi* Didier, 2002 (Chimaeridae), 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/xx*. 121 p.

a) Species: Pale ghost shark.

b) Methods

- Attempted reconstruction of catch histories before 1990.

- Catches since 1990–91 were compared with TACCs.
- Trawl survey biomass estimates were collated and summarised.
- Biological parameters were reviewed.
- CPUE was estimated for hoki trawlers on the east coast South Island, Chatham Rise and the Sub-Antarctic between 2000 and 2010.

c) Results and conclusions

- Catch histories could not be reconstructed before 1990 because of suspected discarding, conversion of catch to fish meal, and failure of some fishers to distinguish pale and dark ghost shark.
- Pale ghost sharks are mainly caught as bycatch in bottom trawls targeting hoki on the Chatham Rise and the Sub-Antarctic.
- Biomass estimates showed no long-term trends.
- CPUE indices were mostly flat or fluctuated without an overall trend.

d) Study limitations

- Monitoring of pale ghost shark stocks will require more data from research and commercial sources. Observer coverage is reasonable but should be expanded.

3.1.8 Trawl survey monitoring

87 Stevens, D.W.; O'Driscoll, R.L.; Gauthier, S. (2008). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2007 (TAN0701). *New Zealand Fisheries Assessment Report 2008/52*. 81 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, smooth and rough skate, school shark, shovelnose dogfish, northern spiny dogfish, Baxter's dogfish, longnose velvet dogfish, leafscale gulper shark, and longnose chimaera.

b) Methods

- Continue the time series of relative abundance indices of recruited hoki.
- Catch and biomass estimates generated for all species listed. Length-weight regression parameters for most species listed. Length-frequency distributions for a few species listed.

c) Results and conclusions

- The sixteenth trawl survey in the time series.
- Female dark and pale ghost sharks have a biomodal length frequency distribution. Most males caught were mature.
- Female spiny dogfish were in an overwhelming majority. The female length-frequency distribution was bi-modal with peaks around 60–70 and 80–90 cm.
- Biomass estimates for each species were listed.

88 O'Driscoll, R.L.; Bagley, N.W. (2008). Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November-December 2006 (TAN0617). *New Zealand Fisheries Assessment Report 2008/30*. 61 p.

a) Species: Dark and pale ghost sharks, shovelnose dogfish, longnose velvet dogfish, spiny dogfish, Baxter's dogfish, and leafscale gulper shark.

b) Methods

- Continue the time series of relative abundance indices for hoki, hake and ling.
- Catch and biomass estimates for most species listed. Length-weight regression parameters and length-frequency distributions for a few species listed.

c) Results and conclusions

- The tenth summer trawl survey in the time series.
- The length frequency distribution for male dark ghost sharks showed peak catches from 55–60 cm, the female distribution was broad from 30–70 cm.
- The length frequency distribution for male pale ghost sharks showed a peak between 65 and 75 cm, with a long tail of smaller sharks; the female distribution was similar to males, with a peak from 70–80 cm and a long tail of smaller sharks.
- Length frequency distributions for male spiny dogfish peaked at 65 cm, the female distribution was bimodal with peaks around 65 and 85–90 cm.
- Biomass estimates are listed.

89 Beentjes, M.P.; Stevenson, M.L. (2008). Inshore trawl survey of Canterbury Bight and Pegasus Bay, May-June 2007 (KAH0705). *New Zealand Fisheries Assessment Report 2008/38*. 95 p.

a) Species: Spiny dogfish, school shark, rig, dark ghost shark, smooth and rough skate.

b) Methods

- Estimates of relative biomass from winter time series of trawl surveys since 1991.
- Length-frequency distributions and catch rates are provided for some species.

c) Results and conclusions

- Biomass for dark ghost shark was the highest of the six winter surveys and continued a trend of increasing biomass from 1991 to 2007. The highest biomass estimates were from the 100–200 m and 200–400 m strata. The length frequency distribution is bimodal with peaks around 35–40 cm and 55–65 cm.
- Biomass for spiny dogfish was the highest of the six winter surveys, increasing almost three-fold from 1994 to 1996, and remaining at this high level in 2007. Spiny dogfish were caught in all depth strata, with the highest biomass estimates from the strata 10–200 m deep. Length frequency peaks for both sexes were around 55 cm.
- The estimated biomass for elephant fish was the highest of all winter surveys. It is at a level slightly higher than the 1996 survey.
- The estimated biomass for rig was at a level similar to 1991, with the intermittent years half the 1991 and 2007 levels.
- The estimated biomass of rough skate had increased, and was considerably higher than the next highest estimate in 1994.
- The estimated biomass for smooth skate had remained steady, except for a 50% drop during the 1994 and 1996 surveys.
- The estimated biomass for school shark was markedly higher in 2007 than in any other survey year.

90 Bagley, N.W.; O'Driscoll, R.L.; Francis, R.I.C.C.; Ballara, S.L. (2009). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2007 (TAN0714). *New Zealand Fisheries Assessment Report 2009/09*. 63 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, longnose velvet dogfish, Baxter's dogfish, shovelnose dogfish, and leafscale gulper shark.

b) Methods

- Continue the time series of relative abundance indices for hoki, hake and ling.
- Catch and biomass estimates for most species listed. Length-weight regression parameters and length-frequency distributions for a few species listed.

c) Results and conclusions

- The eleventh summer trawl survey in the time series.
- The length frequency distribution for male dark ghost sharks showed peak catches from 55–60 cm, the female distribution was bimodal with peaks at 45–50 and 65 cm.
- The pale ghost shark biomass estimate had increased from the previous year. The length frequency distributions were similar to the previous year, the male distribution had a peak between 65 and 75 cm, with a long tail of smaller sharks, the female distribution was similar to males, with a peak from 70–75 cm and a long tail of smaller sharks.
- The spiny dogfish biomass estimate had increased from the previous year. Length frequency distributions for male spiny dogfish peaked at 65–70 cm, the female distribution was broad from 50 to 95 cm.
- The longnose velvet dogfish biomass estimate remained the same as the previous year.
- The Baxter's dogfish biomass estimate was lower than the previous year.
- The leafscale gulper shark biomass estimate had increased from the previous year.
- The shovelnose dogfish biomass estimate was lower than the previous year.

91 Stevens, D.W.; O'Driscoll, R.L.; Horn, P.L. (2009a). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2008 (TAN0801). *New Zealand Fisheries Assessment Report 2009/18*. 86 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, smooth skate, school shark, and shovelnose dogfish.

b) Methods

- Continue the time series of relative abundance indices of recruited hoki.
- Catch and biomass estimates for all species listed. Length-weight regression parameters for most species listed. Length-frequency distributions for a few species listed.

c) Results and conclusions

- The seventeenth trawl survey in the time series.
- The dark ghost shark biomass estimate had increased from the previous year. Female dark ghost shark length frequency was bimodal with peaks at 50 and 65 cm, the male peak was around 55 cm.
- The pale ghost shark biomass estimate was down from the 2007 figure. Female length frequency distribution was broad from 35 to 85 cm, the male distribution was bimodal with peaks at 45 and 65–70 cm.
- The spiny dogfish biomass estimate was more than double the previous year. Females were in an overwhelming majority. The peak female length-frequency was at 75 cm.
- The smooth skate biomass estimate was lower than the previous year.
- The school shark biomass estimate was lower than the previous year.
- The shovelnose dogfish biomass estimate was lower than the previous year.

92 Beentjes, M.P.; Stevenson, M.L. (2009). Inshore trawl survey of Canterbury Bight and Pegasus Bay, May–June 2008 (KAH0806). *New Zealand Fisheries Assessment Report 2009/57*. 105 p.

a) Species: Spiny dogfish, school shark, rig, dark ghost shark, smooth and rough skate.

b) Methods

- Estimates of relative biomass from winter time series of trawl surveys since 1991.
- Length-frequency distributions and catch rates are provided for some species.

c) Results and conclusions

- The estimated biomass for dark ghost shark was the second highest of the seven winter surveys, and although 16% less than 2007, biomass was still four times that from the 1990s surveys. The length frequency distributions from the last five surveys were similar and generally bimodal.
- The estimated biomass for spiny dogfish was about 20% less than 2007, but still more than double the early 1990s biomass levels, indicating that the increase in biomass between 1994 and 1996 was sustained. The length frequency distributions from 2008 were dominated by smaller fish, particularly females.
- The estimated biomass for elephant fish was the highest of all winter surveys.
- The estimated biomass for rig was more than double the level in 2007.
- The estimated biomass of rough skate was the same as the previous survey in 2007.
- The estimated biomass for smooth skate had dropped slightly in 2008.
- The estimated biomass for school shark had dropped but was still considerably more than in all previous winter surveys.

93 Stevens, D.W.; O'Driscoll, R.L.; Horn, P.L. (2009b). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2009 (TAN0901). *New Zealand Fisheries Assessment Report 2009/55*. 91 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, smooth and rough skate, school shark, shovelnose dogfish, and long-nosed chimaera.

b) Methods

- Continue the time series of relative abundance indices of recruited hoki.
- Catch and biomass estimates for all species listed. Length-weight regression parameters for most species listed. Length-frequency distributions for a few species listed.

c) Results and conclusions

- The eighteenth trawl survey in the time series.
- The dark ghost shark biomass estimate had decreased to a level similar to the 2007 survey figure. Female dark ghost shark length frequency was the same as the previous year, bimodal with peaks at 50 and 65 cm, the male peak was around 55 cm.
- The pale ghost shark biomass estimate increased from the previous year, but not yet back to the 2007 figure. Length-frequency distributions were the same as the previous year, female distribution was broad from 30 to 85 cm, the male distribution was bimodal with peaks at 45 and 65–70 cm.
- The spiny dogfish biomass estimate returned to 2007 levels, after a very high 2008 biomass estimate. Females were in an overwhelming majority. The peak female length-frequency was slightly less than the previous year at 55–65 cm.
- The smooth skate biomass estimate was lower than the previous year.
- The school shark biomass estimate was the same as the previous year.
- The rough skate biomass estimate was the same as 2007.
- The shovelnose dogfish biomass estimate had increased back to the 2007 estimate.

94 O’Driscoll, R.L.; Bagley, N.W. (2009). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2008 (TAN0813). *New Zealand Fisheries Assessment Report 2009/56*. 67 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, longnose velvet dogfish, Baxter’s dogfish, shovelnose dogfish, and leafscale gulper shark.

b) Methods

- Continue the time series of relative abundance indices for hoki, hake and ling.
- Catch and biomass estimates for most species listed. Length-weight regression parameters and length-frequency distributions for a few species listed.

c) Results and conclusions

- The twelfth summer trawl survey in the time series.
- The length frequency distribution for male dark ghost sharks showed peak catches around 55 cm, the female distribution was bimodal.
- The pale ghost shark biomass estimate had decreased to lower than 2006 survey levels. The length frequency distributions were similar to previous years, the male distribution had a peak between 65 and 75 cm, with a long tail of smaller sharks, the female distribution was similar to males, with a peak from 70–75 cm and a long tail of smaller sharks.
- The spiny dogfish biomass estimate had decreased slightly to the same level as the 2006 survey. The length frequency distributions were similar to previous years, the male distribution peaked at 65–70 cm, the female distribution was broad from 55 to 95 cm.
- The longnose velvet dogfish biomass estimate decreased in 2008.
- The Baxter's dogfish biomass estimate decreased again this year.
- The leafscale gulper shark biomass estimate had decreased back to 2006 survey levels.
- The shovelnose dogfish biomass estimate had increased back to 2006 survey levels.

95 Stevenson, M.L.; Hanchet, S.M. (2010). Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2009 (KAH0904). *New Zealand Fisheries Assessment Report 2010/11*. 78 p.

a) Species: Spiny dogfish, northern spiny dogfish, school shark, rig, dark ghost shark, rough and smooth skate.

b) Methods

- Estimates of relative biomass from time series of trawl surveys since 1992. Length-frequency distributions and catch rates are provided for some species.

c) Results and conclusions

- Biomass estimates for spiny dogfish were relatively stable from 1992 to 2007, but there was a sharp increase in 2009. More fish under 50 cm were caught in the 2009 survey than in 2007.
- The estimated biomass for rig had decreased from the previous survey, but was higher than surveys in 2003 and 2005. Length-frequency distributions for rig in 2009 had a strong mode of 1-year and 2-year sharks not seen in any earlier survey.
- The estimated biomass for school shark in 2009 was the highest since 1997 and the fourth highest in the series and has gradually increased since a low in 2003. Length-frequency distributions for 2009 had a very strong mode of juvenile school sharks, not seen in any previous survey.
- The relative biomass of dark ghost shark had more than halved since the survey in 2007.
- Northern spiny dogfish biomass had remained relatively stable for the whole survey period.
- The relative biomass of rough skate had more than halved since the survey in 2007.
- Smooth skate biomass was similar to the previous two surveys, but considerably less than the 1990 surveys.

96 Beentjes, M.P.; Lyon, W.S.; Stevenson, M.L. (2010). Inshore trawl survey of Canterbury Bight and Pegasus Bay, May–June 2009 (KAH0905). *New Zealand Fisheries Assessment Report 2010/29*. 102 p.

a) Species: Spiny dogfish, school shark, rig, dark ghost shark, smooth and rough skate.

b) Methods

- Estimates of relative biomass from time series of trawl surveys since 1991. Length-frequency distributions and catch rates are provided for some species.

c) Results and conclusions

- The estimated biomass for dark ghost shark increased markedly between 1992 and 1993 and the current 2009 biomass is four times greater than in 1992, and the second highest of the eight surveys. The size distributions of dark ghost shark in each of the last six surveys (1993–2009) are similar and mostly bimodal.
- After the peak spiny dogfish biomass in 2007, biomass dropped in 2008 and in 2009. However, the current 2009 biomass is still double that of the early 1990s. Since the 1996 survey the length distributions have been dominated by smaller fish, particularly for females.
- The estimated biomass for elephant fish was half that of the last two surveys, but still above the 1990s surveys.
- Biomass estimates for rig had dropped after the peak biomass of the 2008 survey and are similar to the 2007 levels.
- Rough and smooth skate biomass estimates were the highest from any survey in this time series.
- After high biomass estimates for school shark in 2007 and 2008, 2009 biomass levels have returned to levels similar to those estimated in earlier surveys.

97 Stevens, D.W.; O'Driscoll, R.L.; Dunn, M.R.; MacGibbon, D.; Horn, P.L.; Gauthier, S. (2011). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2010 (TAN1001). *New Zealand Fisheries Assessment Report 2011/10*. 112 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, smooth skate, school shark, shovelnose dogfish, Baxter’s dogfish, longnose velvet dogfish, long-nosed chimaera, and leafscale gulper shark.

b) Methods

- Continue the time series of relative abundance indices of recruited hoki.
- Catch and biomass estimates for all species listed. Length-weight regression parameters and length-frequency distributions for a few species listed.

c) Results and conclusions

- The nineteenth trawl survey in the time series.
- The dark ghost shark biomass estimate had increased to the highest level since 2007. The length frequency distribution for female dark ghost sharks showed a similar peak at 45–65 cm, the male peak was around 55 cm.
- The pale ghost shark biomass estimate decreased back to 2008 levels. Length-frequency distributions were the same as the previous year, female distribution was broad from 30 to 85 cm, the male distribution was bimodal with peaks at 45 and 65–70 cm.
- The spiny dogfish biomass estimate increased slightly from the previous year. Females were in an overwhelming majority. The peak female length-frequency was similar to the previous year at 55–65 cm, with a long tail of large sharks.
- The smooth skate biomass estimate was higher than the previous year.

- The school shark biomass estimate was higher than the previous year.
- The shovelnose dogfish biomass estimate was the highest since 2007.
- The biomass estimates for Baxter's dogfish, longnose velvet dogfish, and long-nosed chimaera were all higher than the last time they were estimated in 2007. Only leafscale gulper shark biomass was lower than 2007.

98 O'Driscoll, R.L.; MacGibbon, D.; Fu, D.; Lyon, W.; Stevens, D.W. (2011). A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2010. *New Zealand Fisheries Assessment Report 2011/47*. 72 p.

a) Species: Multiple.

b) Methods

- Review of all 19 Chatham Rise trawl surveys.
- Document trends in biomass (if catch weight for all surveys was over 10 kg), summarise spatial and depth distributions for all species caught, and document trends in size and sex composition that are regularly measured.

c) Results and conclusions

- Higher catch rates of chondrichthyan allowed better estimates for individual species. The survey estimated biomass for pale and dark ghost shark, spiny dogfish and lucifer dogfish very well. The survey estimated biomass for seal shark, school shark, Baxter's dogfish, and prickly dogfish moderately well. The survey estimated biomass for shovelnose spiny dogfish and smooth skate well. The survey estimated biomass poorly for cat shark, carpet shark, leafscale gulper shark, Dawson's cat shark, frill shark, sharpnose sevengill shark, sixgill shark, mako shark, Plunket's shark, porbeagle shark, Owston's dogfish, longnose velvet dogfish, northern spiny dogfish, rough skate, and electric ray.
- The survey caught but did not estimate biomass for black ghost shark, pointynose blue ghost shark, pacific sleeper shark, thresher shark, Sherwood's dogfish, smooth deep-sea skate, prickly deep-sea skate, deepwater spiny skate, longnose deep-sea skate, Richardson's skate, eagle ray, and oval electric ray.
- For major species, geographic distributions, depth distributions and length-frequency distributions are provided.

d) Study limitations

- Where there has been a change in the level of identification over time, species were grouped into broader taxonomic classes.

99 Bagley, N.W.; O'Driscoll, R.L. (2012). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2009 (TAN0911). *New Zealand Fisheries Assessment Report 2012/05*. 70 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, longnose velvet dogfish, Baxter's dogfish, shovelnose dogfish, and leafscale gulper shark.

b) Methods

- Continue the time series of relative abundance indices for hoki, hake and ling.
- Catch and biomass estimates for most species listed. Length-weight regression parameters and length-frequency distributions for a few species listed.

c) Results and conclusions

- The thirteenth summer trawl survey in the time series.
- Only a small number of dark ghost sharks were caught in the 2009 survey.

- The pale ghost shark biomass estimate had increased to the highest level since the 2006 survey. The length frequency distributions were similar to previous years, the male distribution had a peak between 65 and 70 cm, with a long tail of smaller sharks, the female distribution was similar to males, with a peak from 70–75 cm and a long tail of smaller sharks.
- The spiny dogfish biomass estimate had increased to the highest level since the 2006 survey. The length frequency distributions were similar to previous years, the male distribution peaked at 65 cm, the female distribution was broad from 55 to 95 cm.
- The longnose velvet dogfish biomass estimate had increased to the highest level since the 2006 survey.
- The Baxter's dogfish biomass estimate increased this year.
- The leafscale gulper shark biomass estimate had increased back to 2007 survey levels.
- The shovelnose dogfish biomass estimate increased slightly, to a level similar to the 2006 and 2008 survey levels.

100 Stevens, D.W.; O'Driscoll, R.L.; Dunn, M.R.; Ballara, S.L.; Horn, P.L. (2012). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2011 (TAN1101). *New Zealand Fisheries Assessment Report* 2012/10. 98 p.

a) Species: Dark and pale ghost sharks, spiny dogfish, smooth and rough skate, school shark, and shovelnose dogfish.

b) Methods

- Continue the time series of relative abundance indices of recruited hoki.
- Catch and biomass estimates for all species listed. Length-weight regression parameters and length-frequency distributions for a few species listed.

c) Results and conclusions

- The twentieth trawl survey in the time series.
- The dark ghost shark biomass estimate was the lowest since 2007. The length frequency distribution for female dark ghost sharks showed peak catches from 55–65 cm, the male peak was around 55 cm.
- The pale ghost shark biomass estimate was also the lowest since 2007. Length-frequency distributions were the same as the previous years, female distribution was broad from 25 to 85 cm, the male distribution was bimodal with peaks around 50 and 70 cm.
- The spiny dogfish biomass estimate was the highest since 2007, excluding the artificially high estimate in 2008. Females were in an overwhelming majority. The peak female length-frequency was longer than previous surveys at 60–65 cm, with a solid tail of large sharks.
- The smooth skate biomass estimate was the lowest since 2007, although with a high c.v.
- The rough skate biomass estimate was ten times higher than any other year, with a very high c.v.
- The school shark biomass estimate increased in the last two surveys, 2010 and 2011.
- The shovelnose dogfish biomass estimate decreased in 2011, to a similar level as 2007.

101 Bagley, N.W.; Ballara, S.; O'Driscoll, R.L.; Fu, D.; Lyon, W. (in prep). A review of hoki and middle-depth summer trawl surveys of the Sub-Antarctic, November December 1991–1993 and 2000–2009. *New Zealand Fisheries Assessment Report.*

a) Species: Multiple.

b) Methods

- Review of all 13 sub-Antarctic summer trawl surveys.
- Document trends in biomass (if catch weight for all surveys was over 10 kg), summarise spatial and depth distributions for all species caught, and document trends in size and sex composition that are regularly measured.

c) Results and conclusions

- The survey estimated biomass for pale ghost shark very well. The survey estimated biomass for leafscale gulper shark, longnose velvet dogfish, and smooth and prickly deep-sea skates moderately well. The survey estimated biomass for shovelnose spiny dogfish, Baxter's dogfish, lucifer dogfish, and spiny dogfish well. The survey estimated biomass poorly (c.v. greater than 40%) for prickly dogfish, Portuguese dogfish, little sleeper shark, school shark, dark ghost shark, cat shark, seal shark, Dawson's cat shark, mako shark, Plunket's shark, porbeagle shark, Owston’s dogfish, smooth skate, rough skate, Arctic skate, and longnose deep-sea skate.
- The survey caught but did not estimate biomass for pointynose blue ghost shark, smooth deep-sea skate, prickly deep-sea skate, Richardson's skate, largespine velvet dogfish, and carpet shark.
- For major species, geographic distributions, depth distributions and length-frequency distributions are provided.

d) Study limitations

- Where there has been a change in the level of identification over time, species were grouped into broader taxonomic classes.

3.1.9 Stock assessment and status

102 Dulvy, N.K.; Baum, J.K.; Clarke, S.; Compagno, L.J.V.; Cortes, E.; Domingo, A.; Fordham, S.; Fowler, S.; Francis, M.P.; Gibson, C.; Martinez, J.; Musick, J.A.; Soldo, A.; Stevens, J.D.; Valenti, S. (2008). You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquatic Conservation-Marine and Freshwater Ecosystems 18(5)*: 459–482.

a) Species: Whale, bigeye thresher, thresher, basking, great white, mako, porbeagle, silky, oceanic whitetip and blue sharks; pelagic stingray, manta ray, spinetail devil ray.

b) Methods

- Evaluates the global threatened status of 21 oceanic pelagic sharks and rays that occur in the top 200 m of the ocean.
- Recommendations are made for conservation and management of oceanic pelagic sharks and rays.

c) Results and conclusions

- Eleven oceanic pelagic species were assessed as globally threatened (one Endangered, 10 Vulnerable), five as Near Threatened, two as Least Concern, and the remaining three were Data Deficient.
- These sharks and rays are subject to high and often unrestricted levels of mortality from bycatch and targeted fisheries for their meat and fins.
- Biological parameters and demographic information are listed.

103 Cordue, P.; Starr, P.J. (2008). SPO 3 stock assessment. Report to the Adaptive Management Programme Fishery Assessment Working Group No. AMP-WG-2008/15. 46 p.

a) Species: Rig.

b) Methods

- CPUE abundance indices from a lognormal non-zero model.
- Analyses length frequency data from fishers' logbooks.
- CPUE indices were derived from an earlier period, from the FSU database (1983–1988), and pre-FSU data (1975–1983).

c) Results and conclusions

- The lognormal model based on the set net target shark fishery showed that the fishery had operated at two levels. The fishery in the 1990s operated just above the long-term average, it then dropped to about 70–80% of the long-term average until 2005–06, then an upturn back to the long-term average from 2006–07.
- Different model runs showed a median 10−13% decline/year from 1975 to 1985.
- The stock assessment was inconclusive with regard to stock status. Biomass levels appear to have been stable for the last 15 years and current catches appear sustainable.

d) Study limitations

- Because the model assumed constant recruitment, the historical exploitation rate estimates and the projections need to be interpreted with caution.

104 Tuck, I.; Cole, R.; Devine, J. (2009). Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 42*. 188 p.

a) Species: Numerous species.

b) Methods

- Search literature for potential fish-based ecosystem indicators, then test them on existing New Zealand trawl survey time series (Hauraki Gulf inshore, Chatham Rise middle depths, and the Southland and Sub-Antarctic middle depths series.)

c) Results and conclusions

- Three types of fish-based indicator have been developed for ecosystem-based fisheries management: species-based, size-based, and trophodynamic.
- Species-based measures of diversity appear to be the most useful in identifying changes correlated with fishing intensity.
- Size-based indicators did not appear as useful for New Zealand trawl survey series as they have been overseas.

d) Study limitations

- Taxonomic improvements and possible changes in measurement methods are likely to have introduced a bias into any time series trends in indicators calculated from the raw survey data.

105 White, W.T.; Kyne, P.M. (2010). The status of chondrichthyan conservation in the Indo-Australasian region. *Journal of Fish Biology 76*: 2090–2117.

a) Species: Multiple.

b) Methods

- Review of IUCN threat status of Indo-Australian chondrichthyans, including those in New Zealand.
- Review of conservation measures implemented.

c) Results and conclusions

- In New Zealand, 11% of chondrichthyans are classified as threatened (critically endangered, endangered and vulnerable) and 29% as conservation concern (threatened and near threatened).

- One species (great white shark) is protected.

d) Study limitations

- About 40% of New Zealand species are Data Deficient.
- Data problems include underreporting of by-catch, landings exceeding catch limits under the QMS, mislabelling of product, the illegal take of managed species and a high level of uncertainty surrounding biomass estimates, time series, stock status and ultimately resource sustainability.
- General overview and review, with no species-specific data presented.

3.1.10 Mitigation

106 Jones, E.; Francis, M.P. (2012). Protected rays – occurrence and development of mitigation methods in the New Zealand tuna purse seine fishery. NIWA Client Report Prepared for the Department of Conservation No. WLG2012-49. 35 p.

a) Species: Spinetail devil ray and manta ray.

b) Methods

- Identify methods to mitigate the capture of protected rays in commercial purse seine fisheries.
- Make recommendations for future work to develop and/or assess the importance of methods to mitigate the capture of protected rays.

c) Results and conclusions

- Two protected rays occur in New Zealand waters, the spinetail devil ray and the manta ray. Most captures in New Zealand involve the spinetail devil ray.
- Observer data records suggest a high proportion of rays are lifted from the deck over the side using hooks or ropes passed through gills/pectoral fins.
- It is possible that a proportion of manta rays may suffer post-release mortality as a result of the conditions and injuries sustained during purse seining. The primary recommendation of this study is that there is a need to improve methods for handling and release.
- Handling recommendations listed.

107 Jones, E.; Francis, M.; Paterson, C.; Rush, N.; Morrison, M. (in prep). Habitats of particular significance for fisheries management: identification of threats and stressors to rig nursery areas. *New Zealand Aquatic Environment and Biodiversity Report.*

a) Species: Rig.

b) Methods

- Identify threats to nursery grounds and recommend mitigation measures.
- Identify, and where possible, quantify potential land- and water-based stressors and threats to rig nursery habitats.

c) Results and conclusions

- Rig nurseries with significant levels of either marine and/or land-based anthropogenic stressors are considered potentially vulnerable.
- Use of near-shore nursery areas puts rig in direct contact with human populations. The three main anthropogenic impacts are likely to be habitat degradation and loss, sedimentation and pollution from terrestrial runoff, and direct exploitation via fisheries.
- Metrics are provided with rankings to reflect the level of threat from three main anthropogenic stressors to each nursery habitat.

- Small mesh nets targeting grey mullet or yellow-eyed mullet inside harbours are thought to be the only fisheries that are likely to catch juvenile rig as a bycatch.
- The harbours identified as important rig nursery habitats have all been impacted by anthropogenic activities occurring in the coastal fringe and wider catchment area. These impacts have degraded the water quality, habitat and benthic communities to varying extents. However, juvenile rig appear to be relatively tolerant to these impacts.

d) Study limitations

- A full understanding of how resilient juvenile rig are to anthropogenic impacts requires additional knowledge of how specific habitat utilisation and stressors affect growth and survival.

3.1.11 Summary of research 2008–2012

The 107 studies reviewed here varied greatly in the amount of information provided and analyses conducted. Some studies presented minimal data whereas others were intensive studies (e.g. stock assessment) of individual species. We omitted studies that merely listed a species or provided negligible new information. More than two-thirds (71%) of the 107 identified studies fell into four categories: "Genetics", "Distribution, movements and habitat", "Fisheries, catches, catch per unit effort, and catch composition" and "Trawl survey monitoring" (Table 1). There were few studies covering the other six categories. However, a simple count does not necessarily reflect the relative importance and value of the studies. The two largest categories were broad in scope, which undoubtedly enhanced their numerical importance, while the broadest coverage was achieved by identification guides, a category which only contained four studies.

Table 1: Number of New Zealand chondrichthyan studies from 2008 to 2012, classified by whether they were original or review studies, and by 10 information categories. Review studies are those that do not contain any original data or analyses. The numbers of species included in the studies are also shown. Minor species are not included.

Information category	Number of original studies	Number of review studies	Number of species
Taxonomy	4	0	4
Identification guides	4	0	73
Genetics	11	1	15
Distribution, movements and habitat	21	1	36
Feeding	7	0	19
Age, growth, reproduction and productivity	6	1	9
Fisheries, catches, CPUE, catch composition	29	1	29
Trawl survey monitoring	15	0	33
Stock assessment and status	2	2	14
Mitigation	2	0	3
Total	101	6	83

A full list of the 119 known species of New Zealand chondrichthyans is given in Appendix 1, along with an indication of their occurrence in each of the 10 information categories. Twenty-seven species (nine QMS and 18 non-QMS) occurred in four or more categories. The top six "most-studied" species were rig, leafscale gulper shark, Baxter's dogfish, shovelnose dogfish, porbeagle and school shark. Eighty-three species (70%) occurred in at least one study, although that number dropped to 64 (54%) when those species included only in an identification guide were excluded. Thirty-six species (30%) occurred in none of the studies.

Four new species of chondrichthyans were described (one each of ghost shark, cat shark, lantern shark, and skate). All were deep-living and relatively rare. Four identification guides were published covering 73 species of chondrichthyans (61% of the known fauna). The guides described and illustrated all of the common and many of the rare species which are encountered in fishing operations around New Zealand. Twelve genetic studies addressed questions of species identification, and population structure across varying geographic scales. Genetic divergence was found between populations of species occurring in coastal regions separated by oceanic barriers, such as school shark, bronze whaler shark and short-tailed sting ray, and divergence was also detected in the deeper water leafscale gulper shark. The compilation of genetic data into a DNA barcode database for commercial marine fish species and its potential use to identify fish products has also been described.

A wide range of studies investigated the distribution of species, their movements, and the habitats occupied. Techniques used included tagging (ranging from simple plastic tags to high-tech electronic tags), and trawl, set net and dive surveys. Tagging studies elucidated movement behaviour in a range of different species over various scales. Long distance migrations to tropical waters were undertaken by white, mako and blue sharks. Other species such as the short-tailed stingray, eagle ray and rig were more localised. The chondrichthyan biodiversity of the Norfolk Ridge and Kermadec region have been studied recently, as has the variation in biodiversity of seamount habitats. Reviews of biogeography, life history and fishery data were also undertaken for Antarctic skates, rig, school shark and hammerhead shark.

Six feeding studies have been carried out on a suite of middle depth to deepwater sharks, skates and chimaeras, mainly using stomach content data collected during Chatham Rise trawl surveys. Fish and squid were the primary prey of shark species with chimaeras having a diet dominated by benthic invertebrates and skates also feeding on benthic and natant invertebrates. There was evidence of both depth- and diet-related niche separation. In one study, DNA testing was used to identify stomach contents. The importance of discards in the diet of some sharks and rays was highlighted. In a seventh study, juvenile rig were found to feed mainly on benthic crustaceans such as mud crabs and snapping shrimps in estuaries around New Zealand.

Age and growth studies have been conducted for leafscale gulper shark and shovelnose dogfish from New Zealand waters, indicating that these populations have similar productivity to North Atlantic populations. Biological parameters have been reviewed and updated for Antarctic skates and porbeagle sharks. For the former, alternative ageing methods result in much slower growth rates and greater age at maturity than previously reported. Incubation times and hatching dates were estimated for elephantfish and showed geographic variation in the length of the incubation time.

An international study of the recovery potential of deepwater sharks, skates and chimaeras after fishing included five species that occur in New Zealand waters. It concluded that the rate of population increase for deepwater species was less than half that of shelf and pelagic species.

Thirty studies have carried out fishery characterisations and CPUE analyses, and investigated catch composition and bycatch levels of commercial fisheries. Fisheries with significant chondrichthyan bycatch included surface long lining for tuna (blue porbeagle and mako), demersal long lining for ling (spiny dogfish, smooth and rough skate) and trawl fisheries for arrow squid (spiny dogfish and basking sharks), scampi (ghost sharks), southern blue whiting (porbeagle, pale ghost shark and spiny dogfish), orange roughy, oreo (shovelnose dogfish and lantern sharks) and hoki (multiple species). For some species, such as spiny dogfish and shovelnose dogfish the proportion discarded can be very high (greater than 80%), while other species may be retained either whole or just for fins. Some species, such as school shark, rig and elephantfish, are caught in target fisheries. Characterisation and CPUE analyses were carried out for school shark, rig and pale ghost shark. An Industry survey of relative abundance and catch composition of rig in SPO 7 was conducted over three consecutive years. The Ministry of Fisheries/MPI annual Fishery Assessment Plenary reports (Ministry of Fisheries 2011; Ministry for Primary Industries 2012) provide catch histories, and summaries of productivity, abundance and stock status, for all QMS chondrichthyans.

Time series of trawl surveys have been conducted off east coast South Island, west coast South Island, Chatham Rise, and the Sub-Antarctic at annual or biennial intervals. A total of 13 individual surveys have been reported within the 2008–2012 period. There have also been comprehensive reviews of the Chatham Rise and Sub-Antarctic survey series, resulting in summaries of relative biomass estimates, distribution, and size composition. The reviews of the deepwater surveys identified considerable variation in how well biomass was estimated for different species. Important factors included distribution and abundance within the different regions sampled, aggregative behaviour, and catchability in trawl nets. For example, trawl surveys were not considered effective for estimating rig biomass due to their ability to outswim the trawl.

One full stock assessment was completed for rig in SPO 3. Stock status was assessed using IUCN threatened species criteria for 13 species of pelagic sharks and ray that occur in New Zealand. Ecosystem indicators were reviewed for their utility in assessing New Zealand fish stocks.

Two studies seeking to mitigate the impacts of human activities on bycatch species were carried out. One covered spinetail devil rays and manta rays taken as bycatch in the tuna purse seine fishery, and the other identified threats to rig nursery areas.

3.2 NPOA achievements

The following research and monitoring actions (*in italics*) are specified in Section 4 of the NPOA; actions related to management and compliance have been omitted. Research outputs and outcomes that address these actions are summarised (as bullet points) after each action:

NPOA Section 4.1: *Produce a field identification guide*

- Four field guides have been produced that describe and illustrate 73 species of chondrichthyans (61% of the known fauna). The guides cover all of the common and many of the rare species which are encountered in fishing operations around New Zealand (including the Ross Sea).

NPOA Section 4.2: *Reduce use of generic shark reporting codes*

- The NPOA states that “Introduction of the identification guide discussed above … should decrease the use of the generic codes over time.” Generic codes accounted for 4–5% of the reported commercial catch of chondrichthyans during the five years preceding the publication of the NPOA (Ministry of Fisheries 2008). The main generic code in use during that time was OSD (other sharks and dogfishes). The three guides produced for the identification of chondrichthyans found around New Zealand were published in 2011. [The guide to Antarctic skates was published in 2009 but it does not address the OSD problem as it does not cover sharks and dogfishes.] We do not know whether the guides have been widely distributed through the New Zealand fishing fleet, and in any case, insufficient time has elapsed since their publication for them to have had a significant impact on the use of generic codes. We have not seen a recent analysis of the use of generic codes, so we do not know whether their use has changed since the introduction of the NPOA.

NPOA Section 4.3: *Strengthen existing research and monitoring programmes*

Trends in abundance as estimated from research surveys, observer data, commercial catch and effort, recreational fishing data (including gamefish tagging programmes) and other sources (e.g. tag-recapture data)

- Four series of research trawl surveys to estimate trends in relative abundance have been conducted around South Island, the Chatham Rise, and the Sub-Antarctic. These surveys produced acceptable biomass estimates for some species, but not for others. Biomass estimates of species such as pale and dark ghost shark, spiny dogfish, shovelnose dogfish, longnose velvet dogfish and leafscale gulper sharks were considered reasonable in one or more survey regions. Species that were usually not effectively surveyed include those with patchy distributions, low abundance, low or variable catchability, and low selectivity.
- Acoustic surveys have not yet been used to monitor chondrichthyan biomass. Although sharks lack swim bladders, their liver oil is a different density to that of seawater and so deepwater sharks produce weak echoes. However, the low population density of deepwater sharks means they are difficult to monitor acoustically.
- Observer data have been used to produce unstandardised catch rates for blue, porbeagle and mako sharks in tuna longline fisheries. However these are not believed to index abundance because the New Zealand fishery exploits only a small part of the range of these highly

migratory species, and observer coverage in the domestic fishery is too low to be representative of the catch.

- Commercial catch and effort data have been modelled to generate standardised annual CPUE indices. These indices are thought to index abundance for some stocks and species, and have been produced for all school shark stocks, most rig stocks, the two main elephantfish stocks, the two main pale ghost shark stocks, and spiny dogfish in SPD 3 and SPD 5.
- Recreational fishing data have not been used to monitor abundance in chondrichthyans and are probably not suitable for that purpose given the relatively small recreational catches and their likely non-representative nature.
- Tagging data have not been used to monitor abundance in chondrichthyans.

Trends in catches, e.g. are catch limits being regularly exceeded or substantially undercaught

- Trends in catches and comparisons between catches and Total Allowable Commercial Catches have been published annually for QMS species in the MFish/MPI Fishery Assessment Plenary reports (Ministry of Fisheries 2011; Ministry for Primary Industries 2012). Trends have not generally been published for non-QMS species. However, catches in the Kermadec FMA have been reported for both QMS and non-QMS species. Discard quantities and rates of deepwater chondrichthyans from a range of fisheries in various parts of the EEZ (mainly south of Cook Strait) have been estimated in a series of bycatch reports. There is also a compilation of non-QMS catch histories in some Marine Stewardship Council certification documentation (not reviewed in this report).

Trends in the sizes and maturity stages of sharks taken based on observer data

- Trends in the size composition of blue, porbeagle and mako sharks in tuna longline fisheries based on observer data have been published regularly. Maturity data are currently being collected for the same species but trends have not been analysed.
- Trends in the size composition of spiny dogfish in SPD 5 have been analysed, as have trends in pale ghost shark stocks.
- Trends in the size composition of Antarctic skates in the Ross Sea have been analysed.

Characterisation of the nature of shark catches in various fisheries, e.g. target versus bycatch, to assess risks to shark populations

- Commercial fishery characterisations have been carried out for the main stocks of some target species (rig, school shark), and some bycatch species (spiny dogfish, blue shark, porbeagle shark, mako shark, Antarctic starry skate, Antarctic allometric skate, pale ghost shark).

Stock assessments will be undertaken for those species for which sufficient data exist

- One quantitative chondrichthyan stock assessment (for rig in SPO 7) has been produced.
- Although not generally considered as stock assessments in the New Zealand context, global population status has been determined using IUCN threat categories for 13 pelagic sharks and rays occurring in New Zealand waters. Eight were assessed as globally threatened (Vulnerable), four as Near Threatened, and one as Least Concern.

Biological studies to obtain or refine estimates of the productivity of shark populations

- Biological parameters and demographic information have been summarised for 13 pelagic sharks and rays occurring in New Zealand waters.
- Biological parameters have been updated and summarised for Antarctic starry skate, Antarctic allometric skate, pale ghost shark, and five deepwater shark species (leafscale gulper shark, shovelnose dogfish, Baxter’s dogfish, longnose velvet dogfish, Plunket’s shark). The productivity of the five deepwater sharks was also estimated.
- Age, growth, longevity and maturity have been estimated for shovelnose dogfish and leafscale gulper shark.
- Incubation periods and hatching dates have been estimated for elephantfish.

Analysis of observer and fisher collected data on the fate of sharks (e.g. retained versus discarded)

- Analyses of discarded catch have been conducted for blue, porbeagle, mako and school sharks in tuna longline fisheries; and for spiny dogfish, deepwater sharks, skates and chimaeras in middle depth and deepwater trawl fisheries and middle depth longline fisheries.

Analysis of the effectiveness of Sixth Schedule provisions for shark species

- Data have been collected by observers aboard surface longline vessels on the life status of discarded blue, porbeagle and mako sharks, but no reports analysing the data during the review period were found.
- Data have been collected on the life status of discarded spiny dogfish using destination codes X (alive) and M (dead), but no reports analysing the data during the review period were found.

Review of conversion factors used to convert processed weight to green weight

- A wet fin conversion factor was calculated for blue shark from observer data. Shark fin data are currently being collected from blue, porbeagle and mako sharks for future calculation and refinement of conversion factors.
- Conversion factor data were collected for school shark and ghost shark and presented to the Conversion Factors Working Group, but have not been written up and are not available in report form.

Monitor the use of processed states over time to determine trends in utilisation

- Processed states have been summarised for tuna longline, purse seine and some small trawl fisheries but no reports analysing the data during the review period were found.

Analysis of diet data

- Diet studies have been carried out on a suite of 18 middle depth to deepwater sharks, skates and chimaeras on the Chatham Rise, Wairarapa Coast and Puysegur region. The diet of juvenile rig in estuaries was also described.

Identification of areas of habitat of particular significance to shark species (e.g. spawning, pupping and nursery grounds)

- Estuaries and harbours were surveyed throughout New Zealand and juvenile rig nursery grounds were identified.
- The Poor Knights Islands Marine Reserve was identified as a mating and nursery area for short-tailed stingrays.

Effects of fishing research programmes

- Although no specific ‘effects of fishing’ studies have been directed at chondrichthyans, many studies listed elsewhere have contributed to our knowledge in this area. These include studies on diet, bycatch quantities and handling, and discard rates. Studies on biological productivity of chondrichthyans also contribute to our knowledge of the vulnerability of these species to fishing.
- Studies were conducted on the factors affecting the bycatch of basking sharks in trawl fisheries, and the mitigation of spinetail devilray bycatch in purse seine fisheries.

3.3 NPOA research gaps and recommendations

Research and monitoring actions specified in the NPOA that were not completely addressed are summarised below, and recommendations are made for additional research during the next five years to fill these gaps.

NPOA Section 4.1: *Produce a field identification guide*

Identification guides are now available that cover 61% of New Zealand's chondrichthyans. It would be desirable to extend the coverage to the remaining species. This would assist observers, research staff and fishers to collect data on the biology, distribution and abundance of rare species, some of which are endemic to New Zealand. These species are not important in terms of catch quantity, but if their occasional capture as bycatch is significant in relation to their population size or biological productivity, it may lead to population decline.

NPOA Section 4.2: *Reduce use of generic shark reporting codes*

Now that good identification guides are available for all of the common and many of the rare chondrichthyans, fishers have the information required to accurately identify most of their catch. MPI should ensure that the identification guides are distributed widely to the fishing industry, including in electronic form as many larger vessels have computers on board. The main users of generic codes should be identified and special effort should be made to encourage the skippers and crew of these vessels to record their catch to species level. It should be made clear that generic codes are a last resort. MPI should regularly monitor and discourage the use of generic codes during the term of the next NPOA.

NPOA Section 4.3: *Strengthen existing research and monitoring programmes*

The four trawl survey series underway around southern New Zealand should be maintained as they are an important and often the only monitoring tool for many demersal chondrichthyans, particularly deepwater sharks, skates and chimaeras. There are no analogous trawl surveys operating around the North Island which leaves a huge gap in our knowledge of the chondrichthyan populations there. Some QMS species (spiny dogfish, rough and smooth skates, dark and pale ghost sharks) and non-QMS bycatch species (northern spiny dogfish, stingrays, eagle rays, carpet sharks, and deepwater sharks, skates, and chimaeras) are not currently being monitored around the North Island. Consideration should be given to reinstating North Island trawl surveys on a periodic basis, e.g. two consecutive annual surveys every 5–8 years to provide occasional relative biomass estimates. There is a good historical time series of *Kaharoa* inshore surveys, and a series of deepwater surveys by *Wanaka* in 1985–86, to provide a temporal comparison. The *Wanaka* surveys identified major spatial variability in the size and sex composition of deepwater sharks, especially shovelnose dogfish, indicating that some population components (e.g. mature females) are geographically constrained and may be vulnerable to intensive localised fishing. Reinstating periodic North Island surveys will also have benefits for monitoring many teleost fishes. Baited and unbaited camera survey methods have proven useful elsewhere, and have been trialled in New Zealand. They should be considered as a tool for surveying some shark species in future.

Standardised CPUE analyses are routinely conducted for the main stocks of rig, school shark and elephantfish and we anticipate that they will continue at regular intervals of several years. The first CPUE analysis for pale ghost shark has recently been conducted and a similar analysis for dark ghost shark is anticipated in 2013. CPUE analyses for these ghost sharks should also be conducted at regular intervals. CPUE analyses are regarded as important for some spiny dogfish stocks (see Plenary Report) but have not been updated since 2005–06, and the results of that study (Manning et al. 2009) have not been incorporated into the Plenary Report. As data quality improves, including better recording of discards, CPUE analyses for spiny dogfish should provide better indices of relative abundance. The same may apply to deepwater sharks as species identification improves and the use of generic codes declines. Many other stocks and species may be suitable candidates for standardised CPUE analyses. We recommend that a review of major catch and bycatch species be undertaken to determine which additional species are amenable to CPUE analysis, and that analyses be completed for those species.

Only one quantitative stock assessment was carried out for a chondrichthyan species during the term of the NPOA, and this is clearly a gap that needs to be addressed. However, stock assessments are complex, expensive, and dependent on the availability of specific input data. Some chondrichthyan species, and many stocks, will never be suitable candidates for assessment. Conversely, stock assessment is an achievable goal for major stocks of some species, provided that suitable input data are collected, collated and analysed. A review should be conducted to determine which species and stocks are (a) amenable to quantitative assessment at present, and (b) potentially amenable to quantitative assessment in the next 3–5 years as improved input data become available. Species and stocks that are not suitable or have low priority should be risk assessed using currently available information on their productivity and vulnerability; potential assessment methods include intrinsic rebound potential, used by Simpfendorfer & Kyne (2009) to assess vulnerability of a range of deepwater sharks and rays, and Productivity Susceptibility Analysis which has been used by NOAA to assess a number of shark and skate species.

Stock assessments require a relative abundance index (absolute abundance estimates are difficult or impossible to obtain for most chondrichthyans) such as a CPUE index or trawl survey biomass index (see above for recommendations on these). Other required input data include catch histories, catch composition, and biological parameters such as growth, natural mortality and fecundity rates. These data are available for some species, and are being collected for others. Examples of the latter include vertebrae and fin spines being collected by trawl surveys and observers from blue, porbeagle and mako sharks, rig, spiny dogfish, dark ghost shark and elephantfish, and stored for later age estimation. However, the quantities collected so far are small and not representative of the fisheries. A major issue is the low and unrepresentative observer coverage in many fisheries, and the low priority given to data and sample collection from chondrichthyan bycatch species. A target set of species and fisheries needs to be established for implementing intensive data collection in preparation for future stock assessments. Maturity and reproductive stage data are now being routinely collected from deepwater sharks and chimaeras on research trawl surveys. To date, these data have been used to assess the productivity of two species (shovelnose and leafscale gulper sharks), but continued data collection across all species should provide valuable information. Given the relatively limited extent of geographic and temporal coverage from trawl surveys, data collection should, if feasible, be extended to observers on commercial vessels. However, effective training of observers is required to ensure the quality of data collected. Furthermore, ageing techniques are not available for many deepwater species, and none of the existing ageing techniques has been validated. A research plan to develop, and validate where possible, ageing techniques for a range of species should be drawn up and implemented. This process should involve international collaborations to ensure that ageing techniques are consistent globally for widespread species.

Catch histories back to 1931 are being developed for inshore chondrichthyans (mainly rig, school shark, spiny dogfish, northern spiny dogfish, rough and smooth skate, and elephantfish) under a current MPI research project (SEA2012-10). Unfortunately several small sharks were historically lumped under generic species names, and catches are known to have been under-reported prior to 1986. Hence the catch histories will be approximate only. Attempts should also be made to develop catch histories for deepwater species for which adequate records exist, although unreported discards will be problematic.

Data are being collected by observers on the life status and discards of pelagic sharks and chondrichthyans taken as bycatch in deepwater fisheries. The data should be collated and summarised to estimate minimum mortality rates of discarded fish (maximum mortality rates cannot be estimated without a tagging programme to determine how many live releases subsequently die). Sixth Schedule species should form a major part of the study in order to review the effectiveness of that management tool.

Data being collected by observers on processed states of chondrichthyans should be analysed to monitor trends in species utilisation. Concurrently, any information suitable for conversion factor estimation should be analysed. Priority should be given to providing observers on tuna longline vessels with motion-compensated electronic scales in order to estimate shark fin (and other processed state) conversion factors for individual sharks; currently we have negligible data on how these conversion factors vary with size, sex and individual vessel processing method. Observers have been collecting fin weight data using spring balances, but because of the inaccuracy of these balances in anything other than a calm sea, the data are only useful when aggregated across multiple sharks.

Information on habitats of significance to chondrichthyan species is variable. The existence and location of mating aggregation and nursery areas are unknown for many species. Rig, school shark and elephant fish use shallow coastal waters for nurseries and are therefore likely to be vulnerable to multiple human impacts. A recent survey identified important rig nursery habitats and the relative vulnerability to anthropogenic impacts. The distribution of nursery grounds for school shark and elephantfish should be surveyed and defined, and attempts made to assess and mitigate human impacts on them. The potential importance of the Poor Knights Islands Marine Reserve as a mating and nursery area has been highlighted for short-tailed sting rays, and other nursery grounds may also exist in shallow coastal waters for this and other species such as eagle rays and rough skate. Research and observer data on deepwater sharks, skates and chimaeras should also be analysed to identify locations supporting significant numbers of egg cases, juveniles or reproductively active females with a view to reducing fishing mortality on these vulnerable life history stages.

The very useful series of diet studies carried out for chondrichthyans on the Chatham Rise has provided important new information on diet and how that varies with size and season, and the trophic interactions of chondrichthyans with their prey and predators. Such studies need to be expanded to a wider range of species (particularly inshore species) and locations (particularly west coast South Island and North Island). Spatial variation in diet is likely so Chatham Rise results will not be representative of diets elsewhere.

The effects of fishing on small, rare and uncommon chondrichthyans should be examined carefully as these species may be highly vulnerable and may be heavily impacted without anyone noticing. Some species are endemic and warrant particular attention.

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6. APPENDIX 1.

List of the 119 known species of New Zealand chondrichthyans, along with an indication of their coverage in each of 10 information categories. The last column gives the number of categories in which each species falls, in descending order.

Family	Species	Common name	Taxon-omy	ID guides	Genetics	Distrib, mvmt, habitat	Feeding	Age, growth, reprod.	Fisheries catches, CPUE	Trawl surveys	Stock assess	Mitiga-tion	Number of categories
Triakidae	*Mustelus lenticulatus* Phillipps, 1932	Rig		+	+	+	+		+	+	+	+	8
Centrophoridae	*Centrophorus squamosus* (Bonnaterre, 1788)	Leafscale gulper shark		+	+	+	+	+	+	+			7
Etmopteridae	*Etmopterus granulosus* (Günther, 1880)	Baxter's dogfish		+	+	+	+	+	+	+			7
Centrophoridae	*Deania calcea* (Lowe, 1839)	Shovelnose dogfish		+		+	+	+	+	+			6
Lamnidae	*Lamna nasus* (Bonnaterre, 1788)	Porbeagle		+		+		+	+	+	+		6
Triakidae	*Galeorhinus galeus* (Linnaeus, 1758)	School shark, tope		+	+	+	+		+	+			6
Chimaeridae	*Hydrolagus bemisi* Didier, 2002	Pale ghost shark		+	+		+		+	+			5
Chimaeridae	*Hydrolagus novaezealandiae* (Fowler, 1910)	Dark ghost shark		+	+		+		+	+			5
Squalidae	*Squalus griffini* Phillipps, 1931	Northern spiny dogfish		+		+	+		+	+			5
Etmopteridae	*Etmopterus lucifer* Jordan & Snyder, 1902	Lucifer dogfish		+		+	+		+	+			5
Somniosidae	*Centroscymnus owstoni* Garman, 1906	Owston's dogfish		+		+	+		+	+			5
Somniosidae	*Centroselachus crepidater* (Bocage & Capello, 1864)	Longnose velvet dogfish		+			+	+	+	+			5
Somniosidae	*Proscymnodon plunketi* (Waite, 1909)	Plunket's shark		+		+	+	+		+			5
Dalatiidae	*Dalatias licha* (Bonnaterre, 1788)	Seal shark, black shark		+		+	+		+	+			5
Arhynchobatidae	*Bathyraja cf eatonii*	Antarctic allometric skate		+	+	+		+	+				5
Rajidae	*Amblyraja georgiana* (Norman 1938)	Antarctic starry skate		+	+	+		+	+				5
Lamnidae	*Isurus oxyrinchus* Rafinesque, 1810	Mako, shortfin mako		+		+			+	+	+		5
Chimaeridae	*Hydrolagus homonycteris* Didier 2008	Black ghost shark	+	+	+	+							4
Squalidae	*Squalus acanthias* Linnaeus, 1758	Spiny dogfish		+			+		+	+			4
Rajidae	*Dipturus innominatus* (Garrick & Paul, 1974)	Smooth skate		+			+		+	+			4
Mobulidae	*Manta birostris* (Donndorff, 1798)	Manta ray		+		+					+	+	4
Mobulidae	*Mobula japanica* (Müller & Henle, 1841)	Spinetail devil ray		+		+					+	+	4
Alopiidae	*Alopias vulpinus* (Bonnaterre, 1788)	Thresher shark		+		+			+		+		4
Cetorhinidae	*Cetorhinus maximus* (Gunnerus, 1765)	Basking shark		+		+			+		+		4
Scyliorhinidae	*Cephaloscyllium isabellum* (Bonnaterre, 1788)	Carpet shark		+			+		+	+			4
Carcharhinidae	*Carcharhinus brachyurus* (Günther, 1870)	Bronze whaler		+	+	+			+				4
Carcharhinidae	*Prionace glauca* (Linnaeus, 1758)	Blue shark		+		+			+		+		4
Callorhinchidae	*Callorhinchus milii* Bory de St Vincent, 1823	Elephantfish		+				+	+				3
Rhinochimaeridae	*Harriotta raleighana* Goode & Bean, 1895	Longnose spookfish		+			+			+			3
Chimaeridae	*Chimaera lignaria* Didier, 2002	Purple chimaera, giant chimaera		+	+	+							3
Hexanchidae	*Heptranchias perlo* (Bonnaterre, 1788)	Sharpnose sevengill shark		+					+	+			3
Somniosidae	*Centroscymnus coelolepis* Bocage & Capello, 1864	Portuguese dogfish		+		+				+			3
Oxynotidae	*Oxynotus bruniensis* (Ogilby, 1893)	Prickly dogfish		+			+			+			3
Rajidae	*Zearaja nasuta* (Banks in Müller & Henle, 1841)	Rough skate		+					+	+			3
Dasyatidae	*Dasyatis brevicaudata* (Hutton, 1875)	Shorttail stingray		+	+	+							3
Dasyatidae	*Pteroplatytrygon violacea* (Bonaparte, 1832)	Pelagic stingray		+					+		+		3
Rhincodontidae	*Rhincodon typus* (Smith, 1828)	Whale shark		+		+					+		3
Lamnidae	*Carcharodon carcharias* (Linnaeus, 1758)	Great white shark		+		+					+		3
Scyliorhinidae	*Bythaelurus dawsoni* (Springer, 1971)	Dawson's cat shark		+			+			+			3
Pseudotriakidae	*Gollum attenuatus* (Garrick, 1954)	Slender smooth hound		+		+			+				3
Carcharhinidae	*Carcharhinus longimanus* (Poey, 1861)	Oceanic whitetip shark		+		+					+		3

APPENDIX 1 (cont.)

Family	Species	Common name	Taxon-omy	ID guides	Genetics	Distrib, mvmt, habitat	Feeding	Age, growth, reprod.	Fisheries catches, CPUE	Trawl surveys	Stock assess	Mitiga-tion	Number of categories
Chimaeridae	*Chimaera* sp.	Brown chimaera		+	+								2
Chimaeridae	*Hydrolagus trolli* Didier and Seret, 2002	Pointynose blue ghost shark		+	+								2
Chlamydoselachidae	*Chlamydoselachus anguineus* Garman, 1884	Frill shark		+						+			2
Hexanchidae	*Hexanchus griseus* (Bonnaterre, 1788)	Sixgill shark		+						+			2
Torpedinidae	*Torpedo fairchildi* Hutton, 1872	Electric ray		+						+			2
Arhynchobatidae	*Bathyraja shuntovi* Dolganov, 1985	Longnose deepsea skate		+						+			2
Arhynchobatidae	*Brochiraja asperula* (Garrick & Paul, 1974)	Smooth deepsea skate		+						+			2
Arhynchobatidae	*Brochiraja spinifera* (Garrick & Paul, 1974)	Prickly deepsea skate		+						+			2
Rajidae	*Amblyraja ?hyperborea* (Collette, 1879)	Arctic skate		+						+			2
Myliobatidae	*Myliobatis tenuicaudatus* Hector, 1877	Eagle ray		+		+							2
Odontaspidae	*Odontaspis ferox* (Risso, 1810)	Smalltooth sand tiger shark		+		+							2
Alopiidae	*Alopias superciliosus* (Lowe, 1839)	Bigeye thresher		+							+		2
Scyliorhinidae	*Apristurus* sp.	Cat shark		+						+			2
Triakidae	*Mustelus* sp.	Kermadec rig			+	+							2
Carcharhinidae	*Carcharhinus galapagensis* (Snodgrass & Heller, 1905)	Galapagos shark				+			+				2
Sphyrnidae	*Sphyrna zygaena* (Linnaeus, 1758)	Hammerhead shark		+		+							2
Rhinochimaeridae	*Harriotta haeckeli* Karrer, 1972	Smallspine spookfish		+									1
Rhinochimaeridae	*Rhinochimaera pacifica* (Mitsukuri, 1895)	Pacific spookfish		+									1
Chimaeridae	*Chimaera panthera* Didier, 1998	Leopard chimaera		+									1
Hexanchidae	*Notorynchus cepedianus* (Peron, 1807)	Broadnose sevengill shark		+									1
Squalidae	*Cirrhigaleus australis* White, Last & Stevens, 2007	Southern mandarin dogfish		+									1
Squalidae	*Squalus raoulensis* Duffy & Last, 2007	Kermadec spiny dogfish				+							1
Centrophoridae	*Centrophorus harrissoni* McCulloch, 1915	Harrison's dogfish				+							1
Etmopteridae	*Etmopterus molleri* (Whitley, 1939)	Moller’s lantern shark		+									1
Etmopteridae	*Etmopterus pusillus* (Lowe, 1839)	Smooth lantern shark		+									1
Etmopteridae	*Etmopterus viator* Straube 2012	Blue-eye lantern shark	+										1
Somniosidae	*Somniosus antarcticus* Whitley, 1939	Southern sleeper shark		+									1
Somniosidae	*Somniosus longus* (Tanaka, 1912)	Little sleeper shark								+			1
Somniosidae	*Zameus squamulosus* (Günther, 1877)	Velvet dogfish		+									1
Dalatiidae	*Isistius brasiliensis* (Quoy & Gaimard, 1824)	Cookie cutter shark		+									1
Narkidae	*Typhlonarke aysoni* (Hamilton, 1902)	Blind electric ray		+									1
Narkidae	*Typhlonarke tarakea* Phillipps, 1929	Oval electric ray		+									1
Arhynchobatidae	*Arhynchobatis asperrimus* Waite, 1909	Longtail skate		+									1
Arhynchobatidae	*Bathyraja maccaini* Springer 1971	MacCain's skate		+									1
Arhynchobatidae	*Bathyraja* sp.	Antarctic dwarf skate		+									1
Arhynchobatidae	*Notoraja sapphira* Seret & Last 2009	Sapphire skate	+										1
Dasyatidae	*Dasyatis thetidis* Ogilby in Waite, 1899	Longtail stingray		+									1
Mitsukurinidae	*Mitsukurina owstoni* Jordan, 1898	Goblin shark		+									1
Scyliorhinidae	*Apristurus ampliceps* Sasahara, Sato & Nakaya 2008	Roughskin cat shark	+										1
Scyliorhinidae	*Parmaturus macmillani* Hardy, 1985	McMillan’s cat shark		+									1
Carcharhinidae	*Carcharhinus falciformis* (Bibron in Muller & Henle, 1839)	Silky shark									+		1
Carcharhinidae	*Galeocerdo cuvier* (Peron & Le Sueur, 1822)	Tiger shark				+							1

APPENDIX 1 (cont.)

Family	Species	Common name	Taxon-omy	ID guides	Genetics	Distrib, mvmt, habitat	Feeding	Age, growth, reprod.	Fisheries catches, CPUE	Trawl surveys	Stock assess	Mitiga-tion	Number of categories
Chimaeridae	*Hydrolagus* sp. D [Didier]	Giant black ghost shark											0
Echinorhinidae	*Echinorhinus brucus* (Bonnaterre, 1788)	Bramble shark											0
Echinorhinidae	*Echinorhinus cookei* Pietschmann, 1928	Prickly shark											0
Squalidae	*Squalus* sp. 5	Green-eye dogfish											0
Centrophoridae	*Deania histricosum* (Garman, 1906)	Rough longnose dogfish											0
Centrophoridae	*Deania quadrispinosum* (McCulloch, 1915)	Longsnout dogfish											0
Etmopteridae	*Centroscyllium* sp. cf *kamoharai*	Fragile dogfish											0
Etmopteridae	*Etmopterus* cf. *unicolor*	Bristled lantern shark											0
Somniosidae	*Scymnodalatias albicauda* Taniuchi & Garrick, 1986	Whitetail dogfish											0
Somniosidae	*Scymnodalatias sherwoodi* (Archey, 1921)	Sherwood's dogfish											0
Somniosidae	*Scymnodon* cf. *ringens* Bocage & Capello, 1864	Knifetooth dogfish											0
Dalatiidae	*Euprotomicrus bispinatus* (Quoy & Gaimard, 1824)	Pygmy shark											0
Arhynchobatidae	*Bathyraja richardsoni* (Garrick, 1961)	Richardson's skate											0
Arhynchobatidae	*Bathyraja* sp.	Blonde skate											0
Arhynchobatidae	*Brochiraja albilabiata* Last & McEachran, 2006												0
Arhynchobatidae	*Brochiraja leviveneta* Last & McEachran, 2006												0
Arhynchobatidae	*Brochiraja microspinifera* Last & McEachran, 2006												0
Arhynchobatidae	*Notoraja* [subgenus C] sp. A [Last & McEachran]												0
Arhynchobatidae	*Notoraja* [subgenus C] sp. B [Last & McEachran]												0
Arhynchobatidae	*Notoraja* [subgenus C] sp. C [Last & McEachran]												0
Arhynchobatidae	*Notoraja* [subgenus D] sp. A [Last & McEachran]												0
Heterodontidae	*Heterodontus portusjacksoni* (Meyer, 1793)	Port Jackson shark											0
Pseudocarchariidae	*Pseudocarcharias kamoharai* (Matsubara, 1936)	Crocodile shark.											0
Scyliorhinidae	*Apristurus* cf *australis* Sato, Nakaya & Yorozu 2008	Pinocchio cat shark											0
Scyliorhinidae	*Apristurus exsanguis* Sato, Nakaya and Stewart 1999	Pale catshark											0
Scyliorhinidae	*Apristurus melanoasper* Iglésias, Nakaya & Stehmann 2004	Fleshynose cat shark											0
Scyliorhinidae	*Apristurus pinguis* Deng, Xiong & Zhan 1983	Cat shark											0
Scyliorhinidae	*Apristurus sinensis* Chu & Hu 1981	Freckled cat shark											0
Scyliorhinidae	*Cephaloscyllium* sp.												0
Scyliorhinidae	*Parmaturus bigus* Seret & Last, 2007	Shorttail cat shark											0
Scyliorhinidae	*Parmaturus* sp.												0
Scyliorhinidae	*Parmaturus* sp.												0
Pseudotriakidae	*Pseudotriakis microdon* Capello, 1868	False cat shark											0
Carcharhinidae	*Carcharhinus amblyrhynchos* (Bleeker, 1856)	Grey reef shark											0
Carcharhinidae	*Carcharhinus obscurus* (Le Sueur, 1818)	Dusky shark											0
Carcharhinidae	*Carcharhinus plumbeus* (Nardo, 1827)	Sandbar shark											0
Total	119		4	73	15	36	19	9	29	33	14	3	