Ministry for Primary Industries
Manatū Ahu Matua

Fisheries Assessment Plenary

May 2014 – Supplement

A Celebration of 30+ Years of Fisheries Science

Edited by Pamela Mace and Marianne Vignaux

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1. Introduction

The publication of the latest Fisheries Assessment Plenary report in May 2014 represents the 30th consecutive year that such reports have been produced. In recognition of this milestone, we have produced a Supplement to the Plenary to celebrate 30+ years of fisheries science. The Supplement acknowledges the scientists and other players who have made it all happen and also contains a number of short articles ranging over a variety of topics that we hope will be of general interest.

Also, instead of the usual fish photo we've been putting on the cover of the Plenary reports for the last few years, we've created a cover composed of thumbnail photographs of many of the people who have made significant contributions to our Science Working Group and Plenary processes over the years. This was a lot harder to do than expected, as we needed to track down some of the early players, and even those who are currently active in the field often proved to be elusive as they were away for extended periods of time at sea or overseas or otherwise unavailable.

To everyone who should have been acknowledged but hasn't been, either with photos and short biographies, or at least in a list of other significant contributors (see Section 10), we sincerely apologise sincerely for leaving you out. 30 years is a long period of time to cover and in our brainstorming sessions about who should be included, those of us who've been in this field for a long time had to truly stretch our memory cells.

The purpose of this Supplement to the 30th Fisheries Assessment Plenary is both to celebrate the science and the scientists and to inform interested parties, including the public, about the wide diversity of activities and research we undertake. The articles in the rest of this volume vary in the level of technical detail, but many require little or no technical expertise to be appreciated.

The rest of this volume is divided into nine further sections, with Section 2 acknowledging the current contributors, Sections 3–9 each containing 1–9 authored articles and Section 10 celebrating the people who made it all happen.

2. **The Current Contributors**: the current MPI fisheries science group and Science Working Group members.

3. **Then and Now**: how things were 30 or so years ago and how they've changed and evolved since.

4. **Recent Innovations**: a sample of recent innovations that have had a positive impact on the future direction of fisheries research and science.

5. **The Diversity of Research Areas**: nine articles illustrating the broad range of research fields and endeavours.

6. **Some Cool Fisheries Research**: examples of some of the interesting work that fisheries science involves.

7. **How the Science is Used by Fisheries Managers**: the context for fisheries management in New Zealand and examples of how the science is used by fisheries managers.

8. **How Well Are We Doing**: evaluations of aspects of our processes and fisheries performance, including an interim update of the status of our fish stocks.

9. **The Challenges Still Ahead**: a short summary of challenges for the future.

10. **The People Who Have Made it All Happen**: interviews with some of the scientists who were there at or near the beginning; thumbnail photographs and short biographies that we received for people who have made a substantial contribution to our Science Working Group and Plenary processes over the years; a list of others who have also made a substantial contribution, but who we were unable to make contact with; and a list of MPI and former Ministry of Fisheries Science Officers, who have had the unenviable job of undertaking the nitty-gritty of putting each Plenary report together.

We would like to recognise and thank everyone who has been involved in this important endeavour including scientists and other technical and non-technical experts from research organisations, academia, the seafood industry, marine amateur fisheries, environmental NGOs, the Maori customary sector and the Ministry for Primary Industries and its predecessors, for their substantial contributions over the years.

Our thanks to each and all who have contributed to this special celebratory supplement, and especially to Rosemary Hurst, Adele Dutilloy and Adam van Opzeeland for the extra effort they put into tracking down and compiling the thumbnail photographs and short biographies of as many as possible of the scientists and other players who have made significant contributions over the years.

Pamela Mace and Marianne Vignaux
Ministry for Primary Industries


Common Acronyms

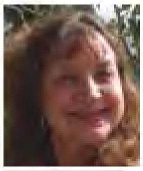
EEZ – Exclusive Economic Zone
FMA – Fishery Management Area
HMS – Highly Migratory Species
HSS – Harvest Strategy Standard
ITQ – Individual Transferable Quota
MAF – Ministry of Agriculture and Fisheries
MFish – Ministry of Fisheries
MPI – Ministry for Primary Industries
MSC –Marine Stewardship Council
MSY – Maximum Sustainable Yield
NIWA – National Institute of Water and Atmospheric Research
QMA – Quota Management Area
QMS –Quota Management System
RFMO – Regional Fisheries Management Organisation
TAC – Total Allowable Catch
TACC – Total Allowable Commercial Catch

2. The Current Contributors

The MPI fisheries science group has a number of diverse roles that include convening and chairing our Science Working Groups, peer-reviewing all research reports, and compiling the annual Fisheries Assessment Plenary reports and the Aquatic Environment and Biodiversity Annual Reviews. We are a small group of scientists (see the following two pages), but we're supported by a much larger number of research providers and other technical and non-technical experts who currently participate in our Science Working Groups (see next page). There are also many others who work behind the scenes staffing the research surveys, conducting other fieldwork, collecting data as fisheries observers, managing the data, and being involved in other support activities that are critical to our mission.

MPI's fisheries science group

Kevin Sullivan: Manager, Fisheries Stock Assessment Science



Pamela Mace: Principal Advisor, Fisheries Science

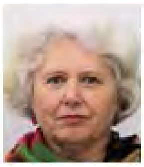
Martin Cryer: Manager, Aquatic Environment Science

Geoff Tingley: Principal Scientist, Fisheries Stock Assessment

John Annala: Principal Scientist, Fisheries Stock Assessment

Julie Hills: Principal Scientist, Aquatic Environment

Marc Griffiths: Principal Scientist, Fisheries Stock Assessment



Mary Livingston: Principal Scientist, Aquatic Environment

Nathan Walker: Principal Scientist, Aquatic Environment

Neville Smith: Principal Scientist, Fisheries Stock Assessment

Rich Ford: Principal Scientist, Aquatic Environment

Rohan Curry: Senior Scientist, Aquatic Environment

Marianne Vignaux: Contractor

Adele Dutilloy: Science Officer

Adam van Opzeeland: Graduate Development Programme – on rotational assignment

Science Working Groups: Membership 2013–14

Deepwater Working Group
Convenor: Geoff Tingley
Members: Owen Anderson, Neil Bagley, Sira Ballara, Michael Batson, Tiffany Bock, Dave Boyer, Malcolm Clark, George Clement, Patrick Cordue, Paul Crozier, Ian Doonan, Adam Dunford, Alistair Dunn, Matt Dunn, Adele Dutilloy, Jack Fenaughty, Dan Fu, Vivian Haist, Jeremy Helson, Ray Hilborn, Peter Horn, Rosie Hurst, Aaron Irving, Rudy Kloser, Yoann Ladroit, Kath Large, Pamela Mace, Dan MacGibbon, Andy McKenzie, Peter McMillan, David Middleton, Richard O'Driscoll, Graham Patchell, Vicky Reeve, Marie-Julie Roux, Tim Ryan, Andy Smith, Paul Starr, Darren Stevens, Dorje Strang, Kevin Sullivan, Rob Tilney, Richard Wells.

Middle Depth Working Group
Convenor: Kevin Sullivan
Members: William Arlidge, Suze Baird, Sira Ballara, Nokome Bentley, Michelle Beritzhoff, Tiffany Bock, Paul Breen, George Clement, Patrick Cordue, Alistair Dunn, Matt Dunn, Charles Edwards, Jack Fenaughty, David Foster, Dan Fu, Peter Horn, Charles Hufflett, Rosie Hurst, Yoann Ladroit, Pamela Mace, Vidette McGregor, Dan MacGibbon, David Middleton, Philipp Neubauer, Richard O'Driscoll, Vicky Reeve, Graham Patchell, Paul Starr, Geoff Tingley, Richard Wells.

Northern and Southern Inshore Working Group
Convenors: Marc Griffiths (Northern), Marc Griffiths and Stephen Brouwer (Southern)
Members: Helena Armiger, Mike Beentjes, Nokome Bentley, Richard Bian, Tania Cameron, Glen Carbines, Patrick Cordue, Ian Doonan, Adele Dutilloy, Alistair Dunn, Chris Francis, Malcolm Francis, Mark Geytenbeek, Vivian Haist, Steve Halley, Stewart Hanchet, Bruce Hartill, Jeremy Helson, Ian Henderson, John Holdsworth, Rosie Hurst, Terese Kendrick, Adam Langley, Laws Lawson, Warwick Lyon, Pamela Mace, Dan MacGibbon, Graeme McGregor, Jeremy McKenzie, Alicia McKinnon, David Middleton, Laura Mitchell, Richard O' Driscoll, Steve Parker, Nathan Reed, Pat Reid, Carol Scott, Paul Starr, Michael Stevenson, Kevin Sullivan, John Taunton-Clarke, Geoff Tingley, Alison Undorf-Lay, Jenny Oliver, Adam van Opzeeland, Cameron Walsh.

Shellfish Working Group
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Antarctic Fisheries Working Group
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Highly Migratory Species Working Group
Convenor: Stephen Brouwer / John Annala
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Rock Lobster Working Group
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Stokes, Daryl Sykes, D’Arcy Webber, Lance Wickman.

Eel Working Group

Convenor: Marc Griffiths

Members: Dave Allen, Steve Allen, Jason Arnold, Mike Beentjes, Santiago Bermeo, Stephen Bishop, Jacques Boubee, Bill Chisholm, Shannan Crow, Bruno David, Alistair Dunn, Emily Funnell, Allen Frazer, Philippe Gerbeaux, Jane Goodman, Tom Hollings, Mike Holmes, Mandy Home, Mark James, John Jameson, Don Jellyman, Doug Jones, Te Puoho Katene, Mick Kearney, Mark Kuijten. Terry Lynch, Mike Martin, Adrian Meredith, Rosemary Miller, Michael Pingram, Garry Pullan, Hamish Quested, Pauline Reid, Nigel Scott, Terrianna Smith, Clem Smith, Paul Starr, Travis Stull, Vic Thompson, Dale Walters, Phillip Walters, Hamiora Wehipeihana, David West, Clare Williams, Erica Williams, Kirsty Woods, Anke Zernack.

Stock Assessment Methods Working Group

Convenor: Pamela Mace

Members: William Arlidge, Nokome Bentley, Paul Breen, Patrick Cordue, Martin Cryer, Ian Doonan, Alistair Dunn, Richard Ford, Chris Francis, Dan Fu, Marc Griffiths, Vivian Haist, Rosie Hurst, Adam Langley, Cath Large, Murdoch McAllister, Vidette McGregor, Andy McKenzie, Dave Middleton, Sophie Mormede, Paul Starr, Kevin Stokes, Kevin Sullivan, Geoff Tingley, D’Arcy Webber.

Aquatic Environment Working Group

Convenors: Rich Ford, Martin Cryer

Members: Blake Abernethy, Ed Abraham, Owen Anderson, Ian Angus, William Arlidge, Louise Askin, Karen Baird, Suze Baird, Barry Baker, Sira Ballara, Andrew Baxter, Brett Beamsley, Andrew Bell, Michelle Beritzhoff-Law, Katrin Berkenbusch, Tiffany Bock, Lesley Bolton-Ritchie, Laura Boren, Christine Bowden, Paul Breen, Stuart Brodie, Niall Broekhuizen, Bruno Brosnan, Martin Cawthorn, Alastair Childs, Steve Chiswell, David Clark, Malcolm Clark, Tom Clark, Rebecca Clarkson, Katie Clemens, Deanna Clement, Chris Cornelisen, Paul Crozier, Rohan Currey, Steve Dawson, Igor Debski, Ian Doonan, Matt Dunn, Adele Dutilloy, Charlie Edwards, Jack Fenaughty, Malcolm Francis, Charmaine Gallagher, Sarah Gardiner, Hilke Giles, Mark Gillard, Paul Gillespie, Neil Hartstein, Jeremy Helson, Judi Hewitt, Julie Hills, Deborah Hoffstra, Stephanie Hopkins, Rosie Hurst, Aaron Irving, Colin Johnston, Nigel Keeley, Dan Kluza, Ben Knight, Anna Kraack, Laws Lawson, Mary Livingston, Carolyn Lundquist, Dave Lundquist, Pamela Mace, Darryl MacKenzie, Lucy Manning, Rob Mattlin, Vidette McGregor, David Middleton, Rosemary Millar, Jodi Milne, Michael Neilsen, Tracey Osborne, Milena Palka, Matt Pinkerton, Irene Pohl, Marine Pomarede, Steve Pullan, Kris Ramm, Will Rayment, Vicky Reeve, Yvan Richard, Graham Rickard, Paul Sagar, Carol Scott, Liz Slooten, Tony Stafford, Kevin Stokes, Katrina Subedar, Alex Thompson, Findlay Thompson, Geoff Tingley, Di Tracey, Ian Tuck, Ben Tuckey, Nathan Walker, Bill Wallace, Barry Weeber, Richard Wells, John Wilmer, Hamish Wilson, John Wilson, Brent Wood.

Fisheries Data Working Group

Convenor: Kim George

Members: Edward Abrahams, Nokome Bentley, Alistair Dunn, David Fisher, Andrew France, Rosie Hurst, Pamela Mace, David Middleton, John Moriarty, Brian Sanders, Neville Smith, Paul Starr, Kevin Sullivan, Daryl Sykes, Finlay Thompson

Marine Amateur Fisheries Working Group

Convenor: Neville Smith

Members: Helena Armiger, Nokome Bentley, Richard Bian, Paul Breen, Martin Cryer, Charles Edwards, Alistair Gray, Bruce Hartill, Andy Heinemann, John Holdsworth, Terese Kendrick, Graeme McGregor, Alicia McKinnon, Paul Pang, Nicola Rush, Paul Starr, John Taunton-Clark, Cameron Walsh, Jeremy Wynn-Jones, Jane Zhao

3. Then and Now

The five articles in this section provide perspectives on how things were 30 or so years ago and how they've changed and evolved ever since. They include the evolution of the Plenary process, what the annual Plenary reports looked like then and now, the RV *Tangaroa* story, what it was like becoming a fisheries scientist 30 or more years ago compared with what it's like now, and how times have changed in terms of the tools and data available to fisheries scientists.

Evolution of the Plenary process

Rosemary Hurst, NIWA

New Zealand has set Total Allowable Catch (TAC) limits since 1978, initially setting limits for only a few species. In 1983, a deep-water enterprise allocation scheme was also put in place (under the "Deepwater Fisheries Policy") for seven of the major species (or species groups) of finfish caught in the greater EEZ (outside the 12 mile Territorial Sea). This was the forerunner of the Individual Transferable Quotas (ITQs) under the Quota Management System (QMS) introduced on 26 inshore and deepwater species in 1986.

The development of these management initiatives placed an increasing demand on fisheries science to identify fish stocks and estimate yields. In preparation for the introduction of the QMS, a meeting of Ministry of Agriculture and Fisheries research and management science staff was held in March 1985 to review available data and assess yields for 26 finfish species or species groups. These assessments were made on the basis of any known biology (e.g. stock structure, growth and mortality), catch histories, catch-per-unit-effort analyses, tagging studies, and individual or short time series of trawl surveys. The background information for this meeting appeared in the forerunner of the current "Plenary" report: "Background papers for the 1985 Total Allowable Catch recommendations" (Colman et al 1985). The following year saw four more species or species groups added, including two shellfish species.

By 1989, the assessment process had become more formally established, and the amount of data and analyses to consider had grown substantially. Ten stock assessment Working Groups were established, with documented terms of reference and formalised participation of fisheries research and management scientists in each group. Working Groups met to develop assessments and recommendations for 33 species (or species groups) that were summarised in draft reports that were then reviewed by a Plenary session held in May. A guide to biological reference points was included in the Plenary report – the first time it was called by this name. This guide detailed how assessment methods had been developed to meet the requirements of management based on Maximum Sustainable Yield (MSY).

In 1990, stakeholder participation in the Working Group and Plenary process was included for the first time, with industry contracted scientists (usually from the USA and Canada), recreationalists and NGOs as active participants. This was a major development towards the more open and transparent peer review process for fish stock assessments that is still in place today.

Today, the Plenary report is split into five volumes – three from a May meeting, covering 82 species or species-groups and two from a November meeting, covering 19 species. Not all of these species are, or can be, reviewed annually. These reports have several major new additions. As of 2013, they included Status of the Stocks summary tables for 174 stocks or sub-stocks, spread over 67 species. These tables have several uses: they provide comprehensive summary information about current stock status and the prognosis for these stocks and their associated fisheries, and they are used to evaluate fisheries performance relative to the 2008 Harvest Strategy Standard for New Zealand Fisheries and other management measures.

The reports also now incorporate a new science information quality ranking system, as specified in the Research and Science Information Standard for New Zealand Fisheries which was approved in April 2011. Many key species also have environmental and ecosystems considerations sections.

The Plenary report then and now

Marianne Vignaux, MPI

The 1985 Plenary report ("Background papers for the 1985 Total Allowable Catch recommendations") was somewhat more modest than today's 5 volume 1992 page opus (3 volumes in May and 2 in November of each year). At only 259 pages, covering only 26 species, it is dwarfed by its younger brother. For one thing, it covered fewer species (today's report covers 101 species), but there was apparently also much less to say about each one. The hoki section for example is only 3 pages – whereas in the 2014 report it requires 36 pages to cover the detail of the sophisticated modelling, including 4½

Paper 25/1

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SNAPPER

R.J. Sullivan

INTRODUCTION

Snapper have been studied extensively in New Zealand and many aspects of their biology are now understood. Much less information is available on the size of the resources and the potential yield which could be harvested on a sustained basis. Studies are currently being undertaken to estimate stock sizes and long-term yields of snapper. However, to ensure conservation of the resource it is necessary to make yield estimates immediately, based on the sparse amount of information available. More accurate yield assessment may be possible in the future for some stocks, after analyses of tagging programmes, shed sampling, and trawl survey data.

BIOLOGY

The biology of New Zealand snapper has been documented in many published articles and papers; therefore, a brief summary only will be presented here. (Refer to Paul (1979) for an extensive bibliography of published material. Detailed information on snapper may be found in papers by Cassie, Crossland, and Paul.)

New Zealand snapper, Chrysophrys auratus, belong to the family Sparidae (sea breams). They are abundant in the warmer waters of New Zealand and similar species also occur in Australian and Japanese waters. Snapper are most abundant in the Hauraki Gulf, but commercial quantities are also found in east Northland, Bay of Plenty, the west coast of the North Island, and to a lesser degree in Hawke Bay, Tasman Bay, and the Marlborough Sounds.

The first page of the snapper paper from the 1985 report

The 2014 Plenary report includes photos of each species for the first time.

pages of references in the "For Further Information" section – a pretty comprehensive bibliography of the research that has been done on hoki over the last thirty years.

And of course, along with 30 more years of catch history, our understanding of the biology of the species and the fisheries has increased hugely over the past 30 years. In 1985 hoki was assessed as a single stock, with only one major spawning ground known at that time. Now modelling needs to deal with the complexity of two stocks, with separate spawning grounds, and separate adult populations, but a common nursery ground for both stocks on the Chatham Rise.

In 1985 there were concerns about the sustainability of HAK 7, with a quota of 1000 t to allow stock recovery after a 17 806 t catch in 1977–78 but in hindsight the stock status trajectory shown in this year's Plenary Report indicates that in 1985 it was still in the "good"

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TABLE 1: Hake catches by management area, 1975–84

Year	Area C	D	E	F	G	H
1975–76*	41	10	58	4	71	
1976–77*	85	19	352	39	5 005	
1977–78*	38	1 251	24	172	17 806	
1978–79*	13	5	648	123	464	
1979–80*	48	559	274	85	4 592	
1980–81*	–†	–	–	–	2 354	
1981–82*	20	1 066	133	147	2 776	
1982–83*	25	98	113	73	542	
1983‡	130	269	246	205	763	†
1984‡	137	368	386	365	905	

* Apr–Mar.
† Not available.
‡ Jan–Dec.

The hake catch history from the 1985 report – note how short it is compared to the 2014 version.

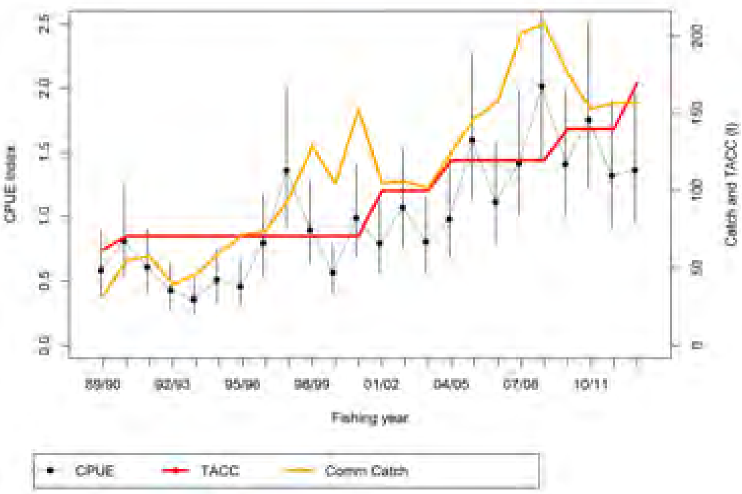
quadrant, with biomass a high proportion of virgin biomass and annual fishing intensity well below a safe threshold. It is good to see that although the stock trajectory wandered out of this area in the early 2000s, with a TACC of 6855 t, it is back in the "good" quadrant again now, and supporting a TACC of 7700 t.

Table 2: Reported landings (t) of hake by Fishstock from 1983–84 to 2012–13 and actual TACs (t) for 1986–87 to 2012–13. FSU data from 1984–1986; QMS data from 1986 to the present.

Fish stock	HAK 1		HAK 4		HAK 7		HAK 10		Total	
FMA(s)	1, 2, 3, 5, 6, 8 & 9		4		7		10			
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84[1]	886	–	180	–	945	–	0	–	2 011	–
1984–85[1]	670	–	399	–	965	–	0	–	2 034	–
1985–86[1]	1 047	–	133	–	1 695	–	0	–	2 875	–
1986–87	1 022	2 500	200	1 000	2 909	3 000	0	10	4 131	6 510
1987–88	1 381	2 500	288	1 000	3 019	3 000	0	10	4 689	6 510
1988–89	1 487	2 513	554	1 000	6 835	3 004	0	10	8 876	6 527
1989–90	2 115	2 610	763	1 000	4 903	3 310	0	10	7 781	6 930
1990–91	2 603	2 610	743	1 000	6 148	3 310	0	10	9 494	6 930
1991–92	3 156	3 500	2 013	3 500	3 027	6 770	0	10	8 196	13 780
1992–93	3 525	3 501	2 546	3 500	7 154	6 835	0	10	13 225	13 846
1993–94	1 803	3 501	2 587	3 500	2 974	6 835	0	10	7 364	13 847
1994–95	2 572	3 632	3 369	3 500	8 841	6 855	0	10	14 782	13 997
1995–96	3 956	3 632	3 466	3 500	8 678	6 855	0	10	16 100	13 997
1996–97	3 534	3 632	3 524	3 500	6 118	6 855	0	10	13 176	13 997
1997–98	3 810	3 632	3 524	3 500	7 416	6 855	0	10	14 749	13 997
1998–99	3 845	3 632	3 324	3 500	8 165	6 855	0	10	15 334	13 997
1999–00	3 899	3 632	2 803	3 500	6 898	6 855	0	10	13 599	13 997
2000–01	3 628	3 632	2 784	3 500	7 698	6 855	0	10	14 111	13 997
2001–02	2 870	3 701	1 424	3 500	7 519	6 855	0	10	11 813	14 066
2002–03	3 336	3 701	811	3 500	7 433	6 855	0	10	11 580	14 066
2003–04	3 466	3 701	2 275	3 500	7 945	6 855	0	10	13 686	14 066
2004–05	4 795	3 701	1 264	1 800	7 317	6 855	0	10	13 377	12 366
2005–06	2 742	3 701	305	1 800	6 905	7 700	0	10	9 952	13 211
2006–07	2 025	3 701	899	1 800	7 668	7 700	0	10	10 592	13 211
2007–08	2 445	3 701	865	1 800	2 620	7 700	0	10	5 930	13 211
2008–09	3 415	3 701	856	1 800	5 954	7 700	0	10	10 226	13 211
2009–10	2 156	3 701	208	1 800	2 352	7 700	0	10	4 716	13 211
2010–11	1 904	3 701	179	1 800	3 754	7 700	0	10	5 837	13 211
2011–12	1 948	3 701	161	1 800	4 459	7 700	0	10	6 568	13 211
2012–13	2 079	3 701	177	1800	5 434	7 700	0	10	7 690	13 211

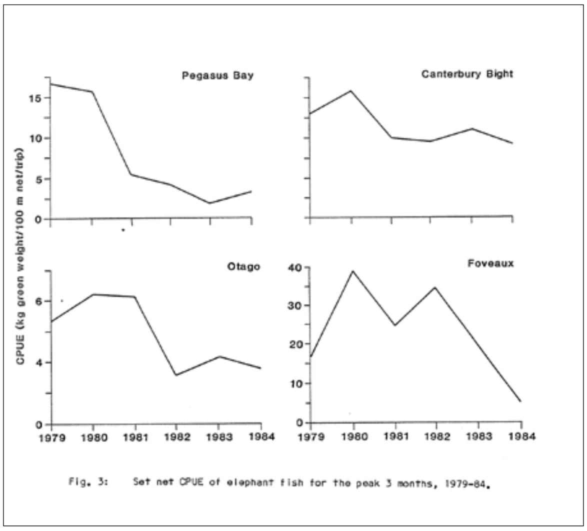
The hake catch history from the 2014 Plenary report 367

Using the advanced technology of 1985, the first Plenary was produced in simple text, with graphs and maps on a separate page, and no colour. The CPUE plots for elephant fish have certainly changed a lot over the years. In 1985, even italicisation to distinguish the Latin of species names was merely indicated by underlining. And with only plain text and simple graphics there were no formulae or stock status trajectories. To our eyes the font appears old fashioned, even quaint, but to the 1985 eye, it was presumably fresh.



The ELE 5 stock status trajectory from the 2014 Plenary report.

And the point is, it did the job of giving "a brief account of the information available on the fishery for each species, of how the information has been interpreted and used, and how estimates of available yield have been derived", summarising all that was known about the stocks, up to the last minute, so that fisheries managers and stakeholders had a single place to go to find everything they might want to know. And in the days before search engines and laptops in meetings, that was even more precious than it is today.



Elephant fish CPUE from the 1985 document.

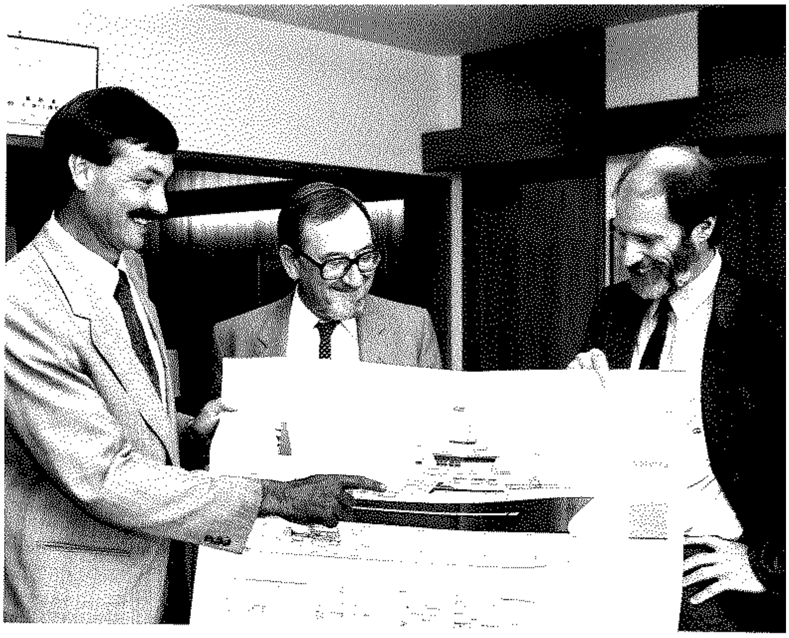
The RV *Tangaroa* story

Don Robertson, Lake Hawea, Central Otago; formerly NIWA

In 1977 the Government passed important legislation in the form of the Territorial Sea and Exclusive Economic Zone Act consistent with the United Nations Convention on the Law of the Sea. This enabled the declaration in the following year (1978) of a 12 nautical mile Territorial Sea and beyond that a 188 nautical mile Exclusive Economic Zone (EEZ – or the "200 mile limit") with a combined total sea area some 15 times the land area of New Zealand. As a consequence of this New Zealand took responsibility for resources in this huge newly declared zone including all fisheries. The scale of the expanded responsibility for fisheries jumped from around 50 000 tonnes annual harvest (of all species) in the Territorial Sea to a total harvest at the time (mainly by foreign fleets) in excess of 500 000 tonnes reported annual harvest for the combined Territorial Sea and EEZ.

To meet these new responsibilities a Deepwater Section was formed in MAF Fisheries Research Division with a team of scientists and technicians charged with carrying out research and stock assessments on a range of new and unstudied deepwater fish species. Pressure on these stocks grew rapidly as did the pressure on the Deepwater Section staff to improve their understanding. Some of the deepwater fisheries around New Zealand were by far the deepest in the world and required new and challenging approaches.

At that time research efforts to support the new deepwater species stock assessments and subsequent Total Allowable Catch (TAC) recommendations were rudimentary and constrained by inadequate research vessel capability. The 42 metre Research Vessel *James Cook* was incapable of effectively or safely carrying out extensive offshore deepwater research such as trawl surveys in depths from 400 to 1500 metres. Cooperative ventures with foreign partners who provided research vessel access were used initially to begin understanding some of the new deepwater species. However, these vessels were infrequently available and their science teams often had their own agendas. To enable offshore research on deepwater species such as orange roughy, hoki, oreos, hake etc from 1981 commercial trawlers were chartered under a system known at the time as "charters for quota". Fishing companies would competitively bid (in an open tender process) a tonnage of species quota in exchange for provision of vessel time (usually 4–6 weeks) and facilities for deepwater surveys.



Inspecting the plans for the newly approved vessel in 1989 are Hon Ken Shirley (Minister of Fisheries), Malcolm Craig (Group Director MAF Fisheries) and Dr Don Robertson (Deputy Manager, Marine Research, MAF Fisheries) (Photo: NIWA).

This system continued for a few years until Treasury deemed it to be a form of bartering and it was therefore ruled to be an inappropriate method. Treasury asked for an estimate of the annual costs of paying cash for charters. After submission of a proposal through the Minister, Cabinet approved an annual allocation of around $6.5 million to replace "charters for quota". The use of large commercial fishing vessels for deepwater research continued with up to 6 charters per year until 1991 but from the outset was fraught with difficulties. Problems included the lack of continuity of vessels for time series of comparable sampling, the difficulty of using a variety of research tools on vessels designed solely for trawling, variable quality of vessel working conditions and health and safety provisions, attempts by vessel crews to influence the research processes and results to benefit their companies, and conflicts with some foreign charter arrangements where their New Zealand company contracts were inconsistent with the MAF Fisheries charter contracts. These difficulties and others constrained and at times compromised research on deep water fish stocks using commercial vessel charters. This also led to fishing industry members at times using these difficulties to challenge aspects of some stock assessments.

To address these problems, initiatives were started from the early 1980s to seek Government approval for the provision of funding for a purpose built deepwater research vessel. Substantial research was carried out on global fisheries research vessel configurations and on shipyards with the skills and experience and record of excellence. Many meetings were held in MAF Fisheries to discuss with Deepwater Section staff what features were desirable to include in such a vessel. Numerous departmental, Treasury and Cabinet papers were prepared over about 8 years – the most novel being a complex stochastic cost-benefit analysis. After many rejections and increasingly compelling proposals, Cabinet finally approved the case for purchase with an allocation of $32 million. The approval was signed off in 1989 by then Minister of Fisheries, Ken Shirley. The years of planning were followed by a tender process leading to the careful selection of two excellent Norwegian companies – marine architects Skipsteknisk based in Aalesund and ship builders Mjellem and Karlsen in Bergen.

The result was the construction on time and under budget of a very well made purpose built 70 metre, 3000 kW, 60 day endurance deepwater fisheries-oceanographic ice strengthened research vessel – the RV *Tangaroa* – delivered to New Zealand and ready for action in May 1991. RV*Tangaroa* is a national asset for New Zealand and continues to be highly successful after nearly 25 years of almost continuous operation.

Read more about how the *Tangaroa* has contributed to our understanding of fisheries and marine ecosystemsin the article by Richard O'Driscoll and others on "Chatham Rise Trawl Surveys" and Ian Tuck's article "Ecosystem indicators from the Chatham Rise trawl surveys" in Section 6.

The RV *Tangaroa* on the water (Photo: NIWA).

Becoming a fisheries scientist then and now

Adam van Opzeeland and Adele Dutilloy interview Chris Francis (formerly NIWA) and Sophie Mormede (NIWA)

How does one become a fisheries scientist? We had a chat with two fisheries scientists of differing generations to explore the differences, and the many similarities, upon entry to the field.

Chris Francis did his undergraduate degree in mathematics at Canterbury University in the 1960s before a long and successful career in fisheries science, contributing around 70 stock assessment reports before his recent semi-retirement. Sophie Mormede entered the New Zealand fisheries science arena in the 2000s having studied mathematics, physics and chemistry in France and Scotland, and now plays an active and leading role in the Antarctic Working Group and as a member of the New Zealand delegation to CCAMLR.

Both Sophie and Chris are testament to the importance of quantitative data analysis expertise in fisheries science. Neither had any academic background in biology; instead sharing an interest in the structure and methodological nature of mathematics. Sophie cites the biology as an initial challenge, "you guys (biologists) think biology is the easy one, and I think maths is the easy one. You need to remember too many things, I don't have a great memory, but I can figure things out."

Both scientists agree that this has not been an ongoing restriction. Sophie credits the importance of the Science Working Group structure in effectively combining the maths with the biology; "our teams are multidisciplinary so there are people to do that work and tell you what you need to know", while Chris cites the importance of knowing "what the biologists consider to be important". He also spoke eloquently of the challenges in applying mathematics to biological settings; "What's attractive to me, and very challenging to me, is that mathematics is a very hard-edged subject, biology is a very soft-edged subject...which creates an ongoing challenge to fit mathematics to biological parameters".

Sophie and Chris identify the opportunities to help develop and evolve new and exciting work as highlights of their time as fisheries scientists. Chris was around during the early stages of the development of New Zealand fish stock assessments, playing a leading role in the genesis and growth of several techniques. Although Sophie came along at a time when many existing methods were already proven and in place, the ever-evolving drive for more efficient and data-rich science means she too has been able to develop her own models and techniques.

Chris is particularly proud of his role in developing CASAL, the single-species modelling software system created at NIWA in the early 2000s, and still used as the foundation of stock assessments for most New Zealand species, and several international species today. "It allowed a broader range of people to do stock assessments. CASAL facilitated understanding and allowed us to communicate a lot better." For Sophie, CASAL was an example of a stable existing tool. "The basic tools that we have for stock assessment have been created and are stable...those tools are incredibly useful." She credits her own recent multispecies model as a highlight "I didn't think it was going to work but it did. Some of the work we do is pretty cool; it's very out there and new and exciting (when it works!)."

Though entering the fisheries science world at very different times and both having very little biological training upon entry, both Chris and Sophie say they are pleased to have chosen a career applying their mathematical talents to the advancement of the science that supports fisheries management. Both spoke of a need for ensuring the science takes centre stage in the future of New Zealand fisheries, and the importance of ongoing diligence to ensuring the competency and sophistication of scientific methods. Sophie highlights the role of technological advance in this, "computing capacity increases all the time, allowing the modelling of populations to become more complex and more life-like."

How times have changed

Chris Francis, recently retired from NIWA (but still active in research)

30 years ago the stock assessment situation in New Zealand was totally different from what it is now. The major differences concern data, expertise, and computing power.

I had been working for the Fisheries Research Division (part of the former Ministry of Agriculture and Fisheries) since 1976, and we had been collecting lots of data. Our focus was on understanding the biology of our major fish stocks, and the dynamics of their fisheries. However, we had not been systematically building up the time series of data that we now deem necessary for quantitative stock assessments (for example abundance surveys, and annual measurements of the lengths and ages of fish in the commercial catch). I think it would be accurate to say that 30 years ago all our fish stocks were what we would now call data poor. Nowadays we have substantial time series of data for all our major fish stocks.

The Fisheries Research Division had little or no expertise in stock assessment 30 years ago. It certainly wasn't part of my education. My training had been in pure mathematics, with only very limited statistics (few universities taught much statistics in those days), and no biology past the third form (year 9 in today's parlance). My initial job was to provide mathematical support to the acoustics team. The earliest Plenary meetings didn't involve me because the main skill needed was knowledge of the fish stocks and fisheries, rather than quantitative analysis.

For my first stock assessment (of orange roughy in 1990) I used a method I'd made up myself. This involved a certain amount of reinvention of the wheel (as I later found out), but it ensured that the method was tailored to the data available. Virtual Population Analysis – a method widely used overseas in those days – required catch-at-age data, which were non-existent for orange roughy. Today, it is still not easy in New Zealand (or anywhere) to hire scientists skilled in stock assessment. However, the depth of experience in this country, together with the existence of relevant software (most importantly, CASAL) makes it relatively easy for new scientists with quantitative skills to learn on the job about stock assessment.

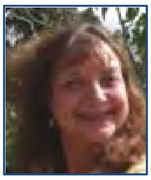
When I started work in fisheries we had only a single computer (a PDP-11), which sat in its own room and could support only one user at a time. There was no screen (communication was via a teletype keyboard), and its core memory held 64 kB, a tiny fraction of the 2 GB of RAM my current (rather outdated) computer has. By the time of my first assessment I think I had a terminal on my desk linked to a multi-user computer, but that computer would have had substantially less computing power than most modern smart phones, and word processing was still the domain of specialists.

The huge expansion of computing power over the last few decades has produced a commensurate expansion in the number of calculations underlying a typical assessment. A major effect of this expansion is that we are now much better able to quantify the uncertainty associated with our assessments. For this we use tools (e.g. Monte Carlo simulation, bootstrapping, and Bayesian methods) which were theoretically possible, but practically unthinkable, before the advent of modern computers.

4. Recent Innovations

The four articles in this section provide a small sample of recent innovations that have had a positive effect on the future direction of fisheries research and science. They cover New Zealand's Harvest Strategy Standard, New Zealand's Research and Science Information Standard, promoting fisheries science in universities, and the formation of a new Chair of Fisheries Science at Victoria University of Wellington.

The Harvest Strategy Standard for New Zealand Fisheries[1]



Pamela Mace and Stuart Brodie, MPI

The "Harvest Strategy Standard for New Zealand Fisheries" (HSS), approved by the Minister of Fisheries in October 2008, is a policy statement of best practice in relation to the setting of fishery and stock targets and limits for fish stocks in New Zealand's Quota Management System (QMS). The intention is to provide guidance on how fisheries law should be applied in practice for the setting of a Total Allowable Catch (TAC). Setting TACs is a cornerstone of the QMS and sustainable utilisation of our fisheries resources. The role of a TAC is a relatively simple construct; the scientific basis upon which it is determined is a more complex exercise.

For the vast majority of fish stocks in the QMS the requirement is to set a TAC that maintains a stock at or above a biomass level (B) that can produce the maximum sustainable yield (MSY). There is no single universally recognised method of calculating B_{MSY} (the biomass associated with MSY). It is a function of the fishing strategy adopted, the biological characteristics of the species, the available information, and the type of analytical technique used to assess the status of the fish stock.

A target is a specific MSY-compatible reference point about which a fishery or stock should fluctuate. The target must take account of the productivity of the stock in question. The target is not a minimum – the expectation is that there is an equal chance of the stock being below or above it. On the other hand, the use of biomass limits reflects environmental bottom lines. The lower the biomass becomes, the greater the sustainability risk and the less the role of the species in its ecosystem.

Two biomass limits are defined: a soft limit and a hard limit. The soft limit is defined as ½ B_{MSY} or 20% B_0[2] (whichever is higher). Stocks that fall below the soft limit are required to undergo a formal, time-constrained rebuilding plan. The hard limit is defined as ¼ B_{MSY} or 10% B_0 (whichever is higher), and fisheries closures should be considered for stocks that fall below this limit in order to expedite rebuilding.

The HSS is supported by Operational Guidelines that provide guidance on methods for calculating the various reference points and developing rebuilding plans. Together, they are used to define and set targets and limits and to evaluate stock status relative to the targets and limits.

1 http://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

2 B_0 is the pre-fishing biomass level.

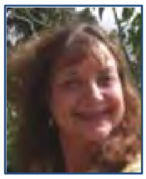
The benefits of the HSS are that:

- There is greater certainty and transparency regarding the current biological status of a fish stock. The Fisheries Assessment Plenary reports provide assessments of stocks in relation to the targets and limits. This information is incorporated into advice to the Minister responsible for fisheries on setting TACs for relevant fisheries.
- The ability to report the status of fish stocks in relation to common reference points provides greater confidence about the health of New Zealand's fisheries resources.
- It is consistent with the best practice approaches of other countries and international fisheries organisations. In many instances a default target of 40% B_0 has been adopted.
- It provides a foundation for market access and certification of New Zealand's fish products. Certification by the Marine Stewardship Council has been achieved for five New Zealand fisheries – hoki, three stocks of southern blue whiting and albacore troll – with a further three stocks of hake and five stocks of ling almost through the process. The HSS is a key component of demonstrating the ability of New Zealand fisheries to meet MSC requirements.

While the HSS may have been initially viewed with some trepidation by fisheries stakeholders, it is now accepted as a key component of the New Zealand fisheries management regime. Going forward, MPI aims to progressively apply the HSS to more fish stocks. Most of the major QMS fisheries are now assessed in terms of the HSS, and work is progressing on applying the HSS to low knowledge fisheries.

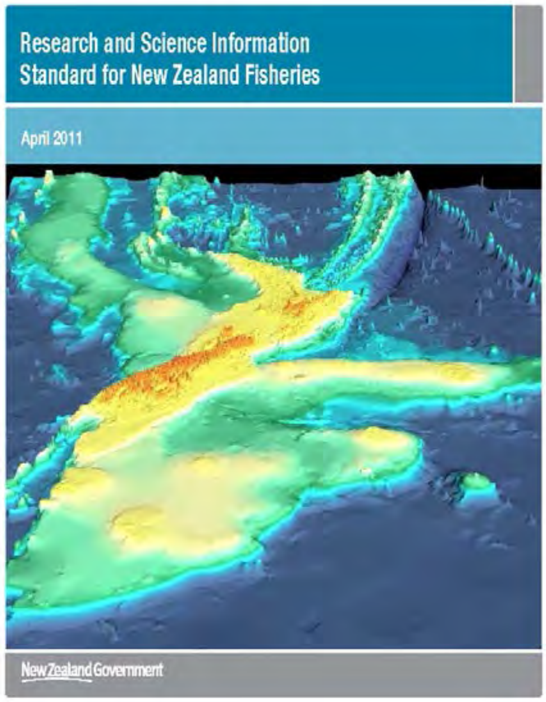
A summary of the performance of New Zealand's fisheries with respect to the HSS is provided in Section 8.

The Research and Science Information Standard for New Zealand Fisheries[3]

Andrew Penney, ABARES (Australia) and Pamela Mace, MPI

Since inception, a fundamental role of the Fisheries Assessment Working Groups has been to conduct rigorous peer review of research and science information intended to inform fisheries policy and management decisions. This has been reflected in the Working Group terms of reference for many years and the groups have established a respected reputation for ensuring that managers are provided with information that they can trust, and which will withstand scrutiny and criticism.



Cover of the Research and Science Information Standard (Image: A. Penney).

The past couple of decades have seen increasing complexity of scientific research and a move towards obtaining scientific information from a broader range of sources, including academic, industry and non-governmental organisations. There has been a

[3] http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1927

simultaneous increase in public awareness of, and emphasis on, requirements to ensure the sustainability of fisheries, raising the level of scrutiny of fisheries management decisions. These developments led to an initiative in 2010 to fully document, consolidate and augment the science quality assurance standards and processes that must be used when fisheries research is conducted and evaluated.

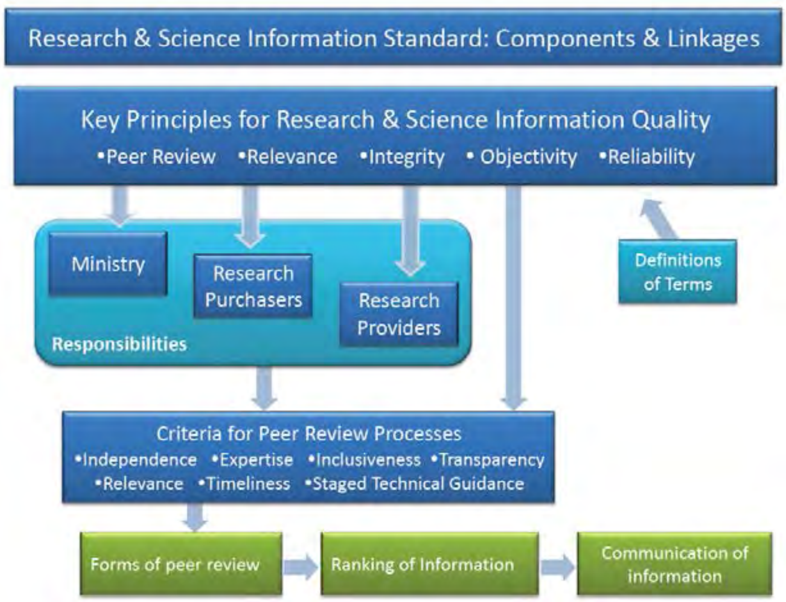
To provide a foundation of international best practice, Andrew Penney first reviewed existing international science quality assurance standards, guidelines and processes. The first attempt to develop key principles for science quality assurance can be traced back to the United Kingdom in 1995, following a series of crises of public confidence in government decision making, particularly the handling of the bovine spongiform encephalopathy (mad cow disease) outbreak. Public concern at the scientific basis for government decisions relating to this and other environmental and public health crises led to their Government Chief Scientific Advisor developing a set of key principles for ensuring the quality and reliability of scientific advice.

Over the following fifteen years, science quality assurance guidelines spread from the UK to Europe, Canada and the USA in response to various crises of public confidence in those countries, usually relating to public health and environmental sustainability concerns. Along the way they steadily evolved from broad guiding principles, to national standards with increasingly specific definitions and implementation guidelines, to formally implemented, documented and audited science quality assurance processes.

By 2010, international key principles, definitions, quality assurance guidelines and peer review requirements had become well established and well documented. We were therefore able to select elements from this international experience and adapt them as necessary to New Zealand's requirements, constraints and existing peer review process.

The resulting *Research and Science Information Standard for New Zealand Fisheries*, adopted in 2011, is built around a set of key principles for science information quality, termed the *PRIOR* principles, which need to be satisfied before research and science information is used to inform fisheries management decisions. These are ***P***eer Review, ***R***elevance, ***I***ntegrity, ***O***bjectivity and ***R***eliability, and are defined in the Standard.

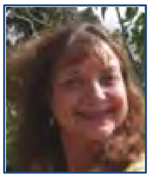
Expectations of the Ministry, research purchasers and research providers in implementing these principles are described. The standard goes on to provide explanation and implementation guidance for criteria for effective peer review processes, emphasising the importance of independence, expertise, inclusiveness, transparency, relevance and timeliness (see diagram below). An important aspect, particularly for ensuring that peer review processes are efficient and cost effective, is a flowchart depicting alternative stages and levels of peer review, depending on the novelty, complexity and contentiousness of the research. Finally, the standard provides guidance on evaluating and ranking the quality of science information during the peer review process.



Components of the Research and Science Information Standard and the linkages between them.

The requirements of this standard have been incorporated into the terms of reference for Fisheries Assessment Working Groups, creating greater clarity around peer review processes and criteria to be followed by Working Group participants. These guidelines are ensuring that Working Groups continue to deliver high quality science information and advice, and that the public can have confidence that fisheries management decisions are based on reliable scientific information.

Promoting fisheries science in New Zealand universities



Rich Ford and Pamela Mace, MPI

Fish stock assessments are needed so that we can determine sustainable levels of harvest. However, there is a global shortage of people with stock assessment skills and this is affecting New Zealand's ability to conduct stock assessments. So in 2006 the Ministry of Fisheries and NIWA started what is now the MPI/NIWA Postgraduate Quantitative Fisheries Scholarship to develop this skill within New Zealand.

Unfortunately, there were few postgraduate students available with the best blend of quantitative skills (preferably applied statistics) and marine biology. This meant that before 2008 only one scholarship was granted, to Oliver Hannaford at Auckland University (see table).

Therefore in 2010 the Ministry of Fisheries started awarding what is now the MPI Undergraduate Scholarship in Quantitative Marine Science. The aim of this scholarship is to encourage students to graduate from their first degree with a mix of quantitative courses and marine biology courses. This should also help to promote the benefit of quantitative skills to undergraduates and hopefully ensure more applicants for the postgraduate scholarships.

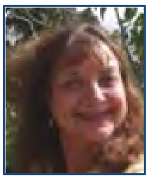
This concerted long-term effort of communicating both with universities and within MPI about the need for more quantitative fisheries science skills has now started to reap rewards. We have now had 17 undergraduate and eight postgraduate scholarship recipients. Many of our recent postgraduate recipients also received our undergraduate scholarships. The range of topics covered (or proposed to be covered) by the postgraduate scholarship students can be seen in the table.

Student (year awarded)	University	Degree	Topic
Oliver Hannaford (2006)	Auckland	MSc (completed)	A Bayesian model of the west coast snapper (*Pagrus auratus*) fishery
Vidette McGregor (2008)	Victoria	MSc (completed)	Investigation and development of post-season modelling of Arrow squid in the Snares and Auckland Islands
Kristin McLeod (2008)	Massey	MSc (completed)	Risk analysis of a flatfish complex
Darcy Webber (2012)	Victoria	PhD (partial funding support – ongoing)	Spatial complexity in stock assessments
Kath Large (2012)	Victoria	MSc (completed)	Population changes in rattail species on the Chatham Rise
Lisa Hall (2012)	Canterbury	MSc (ongoing)	Assessment of the Priceless orange roughy stock (planned)
Annie Galland (2013)	Victoria	MSc (ongoing)	Ageing and development of biological parameters for deepwater species
Max Schofield (2013)	Victoria	MSc (ongoing)	Investigating hyper-depletion in various New Zealand fish stocks
Craig Marsh (2014)	Victoria	MSc (ongoing)	Investigation of alternative spatial/temporal assumptions within SPM (Spatial Population Model) for tuna and other highly migratory species
Helena Lawrence (2014)	Victoria	MSc (ongoing)	Stock assessment on Patagonian toothfish in the Ross Sea

Particular successes from the programme have included Vidette McGregor and Kath Large getting permanent jobs in this field at NIWA and Darcy Webber winning prizes for his research from both the New Zealand Marine Sciences Society and the Statistics Society of New Zealand.

Another highlight has been the appointment of Matthew Dunn from NIWA to Victoria University as a chair of Fisheries Science (partially funded by MPI for the first three years; see the following article) and Ian Tuck (another Fisheries Scientist) to a 0.2 appointment at Auckland University in the Statistics Department. This now means that there are three experienced stock assessment scientists (including Russell Millar at Auckland University) in universities to help train the next generation. It is hoped this effort from MPI in conjunction with NIWA and the universities will mean that New Zealand will continue to have the ability to perform fish stock assessments to support sustainable fisheries into the future.

New Zealand's first Chair in Fisheries Science



Pamela Mace, MPI and Matthew Dunn, Victoria University of Wellington

In 2013, MPI sponsored the creation of a new Chair in Fisheries Science within the School of Biological Sciences at Victoria University of Wellington (VUW). MPI has provided partial funding for the first three years, and MPI and VUW have agreed on a Memorandum of Understanding that outlines the responsibilities of each organisation. MPI also chairs an Advisory Committee that keeps track of progress.

Science graduates entering the world of fisheries need to be highly-skilled quantitative biologists as the research techniques become increasingly sophisticated. For many years, skilled graduates were proving difficult to find, not only in New Zealand but worldwide. The position was therefore created to encourage and train a new generation of fisheries scientists.

The inaugural holder of the Chair is Dr Matthew Dunn. Matthew joined Victoria University of Wellington with nearly twenty years of experience in applied fisheries science, and following a decade at the National Institute of Water and Atmospheric Research (NIWA). Matthew has a background in fish biology and fisheries stock assessment.

A dedicated postgraduate course in fisheries is now planned to start at the university in 2015. In addition to training new fisheries scientists, the role of the Chair is to work closely with a range of New Zealand science organisations, and to conduct novel fisheries research. It is hoped that this research will be useful to MPI and industry, and tackle issues that other organisations do not have the time or resources to address. Matthew has started by researching some common but poorly known by-catch species, and the effects that environment and climate can have on New Zealand fish populations.

Participants at the launch of the VUW Fisheries Science Chair (Photo: Image Services VUW).

5. The Diversity of Research Areas

This section includes nine articles that illustrate the broad range of research fields and endeavours that fisheries scientists and other technical experts undertake. They include research planning, the Observer Programme, customary fisheries science, marine recreational fisheries science, the environmental effects of fishing, research into marine biodiversity and ecosystem services, aquaculture and its environmental effects, international science obligations, and data management.

The research planning process

Kevin Sullivan, MPI

Research planning is an important process in the annual cycle of fisheries management in New Zealand. In earlier years, the Ministry's scientists developed medium term (5-year) research plans for each research portfolio in conjunction with NIWA scientists, other research providers and the various stakeholders in the fisheries. Each year the final annual research plan was determined by a Research Coordinating Committee where projects were prioritised based on a combination of feasibility and cost. Higher risk fisheries attracted more research and higher cost recovery levies. However, over the years the purchasing power of the research budget has continuously decreased, while the requirements for information have continuously increased (more species have been added to the QMS and the effects of fishing on the environment and international fisheries science obligations have been given more attention).

In recent years the implementation of Fisheries Plans has resulted in responsibility for research planning being shared between fisheries managers and scientists within the Ministry. National fisheries plans for deep-water and highly migratory species have been approved by the Minister. In addition, draft 5-year plans exist for inshore shellfish, inshore finfish and freshwater fisheries. For all these fisheries annual operational plans (AOPs) specify the management actions and services to be carried out in the following year. One component of the AOP is the research needed to support decision-making in relation to the sustainable utilisation of fisheries.

In the transition period, the research planning process followed in each research portfolio has varied as the development of national fisheries plans and AOPs have been at different stages for each fishery:

- In 2010 a 10-year research programme for deepwater fisheries was developed through a series of meetings of the stock assessment and aquatic environment advisory groups (SAAG and AEAG). These groups consisted of invited technical experts who advised on the options for carrying out stock assessment research on the nine main deepwater species and research to assess the effects of fishing on the environment. The first five years of this 10-year programme has been almost completed.
- For inshore research a new template for research projects was developed to include management objectives from the national fisheries plans. A scoring system was developed in 2012 to rank the proposed research projects in order of priority within each research area. Rock lobster fisheries research is discussed at the National Rock Lobster Management group each year. Similarly, inshore finfish, eel and shellfish projects are consulted on with inshore stakeholder groups to determine the inshore research programme.
- Initial research proposals for Highly Migratory Species (HMS) fisheries are developed at meetings of the HMS Research Advisory Group. The research projects are then discussed at meetings of the Fisheries Plan Advisory Group as part of the process for developing the Annual Operational Plan for HMS fisheries. The

Research Plan for 2011–16 for HMS in New Zealand has been developed for consultation with stakeholders to guide future research in support of the national fisheries plan.

- For Aquatic Environment research a revised research planning process was followed in 2014**.** The template for research projects includes information on management context of the research as well as the specifics of the proposed research. Discussions were held with the Department of Conservation to harmonize the two research programmes and to ensure that there was no duplication.
- Research projects for Marine Amateur Fisheries were developed using a new template for research projects that includes management objectives from the national fisheries plans.
- Initial research proposals for Antarctic fisheries were developed at a meeting of the Antarctic Fisheries Research Planning Group. The research projects were then developed in discussion with the MPI International Fisheries team and in line with the CCAMLR 3–5 year plan for Ross Sea fisheries (developed with the Ministry of Foreign Affairs and Trade and stakeholders to guide future research in support of the New Zealand's involvement in Antarctic fisheries).
- The Ministry for Primary Industries also has responsibility for contracting some research in the marine biodiversity area funded through the *Biodiversity Strategy*. Because the stakeholder groups with interests in this research are wider than those with interests in fisheries research, the Ministry has established a separate but parallel research planning process for this area.

The output of all this research planning is an annual Fisheries Services Plan that includes all the new projects to be contracted in the next year. In recent years many of these projects have been tendered for multiple years to reduce administration costs. The final approved projects are tendered out throughout the year to approved research providers on a competitive basis.

The other parts of the cycle are the reporting back of research results to the various Science Working Groups and the updating of the Plenary document for each fish stock. Fishery managers use the updated information and the formal stock assessments to review regulations on fishing and update TACs for the QMS stocks if required.

The Observer Programme

Andrew France, MPI

In June 1985 the New Zealand Government announced its intention to establish an Observer Programme to monitor the activities of vessels fishing in New Zealand's Exclusive Economic Zone (EEZ). This was done in order to obtain independent catch and biological information from vessels operating in the then rapidly developing deepwater fishery. At the time there were concerns over misreporting, under-reporting and non-reporting of fish dumped or lost from burst trawl nets.

The programme was created as part of the Ministry of Agriculture and Fisheries (MAF) and began sea-going operations in April 1986. In the first year observers completed 5743 days at sea. During the first few years of operation, observers measured about 110 000 to 140 000 fish each year and collected about 3000 to 7000 otolith pairs.

Observers are critical to New Zealand's world leading fisheries management regime. They record accurate and reliable data relating to vessel catch and processing and monitor the environmental impact of fishing activity. At-sea observation duties are carried out by a number of observers, based around the country. The nature of this work involves extended periods of time at sea on fishing vessels of varied nationality. Observers go to sea on vessels like this:

...and even like this:

The primary tasks of observers are to collect independent catch and fishing effort data; collect biological data; conversion factor data; record details of marine mammal and bird captures and their behaviour around vessels; and collect unusual specimens.

Observers complete a separate catch and effort logbook for fishing events undertaken by the vessel they are on board. The observer's logbook contains catch calculations and amounts for every species caught. They also collect details about the fishing operations such as start and finish times, positions, fishing and bottom depths, mitigation devices used and data on what the vessel does with the catch for each tow or set.

Observers are not enforcement officers. They have no powers to give the master orders with respect to management of the vessel, except to request reasonable co-operation and assistance from the master to facilitate their own duties as observers. They do, however, have a responsibility to record offences as part of their observing duties and will inform vessel personnel of non-compliant behaviour and assist them to improve their operation.

As the programme has evolved, observers have been tasked with collecting more and different types of information. For example, they now collect details of benthic material caught and abundances and identification of seabirds and marine mammals observed.

In the 2012–13 year observers completed 10 398 days at sea, measured over 776 000 fish and collected over 67 500 otolith pairs. The fisheries where this coverage was achieved included the deep-sea trawl, inshore trawl, demersal long line, surface long line, troll, purse seine and inshore set net fisheries on vessels operating both inside and outside the EEZ.

Customary fisheries science

Te Puoho Katene, MPI

MPI has identified customary research as an increasingly important part of its role to provide the best available information to inform fisheries management decisions.

There are two reasons for this:

1. To more fully account for stock exploitation in fisheries management; and
2. To enable tāngata whenua to sustainably manage and exercise their customary fishing rights.

Assessing the status of any wild population is always tricky when the information available is imperfect. While the data received through commercial catch landing provides an account of commercial utilisation, the remaining two significant stakeholder groups, recreational and customary, are information-poor. As such, a concerted effort has been placed on attaining information to more accurately account for the impact of these sectors on fish stocks.

Furthermore, MPI are responsible for enabling tāngata whenua to have input and participation to inform the Minister on fisheries management decisions. The Minister’s obligations in this regard stem from both the Treaty of Waitangi (Fisheries Claims) Settlement Act (1992) and the Fisheries Act (1996). The 1992 Settlement Act gave effect to the full and final settlement for tāngata whenua in regards to commercial fishing rights. The customary (non-commercial) aspect to fishing was given effect through the introduction of the Kaimoana & South Island (Customary Fishing) Regulations (1998 and 1999 respectively).

These regulations introduced a suite of tools for tāngata whenua to utilise in managing and exercising their customary fishing right. However, in order to address provisions in the Regulations, tāngata whenua requested funding to research information related to customary gathering and traditional practices with regard to mahinga mātaitai and tauranga ika (traditional harvesting sites and fishing grounds). This gave rise to the Customary Fisheries Research Fund. This annual fund receives and funds proposals aimed at enabling tāngata whenua to manage their customary (non-commercial) fisheries through the provision of pertinent information. Since its establishment, this round has funded over thirty projects around the country, as far afield as the Chatham Islands.

The focus for projects in this Fund has shifted in recent times. The scope of the Fund still includes its original focus on gathering traditional knowledge, but is now often complemented with other information needs for customary management, including quantitative information. This can be seen from the successful applicants in 2014, whose projects include:

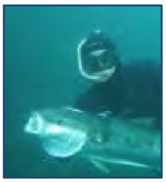
- Designing and implementing an eel monitoring programme, to track the effects of proposed bylaws and inform fisheries management.
- Establishing a Bayesian ecosystem-based fisheries model that integrates stakeholder perspectives – kahawai case study.
- Partnering with Victoria University to conduct baseline abundance surveys and tagging of pāua, and building hapū capacity to continue ongoing survey work.
- Undertaking a desktop study and kaumātua interviews to inform sustainable management of freshwater fisheries.

Customary fishing is still an area that requires greater work to improve access to information. The Customary Regulations feature quarterly reporting requirements that will undoubtedly increase available information as the Regulations are implemented more fully around the country. In lieu of these reporting requirements (i.e. in areas where the Regulations have not yet been implemented), other initiatives and innovations are required to take tāngata whenua values into account when managing fisheries.

These information needs have, on occasion, led to customary-focused projects being progressed under Fisheries Management's contestable research round, such as the 2013 Highly Migratory Species project *"Rapid Assessment of Iwi Fish Utilisation".* The aim of this project is to collate information and data on the value of customary fishing in pilot groups located in FMAs 2 & 8 (Tauranga and Taranaki areas), in lieu of the Regulations' formal reporting schemes. While the information is qualitative in nature, the ability to take into account the customary value of a fishery plays an important role in informing the Minister's management decisions.

Over time a greater importance has been placed on the effect of non-commercial sectors on fisheries management. While there is still plenty of work to do to raise the quality of available information, there certainly is some demonstrated capacity, as well as a shared willingness by MPI and tāngata whenua, to affect change in this regard.

Marine recreational fisheries science



Neville Smith, MPI

The recreational harvest may form a large component of the total catch in some fisheries, in particular in the snapper and kahawai fisheries in north eastern New Zealand. In a wide range of inshore fisheries the recreational harvest is important to recreational fishers. The science challenge has been, and remains scale: the considerable length of the New Zealand coastline; the large number of species taken; the large number of access points and methods used; and, unsurprisingly the weather.

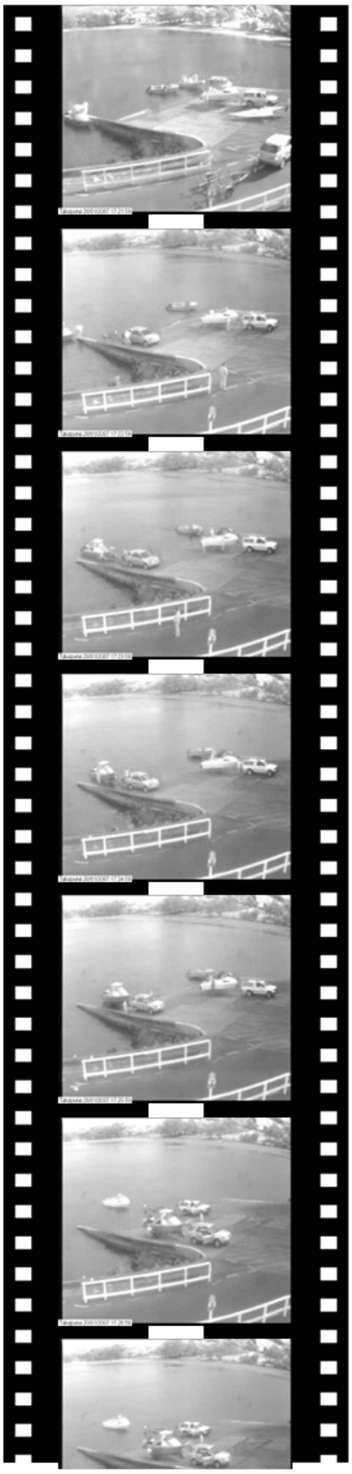
Recreational fisheries science has had an interesting journey over the last thirty years. Research started as an ancillary to projects in commercial fishery moving to a series of recreational specific approaches using offsite and then onsite approaches. Recently we have seen the evolution of an integrated approach using both offsite and onsite methods, periodic surveys and ongoing monitoring.

There are two broad approaches to estimating recreational fisheries harvest: onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data.

The first estimates of recreational harvest were calculated using an onsite approach, a tag ratio method in the mid 1980s. A tonnes per tag ratio was obtained from commercial tag return data and this tonnage was multiplied by the number of tags returned by recreational fishers to estimate recreational harvest tonnages. The method relied on assumptions about tag reporting which were later shown not to hold, giving a positive bias to estimates.

The next method used was a series of offsite regional telephone and diary surveys through the early-mid 1990s. In 1996 a national telephone and diary survey was conducted, with another following in 2000 (a rolling replacement of diarists in 2001 allowed estimates for a further year). The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early method, the proportion of eligible fishers in the population (and, hence, the harvest) was under-estimated. Another cause of bias was that diarists who did not immediately record their day’s catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys.

These issues led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. Ratios of the aerial count in each area to the number of interviewed parties fishing at the time of the overflight are used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers. Recently work has gone into developing other onsite approaches including implementation of a bus-route approach which combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an survey count of vessels/trailers observed to be fishing at all ramps along the bus-route at a random time of day.



A simpler version of the aerial-access method was first employed in the Hauraki Gulf in 1996, but the full method was developed in 2003–04 and extended to survey the wider SNA 1 fishery in 2004–05 and subsequently other fisheries. The most recent aerial-access survey was conducted in QMA 1 in 2011–12. The bus-route approach was first used for Coromandel scallops and part of CRA 2 in 2010–11, and was repeated in 2011–12.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the implementation of a national panel survey during the

2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. The 2011–12 bus-route and aerial access surveys independently provided harvest estimates for comparison with those generated from the concurrent national panel survey.

These three approaches have been subject to international peer review and appear to provide plausible results that corroborate each other, and are considered to be broadly reliable. In combination with the development of web-camera monitoring of recreational fishing effort over time recreational fisheries science now looks set to mature with a monitoring and periodic survey regime based on robust methods which answer the key questions about the main fisheries. Science to address our information needs in the smaller fisheries remains a developing field. The next thirty years are likely to be just as interesting.

Environmental effects of fishing

Martin Cryer, MPI

When I joined the Ministry of Agriculture and Fisheries in 1990, it was rare to hear about research on the environmental effects of fishing. By and large, research was focussed on assessing the status of a relatively small number of commercially important stocks. The Ministry did have a Non-Fish Species and Fisheries Interactions Working Group (NSFIWG) that summarised information on some protected species interactions annually, but the analysis was not comprehensive and it was not possible at that time to assess the consequences of those interactions. In addition, almost no work was done on other impacts such as fish bycatch, bottom trawl effects, trophic effects, and impacts on the wider ecosystem supporting fisheries. This lack of knowledge did not allow well-informed fisheries management decision-making around environmental effects and, instead, decisions had to be based on value judgements or assumptions.

How things have changed! In 1997, the Ministry discontinued the NSFIWG and established an Aquatic Environment Working Group (AEWG) with a broader mandate. Research on aquatic environment issues was broadened, and investment has increased, especially since 2005. A formal publication series to summarise the results of this work and make the information more accessible was established in 2002, and this series took on its current title *Aquatic Environment & Biodiversity Reports* in 2005. Visibility was further enhanced in 2011 with the establishment of the *Aquatic Environment & Biodiversity Annual Review*. This report summarises the state of knowledge each year on several important effects of fishing and, like the Fisheries Assessment Plenary reports, has expanded each year it has been published. The 2013 edition[4] included over 500 pages in 15 chapters ranging from fish and protected species bycatch through

[4] http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122

benthic impacts to ocean climate and marine biodiversity. The 2014 edition will be even more comprehensive.

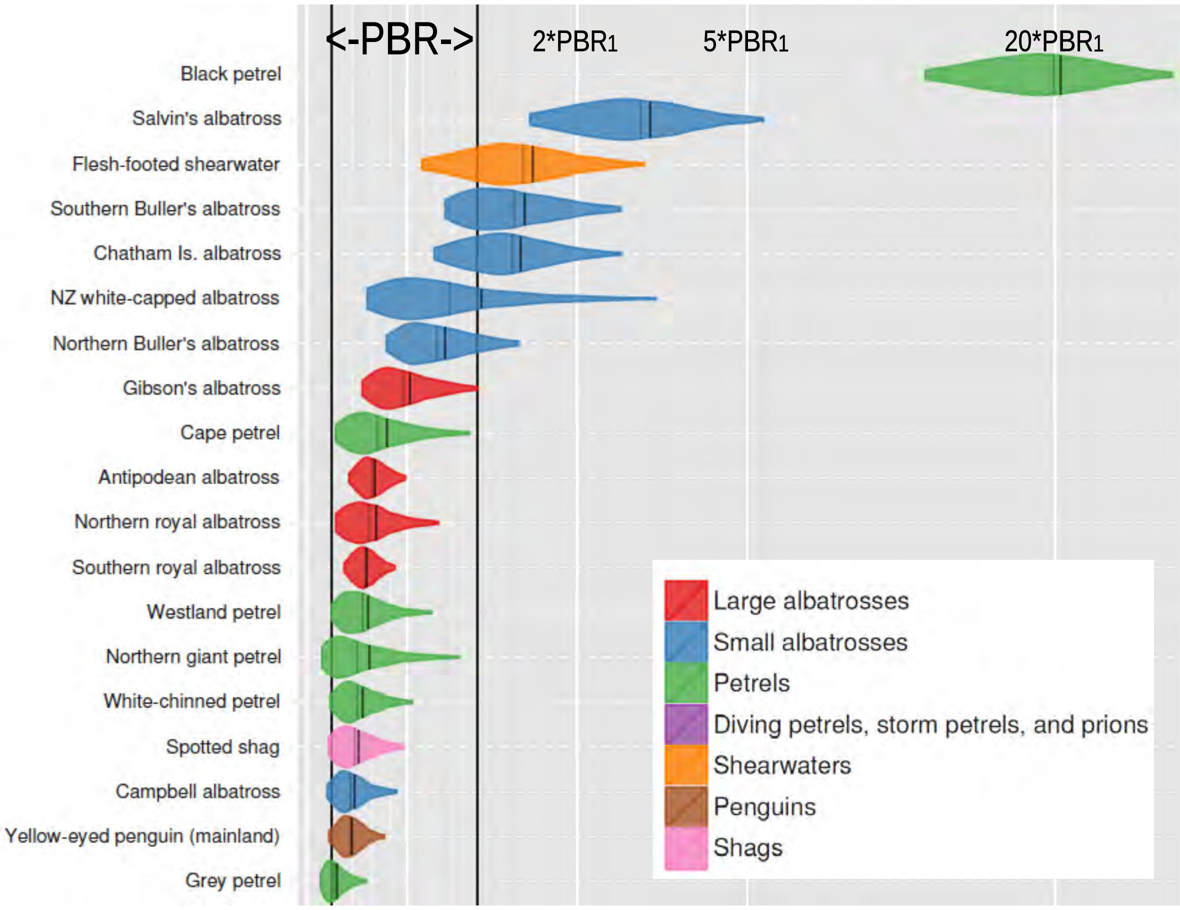
As knowledge has accumulated, and especially since about 2007, risk assessment has become an increasingly important tool for integrating information and identifying priority issues for data collection, mitigation or management. The starting point for risk assessments is typically expert-based, and this can be conducted with very sparse information as long as credible, well-informed experts are available. However, there are limitations to this approach and, as more information becomes available, more quantitative and informative risk assessment can overcome some of these limitations.

MPI's most advanced risk assessment covers almost all seabirds breeding in New Zealand. The current spatially- and seasonally-explicit version provides estimates of fishing-related mortality for every seabird species in relation to its Potential Biological Removals (PBRs), an internationally accepted performance measure that, if achieved, should lead to high population size (see figure below[5]). Being able to compare mortality to this biologically relevant performance measure is an important advantage of the quantitative approach because it allows managers to judge whether, and to what extent, intervention is required. Further advantages come from the ability to separate the risks posed by different fisheries and to identify seasons, areas, and circumstances of most risk. This provides invaluable guidance on where to focus limited resources to reduce risk and to identify the best opportunities for data collection.

The seabird risk assessment is a key component of the 2013 National Plan of Action to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries (NPOA-Seabirds[6]) and, as such, is a valuable contribution to the United Nations Food & Agriculture Organisation's (FAO) International Plan of Action for Seabirds (IPOA). The Ministry is current working on a global implementation of the method to take account of the many overseas fisheries that impact on New Zealand breeding seabirds.Building on the success of the seabird risk assessment, the Ministry is currently working on risk assessments to integrate information and provide guidance on research priorities, the placement of observers, and opportunities to manage the risks posed to marine mammals, non-target fish, sharks, and benthic effects. Where appropriate, these will also feed into international processes.

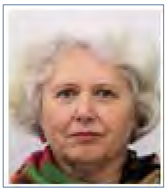
I anticipate that formal quantitative risk assessments will be in place for most individual effects of fishing within the next five years. This will not provide a comprehensive ecosystem approach to fisheries (a goal that is still quite a few years away), but it will provide solid guidance on where management intervention or improved performance may be required as well as assisting with the prioritisation of information collection and data analysis. In short, we will have moved from a situation of scarce data with no obvious process for using it in fisheries management to a situation where data can be used to assess risks in a meaningful and reproducible way, where the real issues can readily be identified, and where next steps in management and data collection are clear.

[5] http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1758
[6] http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1760



Estimated risk ratios (total annual potential fatalities / PBR) from the 2013 seabird risk assessment (see Richard & Abraham 2013). The risk ratio is displayed on a logarithmic scale, with the number of potential bird fatalities equalling the PBR with f = 0.1 and f = 1 indicated by the two vertical black lines, and the distribution of the risk ratios within their 95% confidence interval indicated by the coloured shapes. Mean risk ratios are shown as solid black lines, medians as grey lines. A further 51 seabird populations with median risk ratio of < 0.1 are not shown.

Marine biodiversity and ecosystem services



Mary Livingston, MPI

"Not everything that can be counted counts, and not everything that counts can be counted" Albert Einstein

Biodiversity is a word that some fisheries scientists feel uncomfortable with. Many see it as vague and unmeasurable; an intangible concept, inviting pedantic discussion of its meaning. Yet some fourteen years since its launch as part of '*New Zealand Biodiversity Strategy– Our Chance to Turn the Tide'* in 2000, MPI continues to support the crown funded Marine Biodiversity Research Programme initiated by the Ministry of Fisheries.

This is largely because there is recognition that the sustainability of wild-catch fisheries depends not only on managing fish populations, but also on the state of the ecosystems and habitats that support ecosystem function and the natural productivity of the sea. Biodiversity provides an indicator of how well we are maintaining those ecosystems and habitats.

In addition to obligations under the Fisheries Act 1996, New Zealand is also signed up to a number of international agreements that require commitment to stewardship of the marine environment including biodiversity. MPI also acknowledges that there is a range of societal values beyond commercial, customary and recreational take from the sea that are recognised as part of public wellbeing.

Global markets are now demanding that marine resources be fished sustainably through eco-labelling schemes and other initiatives, and there is a public expectation that this means that marine ecosystems will remain healthy, animals will not be caught illegally, and biodiversity will be maintained.

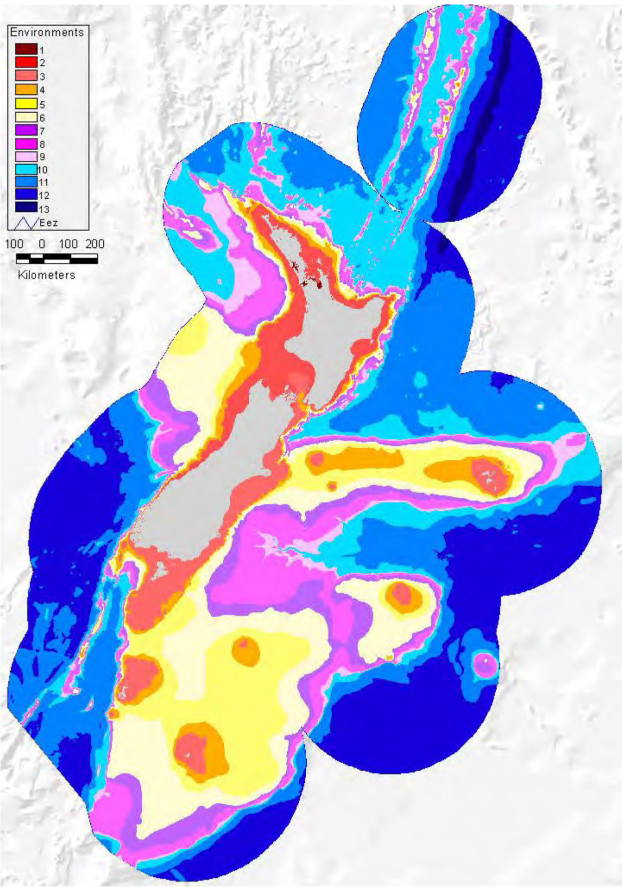
Research on the diversity of fauna and flora in New Zealand waters provides insight into the distribution of rare and indigenous species, and fragile habitats. Further, it enables MPI to investigate critical environmental phenomena that affect biodiversity and fisheries productivity. MPI also recognises that there is a range of societal values beyond commercial, customary and recreational take from the sea that are recognised as part of public wellbeing.

The MPI Biodiversity Research Programme was set up with initial funding of $2.0 million per annum under Theme 3, 'Coastal and Marine Biodiversity' of the *New Zealand Biodiversity Strategy* for a five year period. The principal goal of the MPI Biodiversity Research Programme is:

> *'To improve our understanding of New Zealand marine ecosystems in terms of species diversity, marine habitat diversity, and the processes that lead to healthy ecosystem functioning, and the role that biodiversity has for such key processes.'*

MPI recognises that other programmes both internal and external to MPI are also addressing research questions of high relevance to fisheries management, the environment and biodiversity. Through the Biodiversity Research Programme, synergies are sought where possible so that collectively, the combined research effort produces scientific understanding with relevance for the improved management of the New Zealand marine environment as a whole, not just fisheries.

Priority is given to marine habitats and organisms at risk from large scale human activities such as commercial fishing and downstream effects of land-based activity. Smaller-scale research has been designed to facilitate studies to determine the main natural drivers of biodiversity as well as the effects of human activity, especially in coastal waters. These studies contribute to integrative studies of biodiversity and ecosystem processes occurring on longer and larger temporal and spatial scales. The design of useful long term monitoring programmes that will signal biological changes to productivity and its effects on biodiversity in the marine ecosystem has also been investigated.



Demersal fish optimised Marine Environmental Classification tuned specifically to produce a classification that worked well for fish on or near the bottom as a potential proxy for benthic habitats (Source NIWA-MPI project ZBD2005-02).

The long term goal is that the Biodiversity Research Programme will play a significant role in the development of an ecosystem approach to New Zealand fisheries management both in the EEZ and in the Ross Sea region.

The MPI Biodiversity Research programme has three overarching science goals:

1. To describe and characterise the distribution and abundance of fauna and flora, as expressed through measures of biodiversity, and improving understanding about the drivers of the spatial and temporal patterns observed.
2. To determine the functional role of different organisms or groups of organisms in marine ecosystems, and assess the role of marine biodiversity in mitigating the impacts of anthropogenic disturbance on healthy ecosystem functioning.
3. To identify which components of biodiversity are required to ensure the sustainability of healthy marine ecosystems as well as to meet societal values on biodiversity.

To date, 55 research projects have been commissioned. Early studies focused primarily on the first goal and resulted in reviews, Identification Guides, habitat and community characterisations, and revised taxonomy for certain groups of organisms. There were also large collaborative ship-based surveys that contributed to improved seabed classification in New Zealand waters and the exploration of new habitats in the region and in Antarctic waters.

Over time, the complexity and scale of studies has increased towards studying the functional ecology of marine ecosystems, from localised experimental manipulation to broad-scale observations across hundreds of square kilometres.

A study on changes in shelf ecosystems over the past thousand years is yielding insights into the effects of long-term climate change, changes in land-use, and the effects of fishing on marine ecosystems while more recently, other studies have begun to address the effects of ocean acidification on marine biodiversity. Another study has reviewed genetic variation in the New Zealand marine environment and is conducting field observations on several species to examine genetic variation across latitudinal gradients.

In 2000, the concept of biodiversity was hotly debated among stakeholders and the benefit of the research (other than to scientists) was not widely accepted. In 2014, it is clear that much progress has been made, and the programme has successfully raised the profile of biodiversity in fisheries management, and uptake into policy and management decisions within MPI and across government.

Pristine biodiversity on the seafloor near the Balleny Islands, Ross Sea region, Ocean Survey 20/20, Antarctica 2006 (Source: MPI and NIWA project ZBD2005-03, photo R. Stewart/NIWA).

There is an ongoing role for this programme as the Ministry and New Zealand as a whole continue to wrestle with the need for ecosystem approaches to management, major environmental concerns such as ocean acidification, multiple resource-use effects as the marine economy expands into deepsea mining and drilling, and other emerging issues regarding the marine environment. Closer synergies are expected between MPI, DOC, MfE and MBIE as the marine related National Science Challenges develop and the Natural Resource Sector increasingly embraces a collective approach to responsible and sustainable management of our seas.

Specimen sorting during biodiversity Ocean Survey 20/20 voyage to the Chatham Rise. (Source NIWA-MPI project ZBD2007-01, Photo S. Holmes/MPI).

A full list of MPI Biodiversity projects and the Programme objectives can be obtained from the MPI Annual Aquatic Environment and Biodiversity Review 2012 available from http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122

Aquaculture and its environmental effects

Rich Ford, MPI

Aquaculture planning and consenting in New Zealand is managed by regional councils and unitary authorities under the Resource Management Act. MPI provides science and tools to help councils with this process, including helping them to manage the ecological effects of aquaculture. Marine aquaculture is spread throughout the country but there are particular concentrations in Marlborough, Hauraki Gulf, Northland, and Southland (see figure[7] below).

The aquaculture industry in New Zealand has been prominent since the 1980s and there has been much environmental research into the ecological impacts of aquaculture. Most of the science in New Zealand investigating the environmental effects of aquaculture has focused upon site surveys and monitoring for consent applications, subsequent monitoring, determining carrying capacity or summarising impacts.

[7] Diagram from MPI (2013) Overview of the ecological effects of aquaculture, based on figure in Keeley, N; Forrest, B; Hopkins, G; Gillespie, P; Knight, B, Webb, S; Clement, D; Gardner, J (2009). Sustainable aquaculture in New Zealand: Review of the Ecological Effects of farming shellfish and other Non-finfish species Cawthron Report No. 1476, 150 p.

Geographic locations of main marine farming activities in New Zealand (Image: MPI 2013 modified from Keeley et al 2009).

The potential ecological effects of aquaculture can be classified into a number of categories. In order of decreasing importance for finfish farming (see diagram[8] below) these are:

1. Biosecurity threats,
2. Pelagic effects,
3. Marine mammal interactions,
4. Benthic effects,
5. Seabird interactions,
6. Additive effects,
7. Escapee effects,
8. Wildfish interactions,
9. Hydrodynamic alteration of flows.

Biosecurity is considered the highest priority risk category because potential effects on the environment from a pest or disease outbreak could be widespread and irreversible. Aquaculture activities have the potential to facilitate the spread of invasive species, although they are unlikely to directly introduce them into New Zealand. Aquaculture must be managed alongside other activities in the coastal environment such as shipping and fishing that can also pose biosecurity risks. MPI leads New Zealand's biosecurity system; delivering the border risk management system, surveillance and responses, and working with a range of other parties to effectively manage biosecurity.

Pelagic effects (effects on the water column) of aquaculture (especially fish farms) can also be of concern, because fish excrete nitrogen which can lead to nutrient enrichment, changes in phytoplankton, and depletion of dissolved oxygen within and around the farm. Many factors influence the carrying capacity (how much nitrogen a marine system can absorb without showing adverse effects). These include the level of nutrient input, its chemical form and source (human and/or natural), the temperature, winds, and the current and circulation patterns around the farm. Carrying capacity is a cumulative issue - aquaculture cannot be considered in isolation of other activities or stressors. The recommended approach is to model all nutrient sources and relevant factors and set precautionary limits for discharges from aquaculture operations. Then adaptive management and monitoring can be employed to allow farms to expand gradually if significant adverse environmental effects are not observed.

[8] Diagram from MPI (2013) based on figure in Forrest, B; Keeley, N; Gillespie, P; Hopkins, G; Knight, B; Govier, D (2007) Review of the ecological effects of marine finfish aquaculture: Final Report. Cawthron Report for the Ministry of Fisheries, 80 p.

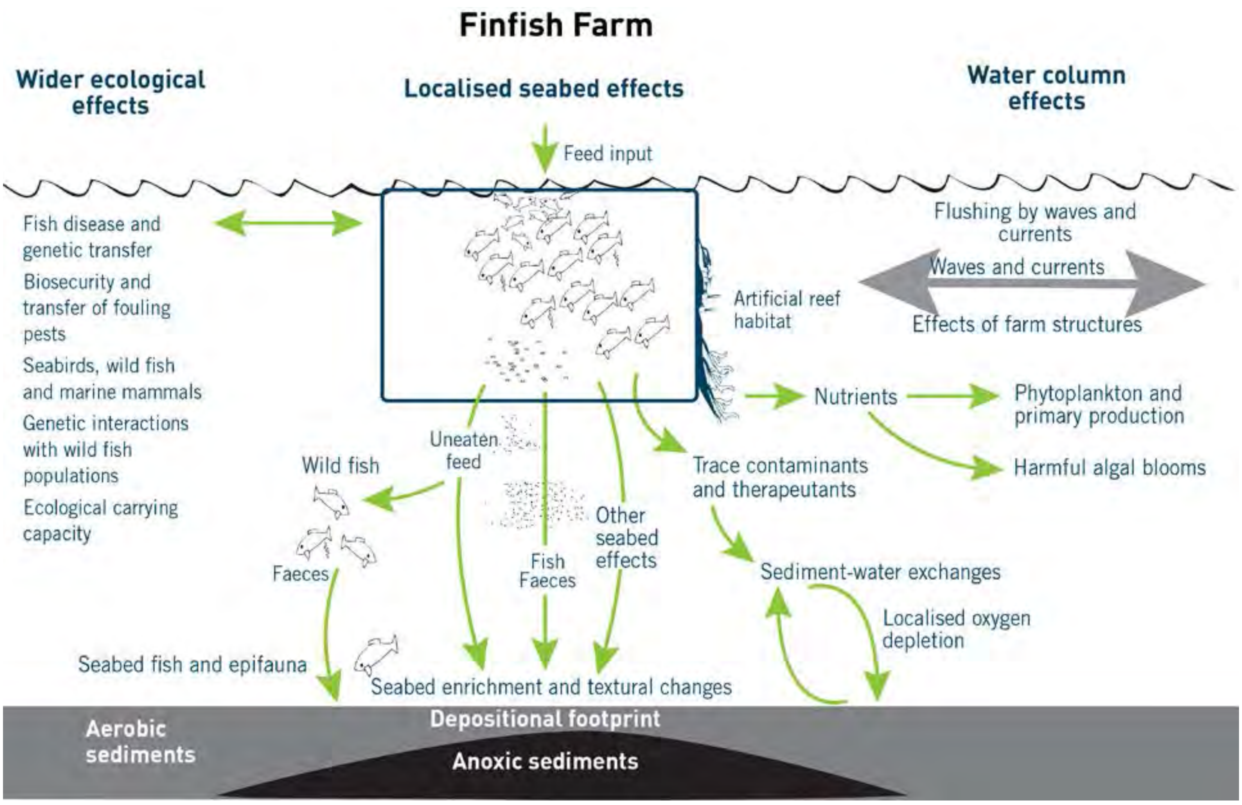


Diagram illustrating the actual and potential ecological effects from finfish aquaculture (Image: MPI 2013 modified from Forrest et al. 2007).

MPI is currently working with multiple stakeholders on a range of projects in this area that include:

- benthic monitoring standards for Marlborough salmon farms,
- decision support tools for councils to improve aquaculture planning,
- better integration of aquaculture consent and state of the environment monitoring,
- collection of baseline monitoring information to improve models of ecological carrying capacity for the Marlborough Sounds, support of collaborative decision making processes around marine spatial planning (Hauraki Gulf) and initial scoping of areas suitable for aquaculture (Southland).

However, the good news is that at present the environmental effects of aquaculture in New Zealand are considered minor when compared to other stressors. A 2009 survey of experts assessed the relative importance of 62 threats on 65 New Zealand marine habitats, and the three threats posed by aquaculture activities were considered minor or trivial.

Read more about this analysis in Alison MacDiarmid's article "Factors impacting the marine environment" in Section 6.

Fisheries science obligations on the international stage

John Annala and Kevin Sullivan, MPI

MPI scientists contribute in many ways to our obligations for international fisheries. Members of the MPI fisheries science team prepare scientific papers and submissions on New Zealand fisheries, participate in Working Groups and Scientific Committees and provide scientific advice to New Zealand delegations at many regional fisheries management organisations. Since 2004, when most of the fish species managed by these organisations were introduced into the QMS, they have generally been reviewed within the Ministry's Fisheries Assessment Plenary process (before then they were reviewed outside the Plenary process in more informal processes run by the Ministry).

The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) manages the resource for the six member countries and co-operating non-members that fish this stock. In 1985 the three major nations then fishing Southern Bluefin Tuna signed a voluntary management agreement that included quotas for each of the countries. In 1994 the current CCSBT was established. Southern bluefin tuna was reviewed informally until 2002 when it was incorporated in the Plenary process.

The Western and Central Pacific Fisheries Commission (WCFPC) manages the tuna and billfish in the region and has assessed most of the important fish stocks in the area with support from the Secretariat of the Pacific Community and the Forum Fisheries Agency. The WCPFC was established in 2004, the same year that many of the species that it manages were brought into the QMS and reviewed in the Plenary process for the first time.

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is well attended by both NIWA and Ministry scientists to ensure that the toothfish fishery is managed using the best information available. CCAMLR was established in 1980 and began actively managing toothfish in the mid-1990s. Toothfish was first brought into the Plenary process in 2005.

The South Pacific Regional Fisheries Management Organization (SPRFMO) manages the large resource of Peruvian jack mackerel in the Pacific Ocean, but also the demersal orange roughy and alfonsino stocks outside the New Zealand EEZ. SPRFMO was established in 2012. Peruvian jack mackerel were brought into the Plenary process in the 1990s coinciding with a westward shift in its distribution across the Pacific, including into the waters around New Zealand. The orange roughy stocks outside the New Zealand EEZ in the SPRFMO Convention area were introduced into the Plenary process in 2006, while the alfonsino stocks have not been included.

New Zealand has also been involved in the Southern Indian Ocean Fisheries Agreement (SIOFA) as required, though we have not been active in this fishery in recent years. The fisheries in this region catch orange roughy, oreos and alfonsino, with none of these stocks being included in the Plenary process.

Scientific advice is also provided to support New Zealand contributions to meetings under the Convention on Trade in Endangered Species (CITES), United Nations conventions, Fisheries and Agricultural Organisation conferences and expert panels and various bilateral agreements.

What happens to the data

Kim George, MPI

Data Management of fisheries research datasets exists to ensure that high quality scientific data is available to those responsible for providing the New Zealand government with advice on the sustainability of New Zealand's marine resources. Scientific data is collected, processed, archived, and made available to support management decisions. Fisheries research data collected for, or by the Ministry for Primary Industries (MPI), plays a key role in ensuring that these outcomes are met. It is therefore essential that the collection, validation, storage and safe keeping of fisheries research data is maintained over a long period. MPI's goal is to have a cost effective, co-ordinated approach to operating a national archive of electronic and physical fisheries data of interest to scientists, researchers, stakeholders, fisheries managers and the general public.

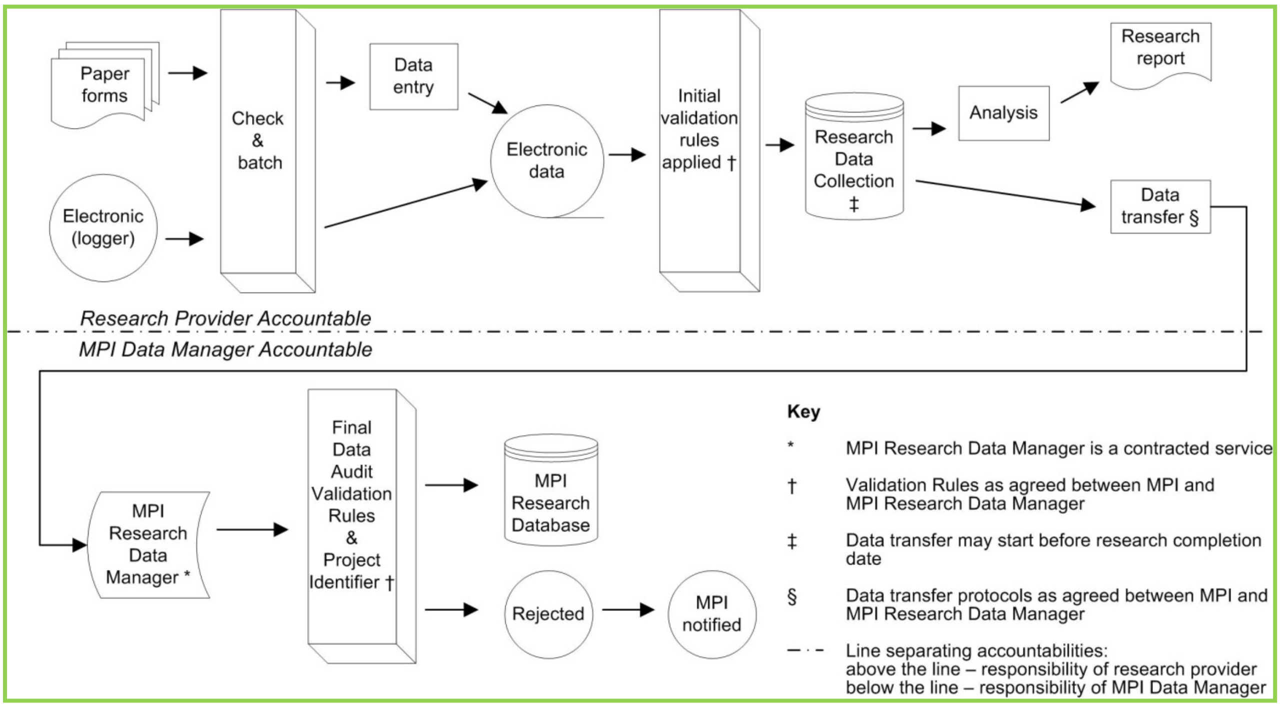


Diagram of research data accountability for existing databases

MPI tenders for, and contracts out, many research projects each year to provide advice on specific resource needs. This research is purchased to support decision making in relation to the sustainable utilisation of fisheries in a healthy aquatic environment. The resulting research projects produce large quantities of data on a wide variety of fisheries related research areas, including; commercial, customary, recreational, socio-economic, and marine biodiversity.

The research data goes back many years and has been gathered at large expense. Within fisheries science, the value of data is often proportional to the length of the uninterrupted time series that is available for analysis. For this reason it is important that fisheries data be safely stored indefinitely. There are datasets from research undertaken in the 1960s available, with some datasets, like annual abundance surveys for Toheroa going back to the 1920s. In 2013 MPI received approximately 200 datasets from 65 completed research projects.

The information and specimens constitute one of the most valuable assets that New Zealand has for managing its fisheries and marine environment. The data is considered to be a key Crown asset, without which the continued assessment of the sustainability of New Zealand's marine resources would be made more difficult. The data must be managed to preserve and demonstrate authenticity, integrity and retrievability to meet business and statutory requirements. Data sets from the research projects, integrated into the appropriate databases, provide long term storage and safe keeping for the data, and can then be make available for subsequent use. The diagram above shows the accountabilities of the Research Provider and Data Manager in populating fisheries research databases.

There are 38 formal fisheries research databases and a number of other datasets stored in various formats. The total volume of data in all databases is 34 GB, with the five largest databases listed in the table below. Although the preference is to have as much electronic data as possible stored in databases, there is still much research data that is not compatible with existing databases, or not required to be put in databases such as video and images. Non-database data stores

Database	Description	First year of data	Size
COD – Centralised Observer Database	Contains the catch and effort information for observed commercial fishing vessels, ageing materials, length frequency and biological data for commercial species as measured by observers, as well as relevant trip and tow information	1986	22 GB
new_fsu	Consists of pre-FSU and FSU (Fisheries Statistics Unit) catch effort data	1972	5392 MB
tuna	Contains groomed commercially collected tuna catch effort data from New Zealand, Australia, and Japan	1980	1984 MB
age	Contains age readings and catalogues of otoliths and other fish ageing material obtained from the Observer Programme, market sampling, and trawl surveys	1970	1389 MB
tag	Contains tag and release details for all tagging programs	1968	887 MB

include acoustic data files at a volume of 6.3 TB, and 960 GB of raw electronic files, images and video.

As well as electronic research data, physical data is also collected and submitted for archiving. Ageing material makes up a large component of the physical fisheries data, with over 1.3 million otoliths from 140 distinct species, collected since 1970, in storage. A further 21 distinct species have had other types of ageing material collected; e.g. vertebrae, spines, scales. Physical fisheries data also include specimens and documents. The National Invertebrate Collection at NIWA includes specimens collected as part of MPI research projects, as well as from MPI observer trips. The current collection of specimens preserved, catalogued and archived, translates to approximately 30 m^3 in volume. There is also approximately 60 m^3 of paper forms archived.

These data are owned by the Ministry and made available to answer additional research questions where relevant. The ability for fisheries researchers to have access to the data collected from previous research projects is essential. In 2013 there were about 100 requests for data stored in one of the 38 fisheries research databases or specimen stores. These came from MPI staff, fisheries researchers, NGOs, stakeholders, media, other government departments, students and the general public. Since 2010 over 700 requests for data have been completed and for the most part, once commercial sensitivities and privacy issues are considered, the data requested is the data released.

Maintaining sound data management principles is essential to ensuring the continued safe storage and accessibility of fisheries research data, for now and the future.

6. Some Cool Fisheries Research

This section includes six articles on some of the cool research that fisheries scientists undertake. The first is about how scientists determine the age of fish. The next two provide insights on the gains in knowledge that have been obtained from 23 years of research trawl surveys on the Chatham Rise. The two following articles explore the roles of seamounts and deep-sea corals in our marine ecosystems. The fifth article outlines how fish, especially sharks, are tracked using modern electronic devices. The final article examines all of the factors that affect the marine environment.

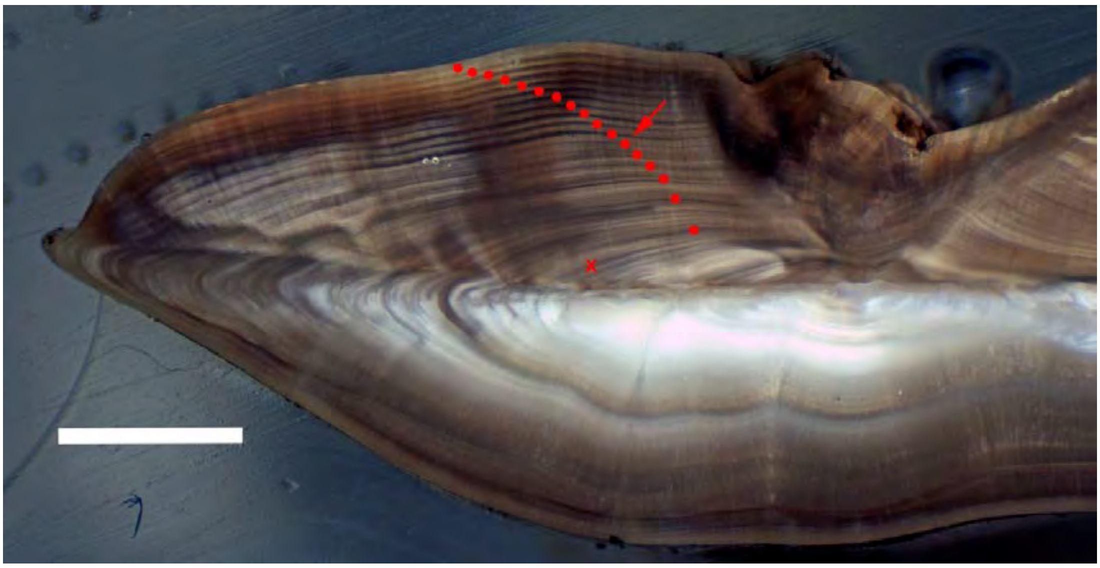
Determining the age of fish

Peter Horn, NIWA

Considerable effort is expended on ageing commercial fish species. But why? Because age information contributes to the monitoring and management of fishery resources in New Zealand by enabling calculations of growth rates and mortality rates, estimation of population age structures and annual spawning success, and providing information useful for investigations of stock structure.

How are fish aged? In biological science, tree rings are well known to indicate annual growth increments. In the animal kingdom, probably the most well known patterns visible externally are on the shells of molluscs and tortoises. However, fish produce growth increments in various hard structures, most notably in their otoliths (or 'ear stones'), but also in scales, spines, vertebrae and other bones.

Well over a million fish are aged each year worldwide, highlighting the importance of age information in fisheries science. All ageing investigations involve a count of microscopic contrasting light and dark zones, although methods vary between species and structures. Scales and some otoliths are examined whole. Other structures (most otoliths, spines and bones) are sliced transversely (like cutting through a tree) and zones are counted across the cut surface. The sliced structure may be untreated, or baked or stained to enhance the visibility of the contrasting zonation pattern. Vertebrae are sectioned or x-rayed, showing regular patterns of higher and lower density material.



A hoki otolith from a 103 cm female, aged 17 years. Dots show annual zones, the arrow shows a relatively faint zone at age 6, and 'x' shows the faint (sub-annual) juvenile zone that is visible on most hoki otolith sections. Scale bar = 1 mm. (Photo P. Horn/NIWA).

Unfortunately, the growth increments formed in fish parts are not as clear as in many trees. The interpretation of the growth zones can be difficult; zones can be diffuse, variable in width, and comprise confusing micro-structure. It is also essential to validate the periodicity of the zones being counted, and this can be a difficult process.

Because ageing information contributes in so many ways to population modelling and management, any inaccuracies in age data can impact seriously on the fished resource. There are examples worldwide where ageing error (usually underestimation of age) has contributed to the overexploitation of a fish population. A New Zealand example is the orange roughy. When the fishery began in the early 1980s the longevity of this species was believed to be about 30 years, and it was subject to high exploitation levels.

Before 1990, published growth parameters (the relationship between length and age) were available for only 15 of New Zealand's commercial fish species, and the ageing technique had been comprehensively validated for only four of these. Many of our commercial species grow quite slowly and to relatively old ages, so their otoliths are difficult to interpret. The complex zonation structure in some otoliths has been partially attributed to the relatively deep waters that New Zealand species inhabit, where seasonal influences on the environment (and hence, on growth) are more blurred than in shallow, coastal waters.

Since 1990, considerable progress has been made in ageing New Zealand fishes. Growth curves are available for about 60 commercial species and about 40 of these are considered fully or partially validated. Usually a single growth curve is not sufficient to describe growth patterns for a species as growth rates can differ between sexes, or between distinct biological stocks.

Fish ageing (including the development of initial growth curves and their validation, and the routine ageing to provide information for resource assessments) will continue to be an important component of fisheries research. The provision of comprehensive and accurate growth information is a key factor in the successful management of fishery resources.

Chatham Rise trawl surveys

Richard O'Driscoll, Darren Stevens, Dan MacGibbon, Dan Fu, NIWA

NIWA has run a Ministry-funded trawl survey of the Chatham Rise using RV *Tangaroa* every year since 1992. This is the most comprehensive time series of fish abundance estimates in New Zealand's 200-mile Exclusive Economic Zone.

The main aim of these surveys is to estimate the abundance of hoki and other commercially important species (such as hake and ling), but during the 23 consecutive surveys to date NIWA scientists have also been able to study other aspects of deepwater biodiversity on the Chatham Rise, including fish distribution, abundance, and ecology.

The hoki fishery is New Zealand's largest fishery, with a current total allowable catch (TAC) of 150 000 tonnes. The Chatham Rise is the second most important hoki fishing area (behind the west coast South Island), with annual catches of 36 000 t to 40 000 t from this area in the past seven years. The Chatham Rise is particularly important because it is also the major nursery area for New Zealand hoki. Juvenile hoki from both eastern and western hoki stocks mix on the Chatham Rise, so this survey provides an opportunity to get an idea of how many small hoki are out there, before they recruit to their respective areas and are caught by the commercial fishery. This allows the Ministry for Primary Industries to set an appropriate catch limit which is responsive to the abundance of small fish coming into the fishery.

Tipping the trawl (Photo: J. Oeffner/NIWA).

Surveys are carried out in January because we believe that this is a time when the most hoki are present on the Chatham Rise. At other times of the year, adult hoki leave the Chatham Rise to migrate to their spawning areas. The surveys are conducted by trawling at depths of 200–800 metres. Trawling locations are randomly selected using a specialised computer programme. The trawl is towed for 3 nautical miles (5.5 km) at a speed of 3.5 knots (6.5 km/h) at each location. Each year the survey has about 100 trawls over a period of about 27 days. All surveys follow standardised and documented protocols. This is vital to ensure that we obtain a consistent series of relative abundance indices. This means that we may not know how many fish are there in absolute terms, but we can tell whether numbers are increasing, decreasing, or remaining the same.

In the wetlab (Photo: R. O'Driscoll/NIWA).

As well as providing an essential input into the stock assessment for hoki, the surveys also fulfil an important ecosystem monitoring role by providing additional information on species distribution and biodiversity. Since the surveys began, scientists have recorded a total of 558 species or species groups and analysed more than one million individual fish, squid, crustaceans, and benthic fauna to help establish abundance trends and spatial and depth distributions. They enter a catch record of every species into a database and bring any species that could not be identified at sea back to NIWA for identification. Rare and new-to-science fish are sent to Te Papa where they are preserved and stored in the National Fish Collection.

Abundance trends have been estimated for 142 species or groups. For the 49 groups where abundance is relatively well-estimated by the survey, biomass has decreased significantly since the start of the time series for only two species: hake and rudderfish. Hoki and arrow squid decreased in the middle part of the time series, but then increased. Eighteen groups increased significantly, 9 increased and then decreased, and 18 showed no clear trend. The proportion of hoki in the catch declined from nearly 60% in 1993 to 21% in 2004, but increased again to make up 30–40% of the total biomass in the past 10 years.

From the first 20 surveys (1992–2011), over one million individuals of 159 species were measured. If laid end-to-end these would stretch from Wellington to Auckland – over 500 km! Of these, 45 species had sufficient information to estimate scaled length frequency distributions by year. Most showed no clear trend in mean length over the period for which length measurements were available. In addition 225 852 fish were individually weighed from a total catch (for the 20 surveys combined) of 3143 t.

Combined with information from reading otoliths we can estimate how many fish of each age are caught. Recent surveys show that there are good numbers of young (1 and 2-year old) hoki which will feed into the fishery over the next few years - this has led to increases in hoki TAC.

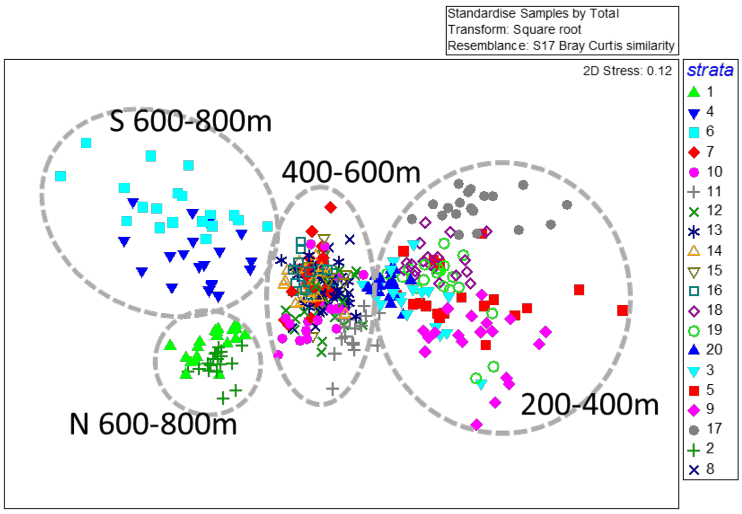
A more detailed description of the Chatham Rise trawl survey series along with a selection of maps and results from the trawl surveys are available and can be viewed at: http://www.niwa.co.nz/fisheries/research-projects/20-years-of-chatham-rise-fish-survey.

Ecosystem indicators from the Chatham Rise trawl surveys

Ian Tuck, NIWA

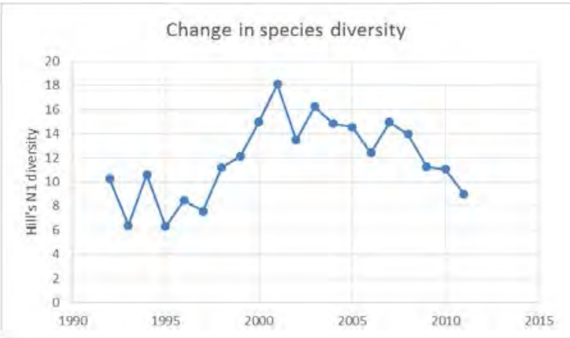
As well as providing abundance indices for key target species for use in stock assessments, trawl survey time series also provide valuable information on changes in the whole fish community over time. Trawl survey time series have been widely used overseas to generate fish based ecosystem indicators, with indicators based on the overall catch composition, the size composition of the fish in the catches, and the feeding or habitat group composition of the catch.

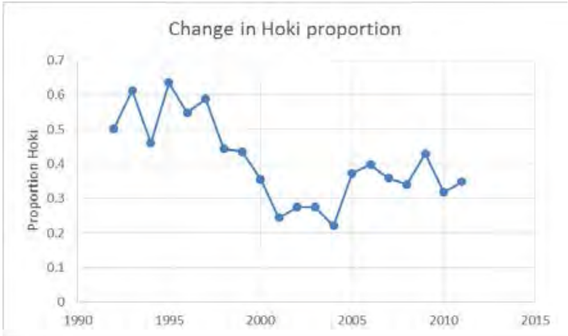
Most measures of species diversity (a combined measure of the number of species present in the catch, and how similar their abundances are) show an increase through the late 1990s, but a decline since 2001. This increase in diversity mainly resulted from a reduction in the abundance of hoki over this period, with hoki becoming less dominant, and abundance therefore being more even between species (giving a higher diversity measure). More recently, hoki stocks have improved, and diversity has reduced again.



Multi dimensional scaling plot of survey strata level catch composition, showing major groups described in the text.

Examining catch composition at the survey strata level, it can be seen that the catch composition falls into four distinct groups (northern 600–800m, southern 600–800m, the 400–600m depth band, and the 200–400m depth band), with some evidence for lesser differences between strata within these groups. More detailed examination of indicators has been conducted across these community groups.



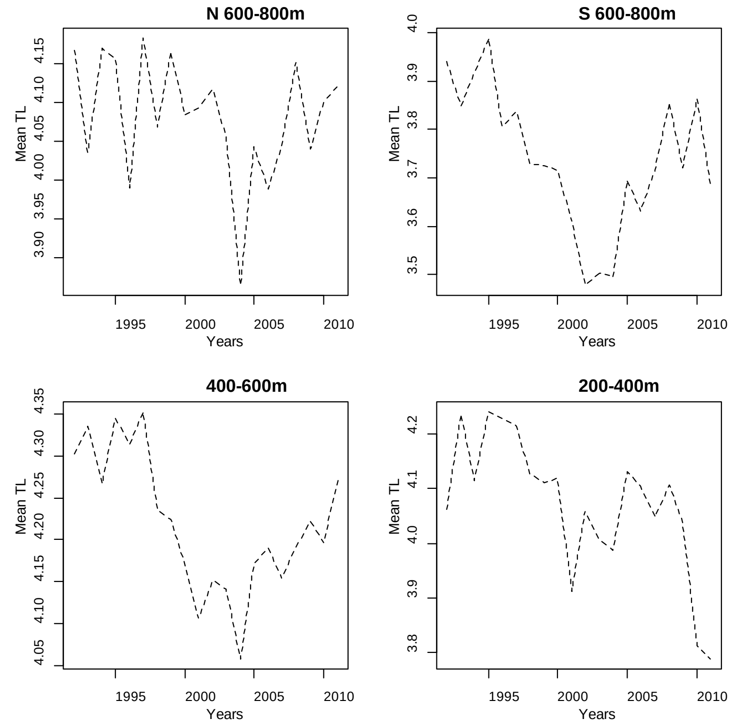


Changes in species diversity (top) and proportion of hoki (bottom) in Chatham Rise trawl survey catches.

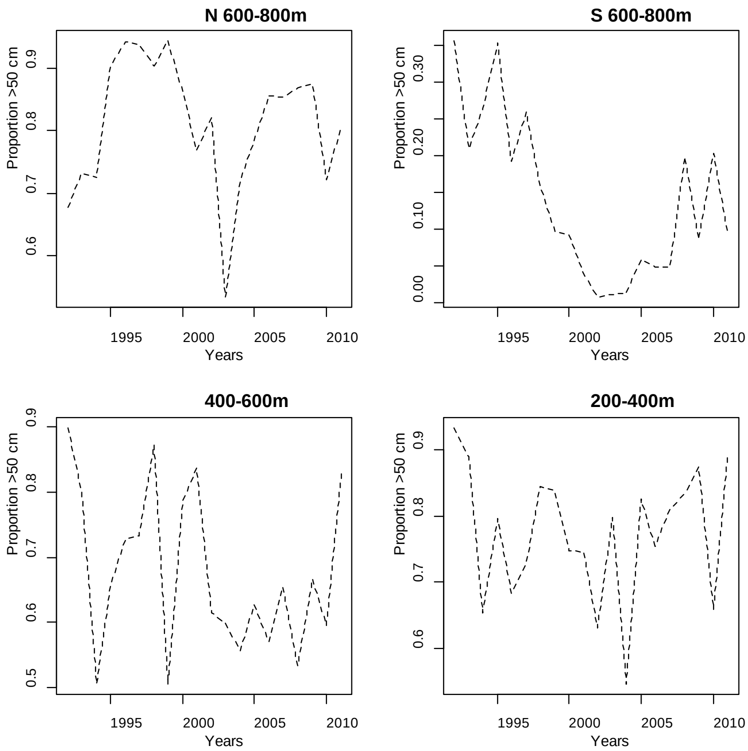
The size composition of a community integrates information about the processes underlying community dynamics such as productivity, mortality and life history strategy. Fishing may also lead to changes in size structure. Size based indicators are considered a powerful approach to monitor the effects of fishing on populations and communities, and a wide range of indicators are available. The proportion of large fish in a community is a commonly used measure, and shows a decline during the early 2000s for the southern 600–800m community, and in the mid to late 2000s for the 400–600m community, but both show an increase in more recent years.

Food web indicators measure the strength of interactions between different components of the community, and can be used to examine structural ecosystem changes. Trophic level identifies the position of an organism within a food web (the higher the number the higher up the food chain), and changes in the mean tropic level across a community can represent changes in community structure. Both the southern 600–800m community and the 400–600m community show a decline in mean trophic level during the early 2000s, with an increase in more recent years. The 200–400m community data show a decline in 2010 and 2011.

Indicators can be difficult to interpret individually, but examined as a suite,



Time series of mean trophic level by strata group from Chatham Rise trawl survey.



Time series of proportion of large fish by strata group from Chatham Rise trawl survey.

encompassing a range of ecological aspects, can provide valuable insights into how fish communities are changing. They are being developed worldwide as part of ecosystem based approaches to fisheries management.

The importance of seamounts in marine ecosystems

Malcolm R. Clark, NIWA

Seamounts are undersea mountains. They occur in all oceans of the world, and cover depth ranges from near the surface to the abyss. There are estimated to be at least 30 000 seamounts (with a height of 1 km or more) globally, and over 100 000 smaller knolls and hills (between 100 m and 1 km height).

Seamounts have three important characteristics that distinguish them from the surrounding deep sea habitat. They are "islands" of shallow seafloor, and provide a range of depths for different communities; the volcanic origin of most seamounts and localised currents mean that bare rock surfaces can be common- in contrast to much of the ocean seafloor which is covered in soft sediment; and hydrographic features and current flows can restrict the dispersal of larvae and plankton and keep species and production processes concentrated over the seamount.

These factors enable a wide variety of habitat types for a huge range of animals, and seamounts often feature high levels of biodiversity and abundance. Their depth range may also facilitate dispersal of species by acting as "stepping stones". This means that seamounts can be very important components of offshore marine ecosystems.

In the immediate New Zealand region, seamounts, knolls and hills are major features of the topography because of the tectonic setting on a plate boundary. There are over 1500 known features, with about 900 inside the EEZ (See figure below).

The location of known seamounts, knolls and hills in the New Zealand region (NIWA data).

Examples of seamount biodiversity: dense beds of tubeworms, mussels, and crabs on Monowai Seamount at 1200 m (left), stony coral reef with seastars on Gothic Seamount at 1000 m (middle), orange roughy aggregating over the summit of Morgue Seamount, 900

Seamount features have been the subject of considerable research in New Zealand, because of their importance for deepwater fish, in particular orange roughy, oreos, black cardinalfish and alfonsino. In the early 1980s less than 20% of the orange roughy catch was taken on knolls and hills, but this progressively increased to over 60% in the mid 1990s and the number being found and fished each year also increased. Therefore fisheries management needed to consider the impacts of such fisheries on the benthic habitat of seamount features and the wider deep-sea ecosystems.

Biodiversity surveys have been carried out on over 60 seamounts, knolls and hills. Their animal communities vary a great deal, often with 5–10% of species being unique. Biomass levels can be very high. Particularly striking are the hydrothermally active seamounts and knolls of regions such as the Kermadec Arc, which can host large numbers of hydrothermal species that are specifically adapted to the warm and chemically-rich conditions (see photos above). Equally impressive are other features at depths of 800–1000m that have dense deep-sea coral reefs, which are able to establish on the rocky summit areas of a seamount, and feed on the plankton and particles that flow past in the currents around the seamount (see photos above). These coral reef habitats can in turn host many other species in, or on top of, their matrix.

The current flows around seamounts also provide a regular input of food for fishes and other plankton-eating animals, supporting dense aggregations of fish (see photos above). Plankton descending in the morning strike the seamount summit or flanks, and accumulate. This is perhaps one of the reasons seamounts often have dense aggregations of fish over them. Orange roughy are well-known for using seamounts as feeding or spawning grounds and therefore seamounts may be important for many stages of the life-cycle of deep-sea fish.

However, seamount communities may be severely affected by exploitation. Deepwater, coral-dominated, communities are highly vulnerable to physical disturbance by bottom trawling. The coral matrix is very fragile, and research on Chatham Rise hills has indicated that recovery may take a very long time, as growth rates of many deep-sea seamount species are slow.

Natural changes are also occurring, and long-term ocean acidification will have important consequences for seamount coral species which are affected by the chemical composition of the water at depth. However, in the short-term, direct human impacts are of most concern, and careful management of seamount resources is required to balance exploitation and conservation of the habitat.

Deep-sea corals

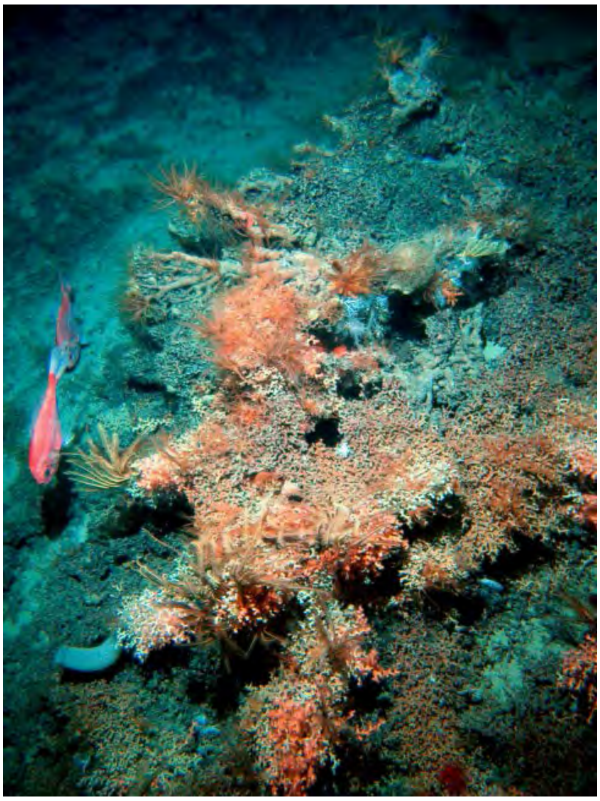
Di Tracey, NIWA

What is a coral: “Coral” is a general term used to describe several different groups of animals in the Phylum Cnidaria, so-called because of their microscopic nettle cells (cnidae) that sting or otherwise immobilize their prey for capture. Corals have hard skeletons made from calcium carbonate and/or organic compounds that make hard materials. This distinguishes them from their soft-bodied relatives like sea anemones and jellyfish.

Stony branching corals and associated invertebrate fauna (brisingid sea stars and glass sponges) on the flanks of a Louisville Seamount. A Baxter’s dogfish is in the foreground (NIWA DTIS image).

Anthozoans are the largest group of Cnidaria, with about 6000 living species worldwide. Their mouths open into a stomach cavity that is partitioned by mesentaries (membranes) that expand the inner absorptive surface. There are two subclasses: the Octocorallia, which have eight mesenteries and tentacles, and the Hexacorallia with tentacles and mesenteries in multiples of six.

The reef structures some corals produce are among the most spectacular ecosystems on the planet, supporting such rich biodiversity and such a high density of marine life that they have been referred to as the "rainforests of the sea." These ecosystems are usually associated with warm shallow tropical seas, however other coral communities thrive on continental shelves and slopes around the world, sometimes thousands of metres below the ocean's surface. These are referred to as "deep-sea corals" or "cold-water corals."



Stony branching corals and associated invertebrate fauna (crinoids and sponges) on the flanks of a Graveyard Hill Complex seamount, with orange roughy to the left of the coral reef matrix (NIWA DTIS image).

A plethora of deep-sea corals in the southern Pacific: New Zealand boasts both warm-water corals with symbiotic algae (zooxanthellae) and deep-sea corals (azooxanthellate) growing at greater depths. At present 1126 cnidarian species have been recorded in New Zealand, of which 330 are still unidentified and/or undescribed. There are also 204 fossil species. In the north of New Zealand's Exclusive Economic Zone (EEZ) around Raoul Island warm-water corals reach their southern limit while along the adjacent Kermadec Ridge cold-water corals thrive at greater depths. Further south in the dark waters of Fiordland, the black coral *Antipathella fiordensis* grows at depths of only 15 to 50 m. The pink stylasterid hydrocoral *Errina* is also found in the sounds of Fiordland.

From small and delicate lace-like forms to massive and hard reef and tree-like structures, corals from the deep ocean have remained mysterious and out of sight to the public for decades. They are found on seamounts, slopes, on ridges and in canyons. In waters deeper than 200 m scleractinian stony corals, both solitary cup corals and the 3-D matrix reef-forming stony corals e.g., *Solenosmilia variabilis*, *Madrepora oculata*, *Goniocorella dumosa* - the most dominant branching stony coral, *Enallopsammia rostrata* and the endemic *Oculina virgosa* occur. Studies indicate the New Zealand region to be a hotspot for these framework building stony branching corals. These and other corals species often show a strong correlation with the location of deep-sea fish species and seamounts and often provide important habitat, refuge, or shelter for fish and invertebrates.

The list of protected corals in the Wildlife Act (2010) includes black corals (Order Antipatharia), gorgonian sea fan sea whip corals (Order Alcyonacea), stony corals (Order Scleractinia), Hydrocorals (Hydrozoa) and all species in the family Stylasteridae. These key groups are found in the deep sea along with sea pens, and the true soft corals.

Further south, the New Zealand Ross Sea Protectorate in Antarctic waters supports a diverse coral fauna with recent research surveys and observer bycatch data revealing the presence of cup corals (but no reef-forming species), the stylasterid *Errina*, and several gorgonian octocorals including Corallidae (precious coral), Isididae (bamboo corals), Primnoidae (sea fans), and Paragorgidae (bubblegum corals).

Research focus: Understanding the ecosystem role, function, and value of deepsea corals and associated fauna has become a priority topic for science managers and researchers in the last decade. To manage and predict potential impacts on deepsea corals we need to know what species occur where, in what form, and their age and growth rate, because deep-sea corals are often fragile and vulnerable to physical disturbance. Due to their worldwide distribution and the fact that some gorgonian and stony coral species can live for centuries, deep corals may serve as a proxy for reconstructing past changes in global climate and oceanographic conditions. The calcium carbonate skeletons of corals incorporate trace elements and isotopes that reflect the physical and chemical conditions in which they grew. Analysis of the coral's microchemistry has allowed researchers to reconstruct past oceanic conditions.

Discoveries of diversity: Corals have been sampled during research surveys and from observed commercial fishing voyages. Live footage of cold-water corals has been captured with NIWA's underwater deep-towed camera systems. Benthic habitat modelling of scleractinian habitat-forming corals have identified that depth and location relative to seamounts are the most important factors in determining their distribution, but organic productivity also plays an important role.

Anthropogenic impacts: Corals are widespread and abundant in our waters but vulnerable to human impacts. The continuing global decline in oceanic pH resulting from rising atmospheric carbon dioxide (CO_2) reduces carbonate ion concentration and saturation state, which are essential components of the $CaCO_3$ mineral from which corals build their skeletons. Recent work has highlighted that the increase in atmospheric carbon dioxide could lead to reduced calcification or dissolving of the skeleton structure, and weakening of the coral-reef structure. Currently live stony branching corals are being held in aquaria at NIWA to begin research on the impacts of ocean acidification on these organisms.

Electronic tracking of fish

Malcolm P. Francis, NIWA

'Fishstocks' are the fundamental units of management within the Quota Management System. Usually a Fishstock reflects a geographically and biologically defined fish population. Knowledge of the distribution and movement of fishes is important for accurately demarcating management units. For inshore and pelagic fish species, tagging is an important tool for determining the geographic distribution and boundaries of biological stocks.

Mako shark with SPOT tag on its dorsal fin (Photo: S. Tindale/ C.Duffy).

Thirty years ago, tags were simple and cheap: they usually consisted of a length of plastic tubing with an attachment anchor, and they were printed with a unique number and a return address. When tags were recovered and returned, they provided information on the fish's recapture position, but nothing about what happened between release and recapture.

Although simple tags are still being used, technological developments in this field have been enormous, with electronic tags now being used to provide a greater array and quantity of information than the simple tags did. Electronic tags may gather information on fish location, depth, temperature (environmental and internal), orientation, swimming speed and the local magnetic force. This information may be stored in memory for later retrieval, or transmitted via satellites to researchers. Satellite bandwidth limitations mean that transmitted data are usually only summaries of the archived data; tag recovery is required to retrieve a full, high-resolution dataset.

The spatial resolution of the location data obtained from electronic tags varies with tag type. Acoustic tags send out coded trains of sound pings that are detected by acoustic receivers deployed in the sea. Pings recorded by the receivers show the date and time that the fish was within the acoustic range of the receiver (usually less than 1 km). Acoustic tag use is therefore limited by the area over which receivers can be deployed and maintained, a challenging task given the exposed nature of the New Zealand coastline and the vulnerability of ocean moorings to storms. In New Zealand waters, acoustic tags have been attached to juvenile rig to monitor their use of estuarine nurseries, and to white sharks to determine how they use their habitat at aggregation sites near seal colonies.

SPOT tags transmit messages to orbiting satellites whenever their aerial is out of the water, thus providing position fixes that are usually accurate to within several kilometres, and often to within 1 km. These tags function anywhere in the world, but are only useful for fishes that come to the surface regularly, and that can be caught and restrained for tag attachment. SPOT tags have been deployed on the dorsal fins of white, mako, blue and hammerhead sharks, and on the tails of striped marlin and broadbill swordfish. Using the accurate position fixes obtained from SPOT tags, it is also possible to identify the environmental and habitat requirements of individual fish, such as sea surface temperature, ocean productivity, and seabed depth along the tracks.

White shark tagged with an acoustic tag (Photo: C. Duffy/ DoC)

Pop-up tags gather data on light, depth and temperature and store them in memory until a predetermined time (usually several months to more than one year) before they release themselves from the fish, float to the surface and transmit data to a satellite. Positions determined from the light levels (by estimating the time of dawn, dusk and midday) are not very accurate (errors may be more than one degree of latitude), but because pop-up tags can be attached with a tagging pole on free-swimming animals, they are easier to deploy than SPOT tags.

The tracks reconstructed from pop-up tags have proven extremely useful for identifying large-scale (international) migration patterns and routes, and the tags have also provided valuable information on vertical distribution and behaviour, particularly when the tags have been recovered after pop-up. Pop-up tags have been used to track white sharks to tropical islands north of New Zealand, and Australia, and porbeagle sharks caught as bycatch in tuna longline fisheries. They have also been used to estimate the release mortality of protected devilrays returned to the sea from purse seine vessels.

Malcolm Francis tagging a white shark with a SPOT tag (Photo: C Duffy/ DOC).

Malcolm Francis tagging a white shark with a popup tag (Photo: W. Lyon/NIWA).

Electronic tags are relatively large and heavy (but they are rapidly becoming smaller), and expensive (hundreds to thousands of dollars each), which limits their application. So far they have been used mainly for tracking large animals such as sharks, marlins and tunas, although small acoustic tags have been used successfully to track juvenile rig less than 40 cm long. Their expense means that sample sizes are necessarily small, but this drawback is balanced by the high quality of the data obtained. Much of the information provided by electronic tags is literally unobtainable in any other way, and has opened doors into our understanding of fish movement and behaviour.

Nearly every species that has been tagged electronically has travelled further and dived deeper than previously realised. Furthermore, electronic tags provide information on fish behaviour that helps us to interpret other fisheries data such as catch per unit effort. As batteries becomes better and lighter, and tags become cheaper because of the increasing quantities being produced worldwide, electronic tagging will become an important tool for a much wider range of fish species, and will provide important new insights into fish behaviour and stock structure.

For more information, see
White sharks: http://www.niwa.co.nz/coasts-and-oceans/research-projects/white-sharks
Mako sharks:
http://www.nova.edu/ocean/ghri/tracking/
(click on 'Mako sharks in New Zealand' on left sidebar under 'Projects', then select shark names near top of right sidebar)

Factors impacting the marine environment

Alison MacDiarmid, NIWA

To put fisheries into perspective, we should remember that fishing is only one effect that humans have on marine ecosystems. MacDiarmid et al (2012)[9] undertook an expert assessment of the impact of sixty-five potentially hazardous human activities on sixty-two identifiable marine habitats in New Zealand's territorial seas and 200 nautical mile exclusive economic zone (EEZ). They found that many of the biggest threats stemmed from human activities outside the marine environment itself. In fact the two biggest threats (ocean acidification and global warming) stemmed from human activities on an international scale.

Each habitat-by-threat combination was given a vulnerability score based on the assessment by habitat experts of five factors including the spatial scale, frequency and functional impact of the threat in the given habitat as well as the susceptibility of the habitat to the threat and the recovery time of the habitat following cessation of disturbance from that threat. Each threat was characterised as largely stemming from global human activities, catchment based activities, human activity directly in the sea or stemming from a mixture of two or more of these.

MacDiarmid et al (2012) found the two top threats, five of the top six threats, eight of the top twelve threats and over half of the 26 top threats fully, or in part, stemmed from human activities external to the marine environment itself. A number of threats to the marine environment derive from the net accumulation of greenhouse gases in the earth's atmosphere caused by the global burning of fossil fuels and reductions in forest cover. By a considerable margin, the highest scoring threat over all marine habitats was considered to be ocean acidification, a consequence of higher CO_2 levels in the sea. The second highest overall scoring threat was rising sea temperatures resulting from global climate change. The other seven threats deriving from global climate change all ranked 19= or higher and indicated the importance of international threats to New Zealand's marine ecosystems.

Threats deriving from human activities in catchments that discharge into the coastal marine environment were among some of the highest scoring threats to New Zealand's marine habitats. Foremost was increased sedimentation resulting from changes in land use. It was the third equal highest ranked threat over all habitats and was the highest ranked threat for five coastal habitats including harbour intertidal mud and sand, subtidal mud, seagrass meadows and kelp forest. Other threats deriving from human activities in catchments ranking 19= or higher include sewage discharge, increased nitrogen and phosphorus loading and heavy metal pollution. Three other highly ranked threats, (algal blooms, increased turbidity and oil pollution) stem in part from human activities in catchments.

Seven of the threats to New Zealand marine habitats ranking 19= or higher were directly related to human activities in the marine environment including fishing, invasive species, coastal engineering and aquaculture. The most important of these was bottom trawling which overall was the third equal highest ranking threat. The second highest ranking marine activity was dredging for shellfish which although destructive usually operates over a smaller spatial scale than bottom trawling. The third highest ranking threat caused by direct human activity in the marine environment was considered to be that posed by invasive species. The responding experts indicated that invasive species threaten forty-five New Zealand

[9] MacDiarmid, A.; McKenzie, A.; Sturman, J.; Beaumont, J.; Mikaloff-Fletcher, S.; Dunne, J. (2012). Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93. 255 p.

coastal and shelf marine habitats. Intertidal reefs in harbours are particularly vulnerable to invasive species and two further harbour and sheltered coast reef habitats are substantially affected. No benthic habitats on the slope or in the deep ocean are threatened by invasive species.

The study by MacDiarmid et al (2012) indicates that generally the number of threats to New Zealand's marine habitats declines with depth, particularly below mean depths of about 50 m. Reef, sand, and mud habitats in harbours and estuaries and along sheltered and exposed coasts were considered to be the most highly threatened habitats. The least threatened estuarine and harbour habitats were saltmarsh and mangrove forests. Slope and deep water habitats were among the least threatened and lowest ranked. The most threatened habitats were considered to be generally impacted by many threats and the least threatened habitats confronted by the fewest threats.

The results of the study by MacDiarmid et al (2012) may be useful in identifying which threats to New Zealand's marine ecosystems require the first and greatest management response and which habitats should be the first focus for management action.

7. How the Science is Used by Fisheries Managers

Why do we do all of the fisheries and marine science that we do? It's certainly not done in a vacuum, nor for its own sake – rather, it's to support New Zealand's Quota Management System (QMS) and to inform our international fisheries obligations (see "The Research Planning Process" in Section 5). Fish stocks fluctuate naturally even in the absence of fishing. In order to manage them effectively, we need to keep track of these fluctuations and adjust Total Allowable Catches (TACs), Total Allowable Commercial Catches (TACCs) and other fisheries management regulations accordingly. Under quota management, which has proven to be the most effective form of fisheries management worldwide, the need for science and continual adjustment to fisheries regulations is never ending!

In this section, we first provide some background on the obligations of fisheries managers under the QMS. This is followed by four articles on how the science is used in deepwater, inshore, highly migratory species and rock lobster fisheries.

How the QMS works

When determining how to best use the fisheries science results, as summarised in the annual Plenary reports, fisheries managers are guided by New Zealand's Fisheries Act 1996, which provides the legislative underpinning for New Zealand's Quota Management System (QMS). The Act sets out the fisheries management purpose, which is to provide for the utilisation of fisheries resources while ensuring sustainability. The Act obliges fisheries managers to base decisions on the best information available, taking into account uncertainties and acting with caution if information is uncertain, unreliable, or unavailable. A lack of information cannot be used as a reason to postpone or not make decisions. The available information can relate to fisheries science, economics, and social science. Further management guidance is provided by the relevant fisheries plans, which explain the management and monitoring approaches and objectives for different fish stocks.

Most, but not all of our stocks are managed under the QMS.

The following brief description of the QMS is adapted from http://fs.fish.govt.nz/Page.aspx?pk=81 and http://fs.fish.govt.nz/Page.aspx?pk=81&tk=400.

New Zealand currently has 100 species (or species groupings) subject to the QMS. These species are split into 638 separate stocks. Each stock is managed independently to help ensure the sustainable utilisation of that fishery.

Quota Management Areas (QMAs) for a species are determined on introduction of that species into the QMS. QMAs are based on a combination of biological and administrative factors at the time of introduction. The starting point for determining QMA boundaries for each species are the ten Fisheries Management Areas (FMAs) that define New Zealand's Exclusive Economic Zone (EEZ). Owing to the nature of fish populations some QMAs incorporate multiple FMAs while others cover only part of a single FMA. Managing fish stocks in QMAs allows us to maintain more control over population size so that we can more easily provide our Minister with advice on sustainable catch levels at a finer scale.

The fishing year for most fisheries is from 1 October to 30 September. However, the fishing year for rock lobster and southern blue whiting, as well as a few other stocks, is from 1 April to 30 March. The fishing year for Lake Ellesmere eels is from 1 February to 31 January.

Under the QMS, the Minister responsible for fisheries (currently the Minister for Primary Industries) is responsible for ensuring that fish stocks are maintained at or above a level that can produce the Maximum Sustainable Yield (MSY). MSY reflects the greatest yield that can be achieved over time while maintaining a stock's productive capacity, having regard to the population dynamics of the stock and any environmental factors that influence the stock. Controls are set so that the biomass level can support the maximum sustainable yield (B_{MSY}). This provides the conditions to maximise the yield of the fishery without compromising sustainability. Once the MSY is identified, the TAC of a stock at that time can be determined.

TACs, once set, remain in place for each of the following fishing years until amended. The Fisheries Act 1996 prescribes that TACs can only be amended at the start of the relevant fishing year. Despite this the Act contains provisions that allow the Minister, for a small number of stocks, to increase the TAC within a fishing year, for the remainder of that fishing year.

The Ministry provides advice to the Minister on the setting and allocation of TACs to each fishing sector. From the TAC an allowance is made to provide for recreational fishing, customary uses and all other fishing-related mortality of that stock. The remainder is available to the commercial sector as the Total Allowable Commercial Catch (TACC). This is the total quantity of each fish stock that the commercial fishing industry can catch for that year. Once the TACC is set the fishing rights are distributed to quota owners through the QMS.

How the science is used in deepwater fisheries



Vicky Reeve, Tiffany Bock and Michelle Beritzhoff, MPI

New Zealand's deepwater fisheries operate over a vast area of ocean, within which the deepwater fish stocks inhabit depths ranging between 200 m and 1200 m. Each deepwater fish stock presents its own unique set of challenges associated with its monitoring, assessment and management. However, for many of the major deepwater fish stocks, these challenges have largely been overcome. The comprehensive data that are collected and analysed each year is testament to the robust science foundation that underpins the management of New Zealand's deepwater fisheries.

Many of the key deepwater fish stocks support dedicated research surveys, which provide high quality fisheries independent data that allows stock status to be estimated with precision. The fisheries data collected during these research surveys is combined with data from MPI's Observer Programme and the commercial catch and effort reporting to inform estimation of stock status and biomass trends via stock assessments.

The quality of each stock assessment is ensured by the collaborative peer review process that takes place in the Fisheries Assessment Science Working Groups and annual Plenary. The review process provides for a high level of input from a diverse range of stakeholders. The level of scrutiny in these forums provides considerable confidence in the quality of the outputs used to inform management decision making.

Two leading deepwater fisheries where management decisions are underpinned by particularly robust science information are the hoki and southern blue whiting fisheries. Both fisheries are independently recognised as sustainable by the Marine Stewardship Council. The quality of the science information for these two fisheries, which is summarised in the Fisheries Assessment Plenary, has strongly supported their ongoing certification.

Hoki

For over 20 years two wide-area trawl surveys have been used to monitor New Zealand's hoki stocks. The surveys provide valuable information on the abundance of not only hoki, but also over 50 other species or species groups. In addition, two acoustic surveys take place regularly to estimate the biomass of hoki on their spawning grounds.

Regular comprehensive monitoring and assessment of the hoki stocks has enabled management decisions to be responsive to the natural fluctuations in stock size. The need for responsive action was crystallised when seven consecutive years of poor recruitment to the hoki stocks was observed. Between 2001 and 2007, the hoki catch limits were reduced significantly when the science information showed a substantial reduction in recruitment into the fishery. These decisions have effectively rebuilt the hoki stocks, which were assessed to be at or above the management target by 2009. Since then, the catch limits have been slowly and conservatively increased and the stock assessments continue to show that the stocks are in good health.

Campbell Islands southern blue whiting

A wide area acoustic survey has been carried out regularly since 1993 on the Campbell Island Rise to estimate the spawning biomass of southern blue whiting. These biomass estimates are combined in the stock assessment modelling with accurate age, sex, and length data derived from sampling by MPI's Observer Programme.

Significant year to year fluctuations in the recruitment of young fish to the population are particularly evident in the southern blue whiting stocks, and the level of monitoring allows annual variations in cohort strength to be tracked through time. The stock assessment also revealed a relationship between cohort strength and the growth rate of individuals within the cohort, whereby slower growth rates are observed for very large cohorts. Understanding the likely future growth rate of strong cohorts within the stock has enabled economic considerations regarding the optimal size of harvest to be incorporated into fisheries management, which increases the value of resulting decisions.

How the science is used in inshore fisheries

John Taunton-Clark, Stuart Brodie, Allen Frazer and Steve Halley, MPI

New Zealand's inshore fisheries include a diversity of species and fishing methods, which create a variety of management challenges. The diversity covers a broad spectrum from rock lobster, our highest valued export species, through to small-scale harbour fisheries for lower-valued finfish species such as mullet. Commercial fishing methods include hand gathering of intertidal shellfish, diving for paua, and bulk harvesting methods such as bottom long lining, set netting, Danish seining and bottom trawling taking a mix of finfish species.

One of the management challenges is that all fisheries sectors (Maori customary, recreational, commercial, and environmental) have strong interests in many inshore species, including iconic recreational species such as snapper and blue cod. Managing these shared fisheries for sustainability requires good scientific information, but informing the options for allocation of resource access between sectors requires a broader spread of social and economic information.

The level of information about inshore fisheries to inform management varies. Fisheries-dependent information is provided through catch and effort reporting, and plays a key role. Scientific research and directed surveys provide information independent of fisheries. Some higher value stocks can support more costly scientific programmes to inform more precise management approaches aimed at maximising value. Species like rock lobster have lengthy time series of CPUE data and the abundance levels relating to CPUE are well understood. This information underpins both the stock assessment and management decisions.

Other valuable stocks such as SNA 1 are well researched and rely on updated fully quantitative stock assessments and biomass surveys to estimate abundance and yield to inform management. Many other species and stocks are not as well understood, with reported catches being the primary indicator of fisheries performance and possible changes in abundance. The information about a stock is in large part reflective of the value of the fishery.

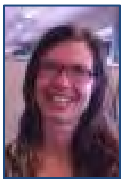
Fisheries science is the foundation for determining a range of management controls for individual species, including stock boundaries, catch limits, minimum legal sizes, daily bag limits, biological status, and the feasibility of allowing return to the sea alive. The scientific scrutiny applied via the Fisheries Assessment Working Groups and the Plenary process ensures that the information is of a high quality on which we can rely, and the Fisheries Assessment Plenary reports play a critical role in shaping management decisions. The ongoing adaptation of the Plenary reports to provide scientific information in a way that is more accessible for managers and the public is increasingly valuable as communities and sectors are seeking greater involvement in fisheries management.

For example, in 2013, the management of the valuable and important SNA 1 stock was reviewed for the first time since the late 1990s. An updated stock assessment was available (although characterised by some uncertainty) and it was one of the first times we had applied the Harvest Strategy Standard to such an important shared fishery. There was considerable debate about the status of the stock, the appropriate reference points, including the biomass target, and rates of biomass change under different catch scenarios. The scientific information in the Plenary report provided the stable reference to anchor discussions and decisions through a highly charged and contentious management decision process.

While further work is programmed to improve certainty of the science, and work is also need to update social, economic and cultural information, the Plenary reports will continue to provide the updated science as the foundation for the development of an agreed management approach and future decisions regarding SNA 1.

As noted above, many of our fisheries have less scientific information to inform management than a stock like SNA 1. Fisheries managers look to science to provide practical solutions to managing these ‘low knowledge’ inshore fisheries. Several operational policies for managing such stocks have been tried in the past – including the adaptive management framework, and the low-knowledge framework – with varying degrees of success. The Plenary reports provide the best scientific interpretation of the available data, as sparse as it might be. This information will continue to support management decisions, helping guide the necessary judgment calls where there is uncertainty and a lack of information.

How the science is used in HMS Fisheries

Arthur Hore and
Stephanie Hill, MPI

Highly migratory species (HMS) spend only part of their time in New Zealand waters, and may migrate over considerable distances. New Zealand cooperates with other countries to manage these species, notably through Regional Fisheries Management Organisations (RFMOs) including the Western and Central Pacific Fisheries Commission (WCPFC) and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT).

The main fishery groupings include large pelagic species such as bigeye tuna, southern bluefin tuna, and swordfish (pelagic fish are those which live near the surface or in the water column). These species form the basis of a valuable commercial surface longline fishery, which catches a range of tunas and other highly migratory species. Large pelagic species are also highly valued by recreational gamefishers, who fish for a wide range of species including marlins, swordfish, and tunas.

New Zealand vessels also take part in a commercial purse seine fishery for skipjack tuna both inside New Zealand waters (off the east and west coasts of the North Island), and elsewhere in the Pacific. The third main fishery grouping for highly migratory species is the commercial albacore troll fishery, which targets albacore tuna off the west coast of both islands over the summer months.

Highly migratory species vary in their biology, value, and harvest method. Each presents its own challenges with respect to ensuring that it remains sustainable and is utilised within acceptable environmental limits. The highly migratory nature of these species presents an additional challenge. The abundance of HMS in New Zealand waters is seasonal, and varies from year to year. If a stock declines globally, its availability is likely to decline in New Zealand waters too (sometimes more abruptly than in its core habitat; e.g. in tropical fisheries).

The Plenary reports for HMS document New Zealand's fisheries for HMS, summarise New Zealand's contributions into international science processes, and report on work done by WCPFC and CCSBT to assess their respective stocks. New Zealand's clear commitment to international scientific processes provides a strong base from which to advocate effective fisheries management of highly migratory fish stocks.

New Zealand fisheries managers use the science reported in the Plenary reports to:

- Advocate for sustainable management measures by RFMOs based on the science;
- Ensure that RFMOs take account of New Zealand's interests (for example to highlight the possible impact of high levels of fishing in the core range for species such as yellowfin tuna, which has become increasingly scarce in New Zealand waters);
- Enact regulations in New Zealand to implement RFMO outcomes; and
- Set domestic catch limits and sector allocations.

How the science is used in rock lobster fisheries

Daryl Sykes, New Zealand Rock Lobster Industry Council

Encouraged by the Chief Scientist and CEO of the Fishing Industry Board I participated in my first Fisheries Assessment Working Group in the mid 1980s. It was a time when the politics of rock lobster fisheries management were routinely tense and occasionally confrontational and as an elected industry representative I very quickly came to understand that the best decisions (by both industry and Ministers) were always going to be made on the basis of good science. The strong partnership between scientists and lobster industry participants took some time to develop within the Working Group environment but for over two decades now has been a significant feature of rock lobster fisheries management in New Zealand.

The Working Group and Plenary processes overseen by the Ministry are characterised by three critical themes – accessibility, transparency and accountability. Whoever made the wise choice to encourage and enable working fishermen to sit alongside biologists and stock assessment scientists to ensure mutual understanding and to seek a proper balance between the practical, pragmatic and theoretical must be well pleased at how long the processes have endured and how effective they have been and continue to be. The inclusion of a peer review process to audit the quality of science being delivered by Working Groups anchors both the credibility and utility of the outputs.

Management decisions informed by rock lobster Fisheries Assessment Working Groups have enabled declines in stock abundance to be reversed and high levels of stock abundance to be maintained across most of the nine lobster stocks. The Working Groups have enabled effective input and participation by fisheries stakeholders and provided an environment for testing and encouraging innovative approaches to the design and function of data management and of operational management procedures. The Working Group process has also drawn the rock lobster industry into a far better appreciation of the importance of accurate and reliable record keeping and reporting and has initiated various investments in fine scale supplementary data collection.

The rock lobster Working Group and the Plenaries conducted under the oversight and guidance of the Ministry have set a secure foundation for management decision making. A critical factor in my view is that the processes encourage and require scientists to do good science – and do not allow them to confuse their core role with their personal management aspirations. This fairly reflects the New Zealand rock lobster industry approach to the management of lobster fisheries – '*the fisheries first, from them all benefits will flow*'.

The Working Group processes that sit behind the production of the Fisheries Plenary reports are of benefit to our fisheries, of benefit to the quality of scientific and stakeholder input and participation, and enhance the worldwide reputation of the New Zealand fisheries management regime. On behalf of the rock lobster industry I thank the Ministry for sustaining the opportunity and sincerely thank all of the personnel, historical and current, who collectively have secured the sustainable utilisation of our lobster fisheries.

8. How Well Are We Doing?

The section contains four articles relevant to an assessment of how well we are doing. While it is by no means comprehensive, it includes an interim update of the status of New Zealand's fish stocks, an evaluation of our Science Working Group processes, third party certification of our fishing practices, and a new graduate student's perspective based on what he learned at university compared with what he has experienced in the few months he has been working in MPI's fisheries science group.

Interim update of the status of New Zealand's fish stocks

Pamela Mace, MPI

This chapter provides an interim update of the status of New Zealand's fish stocks relative to the requirements of the Harvest Strategy Standard for New Zealand Fisheries, which was finalised in October 2008 (http://fs.fish.govt.nz/Page.aspx?pk=113&dk=16543). Normally, these updates take place in September/October once new information on highly migratory species and other species normally included in the November Plenary is available.

Originally, I intended to conduct my usual summary of the status of New Zealand's fish stocks from 2008 to the present, and compare this with the status of the stocks in the very first year (1985) of the Fisheries Assessment "Plenary". However, the Harvest Strategy Standard didn't exist then, so soft and hard limits and overfishing thresholds (see below) were not even defined, let alone being used as benchmarks against which to evaluate fisheries performance. Management targets were also largely undefined other than being loosely related to the modern concepts of balancing utilisation and sustainability and achieving Maximum Sustainable Yield (MSY).

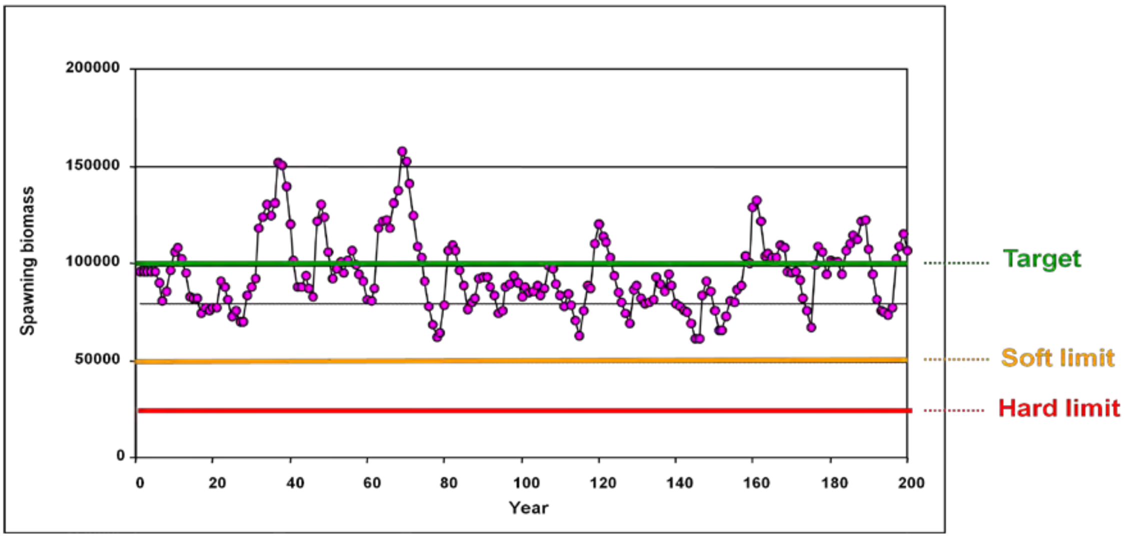
Essentially, in 1985, we did not know the status of most of our fish stocks and, even where we thought we did, in hindsight we were often wrong. For me, it was fascinating to go back and realise the phenomenal amount of research and knowledge we've managed to accumulate over the past 30 years.

Below, I briefly summarise the specifications for the Harvest Strategy Standard, then outline the stock assessment process and summarise the 2014 evaluations. Other articles in this volume provide greater detail on the Harvest Strategy Standard and fisheries management responses.

The Harvest Strategy Standard

The Harvest Strategy Standard (HSS) for New Zealand Fisheries (2008) guides the management of our fish stocks. It specifies four measures that are used to evaluate the status of New Zealand's fish stocks and fisheries, with management priority being on the first three of these:

- the *soft limit* – a biomass level below which a stock is deemed to be "overfished" or depleted and needs to be actively rebuilt;
- the *hard limit* – a biomass level below which a stock is deemed to be "collapsed" where fishery closures should be considered in order to rebuild a stock at the fastest possible rate;
- the *overfishing threshold* – a rate of extraction that, if exceeded, will eventually lead to the stock biomass declining below management targets and/or limits; and



- the *management target* – usually a biomass level,[10] but sometimes a fishing mortality rate,[11] that stocks are expected to fluctuate around, with at least a 50% probability of achieving the target.

The figure above shows the relationship between the *management target* and the *soft* and *hard limits* for a stock that is fished perfectly at a constant rate that tracks fluctuations in stock size. Fish stocks are expected to fluctuate around their targets with at least a 50% probability of achieving the target. This means that for well-managed fisheries at any given point in time approximately 50% of stocks should be above their management targets and 50% below.

The role of the management target is often misinterpreted by the media or incorrectly portrayed by some groups. Simply because a stock is below the management target does NOT mean it is 'overfished' or 'in danger', as is sometimes reported in the media. Stocks that are below biomass limits (the *soft* or the *hard limit*), or where *overfishing* is occurring are in greater need of management intervention and therefore these measures are more relevant in terms of reporting on management issues.

[10] Biomass targets are usually related to, or higher than, the biomass associated with the maximum sustainable yield (B_{MSY}).

[11] Usually the fishing mortality associated with maximum sustainable yield (F_{MSY}) or a related reference point.

More detail on the Harvest Strategy Standard is provided in Section 4.

Stock assessments

Each year, the Ministry for Primary Industries convenes Fisheries Assessment Working Groups that combine the results of scientific research with catch and effort reports from commercial fisheries, data from the Observer Programme, and other information to produce assessments of the status of New Zealand's fish stocks. This information is summarised in two annual Fisheries Assessment Plenary Reports.

There are currently 638 stocks in the Quota Management System (QMS). Of these, 292 stocks are considered to be "nominal" stocks (fish stocks for which a significant commercial or non-commercial potential has not been demonstrated[12]), leaving 346 QMS stocks, plus 16 Highly Migratory Species (HMS) for a total of 364 stocks or species that are included in this evaluation.

The number of stocks of known status relative to the four harvest strategy standard measures varies because, for example, while it may not be possible to determine whether a stock is somewhat above or below its *management target*, it may be clear that it is above the *hard limit*. In 2014, stocks of

[12] Many of these have actually been set up for administrative purposes only and the species itself may actually be rare or absent in some of its Quota Management Areas (QMAs).

known status relative to the *soft limit* accounted for 75.7% of the total landings by weight and value,[13] representing most of the main commercial fish species.

2014 evaluations

New results for 2014 and recent trends in the four harvest strategy standard measures have been compiled in terms of six variables:

i) the number of stocks falling above and below each of the four HSS measures in terms of raw numbers
ii) the number of stocks falling above and below each of the four HSS measures as a percentage of the total number of stocks
iii) the value based on port price of the stocks falling above and below each of the four HSS measures in terms of actual $
iv) the value based on port prices of the stocks falling above and below each of the four HSS measures as a percentage of their combined value
v) the weight of landings of the stocks falling above and below each of the four HSS measures in terms of actual tonnes
vi) the weight of landings of the stocks falling above and below each of the four HSS measures as a percentage of their combined weight

This gives a total of 24 graphs (available on request) which we felt was too many to include here. Instead, on the next page we have presented the graphs corresponding to i) and vi) above. Evaluations of the first three of the harvest strategy standard measures (see above) have been undertaken since 2009, while the last has been calculated since 2008.

The colour coding is as follows:

- Green – all good
- Yellow – continue to monitor
- Orange – develop a rebuilding plan
- Stippled orange – reduce the percentage of the stock that is harvested each year
- Red – consider closures (if they haven't already happened)

The graphs illustrate the following points.

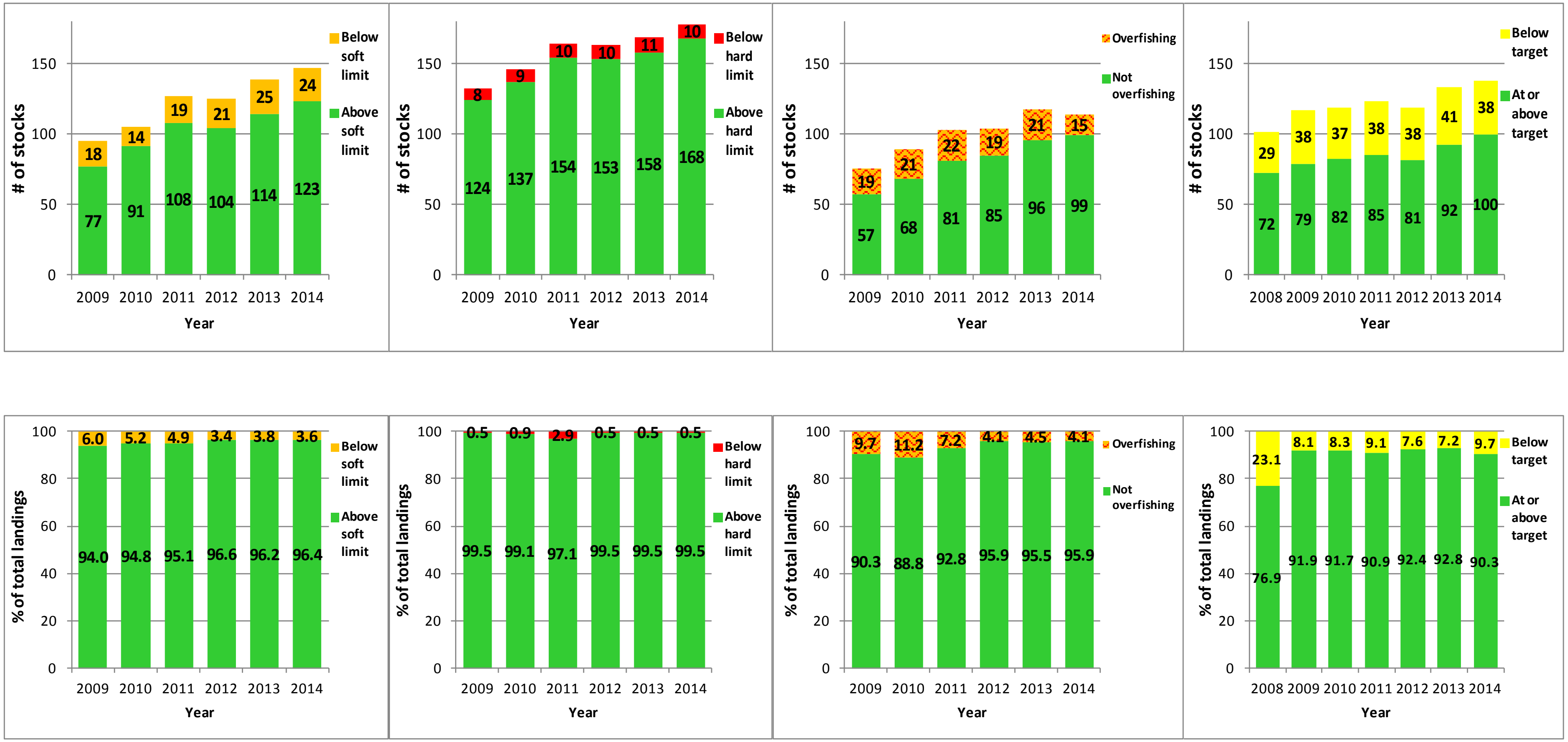
The top row shows that the number of stocks of known status with respect to each of the four harvest strategy standard measures has continued to increase over the last 5–6 years. This represents a concerted effort by Fisheries Assessment Working Groups to bring more stocks from "unknown" to "known" status. It is also evident that the amount of green far outweighs any other colour. In particular, there is relatively little orange and even less red. The yellow portion of the management target graph is far less than 50% even though a well-managed stock is expected to fluctuate either side of the target and to be below it about 50% of the time.

Presenting the stock status results in terms of the percentage of the total landings with good or "not-so-good" status (bottom row) results in a considerable increase in the relative amount of green and a substantial reduction in the amount of all other colours. In particular, there is virtually no red, as most of the fisheries that are below the hard limit have either been closed or have had their Total Allowable Catches considerably reduced.

When summarising overall stock status in terms of the actual numbers (or percentages) of fish stocks, the large number of relatively small fish stocks has a disproportionate influence on the overall result. For this reason, it is probably more appropriate to consider stock status in terms of the weight (or value) of the landings. However, by doing it this way, a single stock with very high landings (or value) can be highly influential. For example, the large reduction in the percentage of the landings made up of stocks below the management target between 2008

[13] This excludes squid, which has a life cycle that is not amenable to management relative to maximum sustainable yield benchmarks.

STOCK AND FISHERY STATUS INFORMATION BY NUMBERS AND PERCENTAGE OF TOTAL LANDINGS: 2008-14



The number of stocks (top row) and the percentage of total landings (bottom row) that are above or below the soft limit, hard limit, overfishing threshold and management target.

and 2009 (bottom row) is the result of the abundance of the western stock of hoki increasing from below to above the management target between those years.

Aside from the increase in the number of stocks of known status, there is little overall trend over the years 2008–14 or 2009–14. Comparing the results for 2014 with those for 2013, the biggest differences are marked improvements in the percentage of stocks where overfishing is not occurring (increasing from 82.1% to 86.8%) and in the percentage of stocks at or above the target (increasing from 69.2% to 72.5%). In all other cases, the direction of the differences is more mixed, but of smaller magnitude.

The main conclusion from these results is that by far the majority of New Zealand's fisheries are performing well.

An evaluation of New Zealand's Science Working Group processes

Paul Starr, fisheries science consultant

My involvement with the New Zealand Science Working Group peer-review process dates back to my first arrival in New Zealand in late 1991 and I have attended at least part of every autumn Plenary session since May 1992. Beginning in late 1999, I became involved with the Canadian Department of Fisheries' Centre for Science Advice Pacific (CSAP) process which reviews fish stocks on Canada's Pacific coast. More recently, I have also been part of the stock assessment review process for king crab and tanner crab stocks in Alaska. I can't claim to be authoritative in a comparison of the New Zealand peer-review process with the "remainder of the world" but my experience is international in scope and across a range of fisheries.

We are all familiar with the peer-review process that is used in scientific journals: two [usually] anonymous reviewers who provide written comment to the editor and the author[s], resulting in the eventual acceptance or rejection of the paper. The Canadian CSAP process emulates this model, inviting two reviewers to provide written comment in the context of meetings similar to our Plenary. After these formal reviews, the meeting attendees comment on the paper and then there is a discussion as to whether the paper is acceptable or needs rejection. This type of review process generally leads to an "all or nothing" choice: it is usually not possible to only accept part of a paper. Also, the paper will be in a late stage of development, making it difficult to change fundamental decisions in how data are handled or in key assumptions. Such a process might work reasonably well if the authors are very experienced and are aware of the important issues. However, this is often not the case and many of the required assumptions need some form of consensus before proceeding.

Some jurisdictions adopt a "feed-back" approach: the meeting reviews the paper and, following discussion, invites the author[s] to make adjustments to assumptions, rerun the model and present the updated results on the next day. This approach has been followed on the east coast of Canada and is often used for the Alaskan crab stock assessments I have been involved with: it works reasonably well as long as the models are relatively simple and the authors are willing to work late into the evening. Mistakes can be a consequence as well. More importantly, the complex Bayesian models which are considered standard here in New Zealand are not very amenable to this approach.

I would describe the New Zealand peer review system as "interventionist". That is, information is presented to a group representing a range of interests and technical expertise that we call the (science) "Working Group" (WG). This information can be at various stages of development for the project, from early conceptual stage to being nearly complete and ready for final approval. If the system is working well, important and/or complex projects will be reviewed several times through the course of development, from early beginnings to several iterations of intermediate results before the project is completed. This iterative process is crucial for gaining acceptance, allowing for feedback at an appropriate level of development and giving enough time for the authors to refine their work without undue pressure.

The American system I mentioned above is really a variant on the Canadian system, with projects being reviewed at a high level by external independent reviewers (often from New Zealand or Canada because of strong domestic conflict of interest rules). This review process, because it occurs once the project is completed, does not lend itself easily to adjustments to improve the analysis. Instead, criticisms can only be corrected the next time that fish stock is assessed.

The Working Group process we use here in New Zealand is not perfect (it requires a lot of meetings attended by individuals who have good understanding of the methods being employed), but I believe the quality of the output justifies the investment we make in the process. The evidence for this is the "good marks" we get when these projects are externally reviewed by invited international experts or through a certification process like the Marine Stewardship Council. We can be confident that the current system will deliver high quality peer review with resultant high quality stock assessments. The challenge will be to maintain that quality into the future!

Market-led fisheries sustainability

Geoff Tingley, MPI

The fact that New Zealand has based its fisheries management on high quality science has produced a number of long-term benefits to New Zealand and its fishing industry. Over the last two decades many markets have started requiring some guarantee that the fish they sell is coming from a sustainably managed source. Retailers, processors and fisheries managers had difficulty in proving this until the advent of the joint Unilever-WWF initiative that led to the foundation of the Marine Stewardship Council (MSC) in 1997.

The MSC Fisheries Standard is based on the UN FAO *Code of Conduct for Responsible Fisheries 1995* and *Guidelines for Ecolabelling of Fish and Fishery Products from Marine Capture Fisheries 2005/2009*. The Standard includes a number of fundamental principles, two of which are open consultation and transparency in considering the information used to manage the fisheries, and adequate peer review of the science used to underpin management advice.

These two principles were, and are, directly mirrored in New Zealand's approach to developing the scientific advice to manage our fisheries through the Ministry's Science Working Group (SWG) process that directly leads to the production of the Fisheries Assessment Plenary and the Aquatic Environment and Biodiversity Annual Review (AEBAR). The SWGs are open to all: government, industry, institutional and independent scientists, environmental NGOs and the general public, provided that they treat work in progress as confidential and behave constructively in accordance with the terms of reference. The inclusiveness of the SWG process exceeds the MSC requirement for transparency and goes a substantial way towards meeting the requirements for peer review of the science. This peer review process is further strengthened for novel or

contentious science as there is a second tier of peer review that can include international reviewers at the annual Plenary meetings or fully independent reviews by a panel of experts at special meetings.

The Plenary and its supporting processes, set up long before third-party sustainability certification existed for fisheries, was ahead of its time in providing high quality science and evidence-based fisheries management advice. It also creates an environment that enables productive partnerships to be developed and provides a sound basis for developing social licence in an area where there are environmental concerns.

The Plenary and its supporting processes have all played a significant part in enabling certification against the MSC Standard of many of New Zealand's fisheries. To date two fisheries for hoki, three for southern blue whiting and an albacore tuna fishery have been certified. Three fisheries for hake and six for ling are approaching the final stages of certification this year, and three orange roughy, two squid and three oreo fisheries are just beginning the process. This represents the majority of the deepwater fish caught in New Zealand, a considerable achievement for the industry-Ministry partnership that needs to continue to deliver this outcome to retain market access for New Zealand's fish.

A graduate perspective

Adam van Opzeeland, MPI graduate programme

Public perceptions are hard to change, especially when it comes to matters of science. The debate about public access to peer-reviewed science, and the way that matters of science are politicised and portrayed in the media, is a complex and ongoing one. As a recent science graduate entering the world of fisheries management, many of what turned out to be my own biases and misconceptions surrounding fisheries management have, encouragingly, been proven incorrect.

According to the 2013 Lincoln University "Environment Perceptions" study, New Zealanders identify marine fisheries (alongside freshwater rivers and lakes) as the resource area in the "worst condition". The study attributes this to scientific uncertainty and political contention over the performance of wild caught fisheries. Perhaps tellingly, marine fisheries also returned among the highest rates of "don't know" responses.

The history of global wild caught fisheries is littered with cautionary tales of unsustainable practice and poor management; and New Zealand has not escaped such examples. These past failures seem to have had something of a hangover effect on our perceptions; I know they have for me and many of my University cohort. Whether through apathy, ignorance or a touch of confirmation bias (one's tendency to look for, and rest on, information that confirms an existing bias), we have indulged in a tendency to dismiss national and world fisheries as a poorly managed, no-holds barred, indiscriminate race to empty the oceans.

It is an easy trap to fall into; a favourite television character of mine once professed that "it is easier to throw rocks at the building than to rebuild from the inside". Attacking policy and practice on the basis of environmental performance is not uncommon, and indeed can be an important and entirely justified practice. Understanding and learning from our mistakes is critical to future success. As students, by applying a little open-minded enquiry and a commitment to thorough, empirical research (a fundamental tenet of higher learning), we can better participate in and contribute to this process.

My experience of fisheries management here in New Zealand has been encouraging. Fisheries management systems are not, as is sometimes believed, devoid of science and governed by excess; but rather fundamentally anchored in, and further striving to foster good science. The modern precautionary approach focuses on applying well-understood techniques to fish stocks whenever the information is available, and employing technological advances and targeted science to better understand indirect and unknown factors wherever possible. Perhaps most encouragingly, scientists and managers are intent on, and at times desperate to, perform more and inform with greater levels of, scientific inquiry.

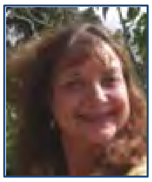
I remember specific dismissals of the QMS in my University years as an example of an archaic single-species approach to fisheries management, ignoring the ecosystem-wide consequences of species removal. This criticism appealed to me; I have great appreciation for the complexity of natural systems. Manipulating complex natural systems such as those of the world's oceans without full knowledge of the nature and degree of flow-on consequences seems short-sighted and even arrogant or barbaric.

To accept this idea and dismiss without further inquiry is easy (my own instance of confirmation bias...or perhaps a tendency to put aside the textbook and put on the Toga!), but short-sighted. I have come to realise that the QMS represents the application of a proven model for single species fisheries management increasingly informed by ecosystem science. The concentration is on applying science to what we know, and on best serving industry, commercial, recreational, customary and environmental stakeholders alike, within environmental parameters. Perhaps most importantly, there is a strong and growing emphasis on the wider aquatic environment; management strategies are informed by factors such as the by-catch of other fish, mammals and invertebrates; the benthic environment below; the migratory species visiting our waters; and the wider trophic effects of fisheries effort.

This year marks the 30th anniversary of the Fisheries Assessment Plenary; a scientific document used to inform the status of New Zealand's fish stocks and guide subsequent management actions. The occasion serves as an opportunity to reflect on the significant scientific, technological, systematic and managerial progress made, significant successes of our modern system, and the pride with which all New Zealand should consider our impressive marine environment. It should also be an opportunity to encourage our bright young minds to explore career opportunities in fisheries science and aquatic environment management.

Little old New Zealand has the 5th largest EEZ in the world, stewardship over important Antarctic marine environments, strong customary marine management and among the best fisheries management strategies in the world. Most importantly, we are constantly striving to do more good science, and to grow and protect our marine resources. Students in particular should be encouraged to take great pride in these facts; to explore and question the science, the management and the issues; and to keep pushing scientific inquiry further.

9. The Challenges Still Ahead



Pamela Mace, MPI

The main challenges have always been, and no doubt will continue to be, obtaining sufficient information to adequately assess the hundreds of fish stocks within and outside of the QMS as frequently as necessary, within a limited budget.

It is only possible to do a full stock assessment for a limited number of fish stocks each year. Therefore we need to prioritise the stocks that we assess in each annual assessment round. Species with the highest priority for new stock assessments tend to be those with the highest volume or value of landings, or those identified as having a potential sustainability risk or utilisation opportunity. But fish stocks fluctuate naturally even in the absence of fishing and unless they are being continually assessed, sustainability risks and utilisation opportunities may be difficult to identify. The problem of prioritising the research will only continue to increase as more stocks are added to the QMS.

Fish stock assessments can also be hard to do, particularly when there are limited amounts of data, or where the data are imperfect. For example, research surveys may not cover the full range of the stock, or commercial indices of abundance such as catch rates may not index stock abundance particularly well. More research, and more data, is always required. Ongoing improvement and development of survey technologies and our stock assessment modelling techniques, particularly for data-limited situations, continues to be an important challenge for the fisheries science community.

Another challenge is that of understanding the environmental effects of fishing. Much progress has been made in accumulating the relevant knowledge over the last ten to fifteen years but this work needs to be strengthened and applied to a greater range of bycatch species and habitat types that may be impacted by fishing gear.

As the use of the oceans for activities such as oil and gas exploration, mining, aquaculture, transportation, recreation and tourism accelerates, a more integrated approach to studying and managing the interactions and cumulative effects of these combined factors will be required. Land-use practices and their downstream effects on coastal fisheries and the environment is also a growing area of research.

On top of this, we are only just beginning to explore how long-term climatic changes in the marine environment might affect New Zealand's fisheries and the health of the marine ecosystem. Ocean acidification and other climate change risk factors in the sea present a challenge to researchers and fisheries managers, and distinguishing natural fluctuations from those caused by human actions remains difficult to do.

Last, but not least, there is a worldwide movement to progress towards an ecosystem-based approach to fisheries management whereby the species and the environment are considered together in a connected and holistic manner. Our current approach of managing each fish stock on a single-stock basis and then embedding this in the context of the rest of the ecosystem (by mitigating impacts on bycatch species and habitats) is a big step in the right direction.

However the challenge is to keep up with global developments in this field so that we are able to continue to provide a modern approach to achieving sustainable fisheries.

10. The People Who Have Made it All Happen

This section celebrates the scientists, technical, and non-technical experts from research organisations, academia, the seafood industry, marine amateur fisheries, environmental NGOs, the Maori customary sector and the Ministry for Primary Industries and its predecessors for their substantial contributions to our Science Working Group and Plenary processes over the years.

It includes:

- interviews with some of the scientists who were there at or near the beginning;
- thumbnail photographs and short biographies of many of the people who have made significant contributions to our Science Working Group and Plenary processes for a sizeable proportion of the last 30 years;
- a list of others who have also made significant contributions, but who we were unable to make contact with; and
- a list of MPI and former Ministry of Fisheries Science Officers, who have had the unenviable job of undertaking the nitty-gritty of pulling each Plenary report together.

To everyone who should have been acknowledged but hasn't been, we apologise sincerely for leaving you out. 30 years is a long period of time to cover and in our brainstorming sessions about who should be included, those of us who've been in this field for a long time had to truly stretch our memory cells.

Our thanks to each and all who have contributed.

Interviews with some of the scientists who were there at or near the beginning


Our two newest and youngest MPI fisheries science staff, Adam van Opzeeland and Adele Dutiloy, interviewed some of the scientists who were there at or near the beginning and made it all happen. The formation and early evolution of the fisheries Science Working Group and Plenary processes has never been fully documented. These interviews provide some valuable background. Each interview was conducted independently, yet they all offer many common perspectives. Importantly, each also provides new insights into how things actually happened.

We hope you enjoy reading about their experiences

Interview: John McKoy and John Annala – the early years


The Science Working Group process and subsequent Plenary documents have formed the basis of the New Zealand government's fisheries science for three decades, but how and by whom were they initiated?

We talk to two of the leading scientists involved in the genesis and early development of the Plenary and Working Group frameworks. John McKoy was a leader in the initiation and early development, and an important fisheries science contributor from the 1970s until the completion of his time at NIWA in 2010. John Annala succeeded him in running the programme from 1989 to 2004, and after a ten year absence he has recently returned to the fisheries science team at MPI.

The pre-Plenary days of New Zealand fisheries science operated in far different world; the nature and strategic direction of the science conducted was largely a reflection of the regulatory climate within which it existed. “Certainly in the inshore fisheries there were very few management rules and regulations. There were no quotas and little attempt to regulate effort. There were mesh sizes and a few closed areas, but that was about it”. The work at that time had greater freedom, but could be said to lack direction, as John McKoy recalls. “There was a lot of information gathered about growth rates, biomass etc., but we weren’t ever that clear about how it was going to be used.” There were yet to be strong links formed between fisheries research and fisheries management. “When we first started working in the whole area in the early 1970s, the research was not closely tied to management needs”.

There were several factors that drove the changes in the 1980s towards a structure and process more akin to what we recognise today. At the forefront of these was the shift to stock assessments and the adoption of an early concept of maximum sustainable yield. A sustainable fishery was based on observations of stable levels of catch over a given time period. “If it looked as if it could be sustained at a reasonable level over a reasonable period of time without much increase in effort...that was the kind of level that we could recommend”.

John Annala recalls an early Plenary-like precursor. “In 1982 or 83 Bob Francis from the US produced a document based on trawl survey estimates for deepwater species...that was the first quantitative attempt at estimating sustainable yields.” It was at this time that another driver and significant milestone was emerging on the horizon – the formation of what we now know as Individual Transferable Quotas (ITQs) under the QMS. “The whole process as we know it now really started evolving a few years before the QMS was introduced.”

With increased focus on the performance of some deepwater stocks, it became clear that the government was set to launch a quota-based policy. “That’s where the real idea of matching the research that was done to the management needs first started getting introduced.” As a reaction to a general feeling that there had been overfishing, the scientists were asked to consolidate their research to provide recommendations for possible TACs.

In the years preceding the 1986 launch of the QMS, scientists were tasked with compiling relevant research and reports to provide a basis for the recommendations. “Basically they were fisheries summaries that described the type of fishery, how much had been caught and the main methods and stuff like that. That became the main source of recommendations for the TACs.” It was from this scenario that the Working Group structure and Plenary documents emerged.

The Plenary documents were conceived both as a natural result of greater workloads, and as a way of ensuring that the scientific foundations of the recommendations were well-documented and readily available to all. John McKoy remembers that “each year we would have this round of producing a document ...but as more and more work was done the reports were getting bigger and bigger...that’s where the framework started...we wanted to include a good explanation of our research and science results.” So they split the document into a summary report for managers and a separate set of “working papers” for the work done to support their conclusions. These were the original Fishery Assessment Research Documents (FARDs), now known as Fisheries Assessment Reports (FARs). As John Annala recalls, “basically the initial Plenary reports were the FARDs stapled together.”

The word “Plenary” may not be literally applicable these days, as the Plenary meetings are usually smaller than in the past and not all stock assessments are subject to a Plenary meeting. John McKoy was happy to take responsibility for the use of the word, and explains the significance. "I think I can take the blame for that. You know how in conferences they have the separate themed sections and then the whole lot comes together for the "Plenary discussion"? We had Working Groups, and then an opportunity for everyone to come together to look at the results, so that's why we called it "the Plenary". It fitted well then, and the name has stuck."

Interview: John Annala and John McKoy – the evolution of the process

The Working Groups, Plenary meetings and documents have gone through substantial changes over the last 30 years. In the second of two articles stemming from interviews with two of the key scientists involved in the development of New Zealand's current fisheries science processes, John McKoy and John Annala, we focus on the evolution of the science and process. As the two Johns took us through the history, several important themes and landmark transitions arose.

A major change was the "opening up" of the process; a conscious decision by the scientists involved at the time to allow access to fisheries science for all stakeholders. This came about through the realisation that the scientific work they were doing contributed to a framework that affected a wide range of stakeholders and thus could not be "secret". "The initial discussions only included the scientists within the Ministry...one day we sat down and thought this is just silly, why not open the whole thing up so that everyone has the information?" This allowed for a wider and more open review of the ever-growing material being presented to the Science Working Groups and the Plenary meetings.

At the time this information was being used as a direct recommendation for setting TACCs. The prospect of opening up the process presented something of a trade-off between keeping the science and advice objective, and allowing the process to be open and transparent for all. John McKoy lists several benefits of the outcome: "1) The information was available to anybody so there weren't any worries about only a privileged few having access to the information; 2) to the extent that they [the stakeholders] wanted to be involved they were able to begin to understand the science process; and 3) they could actually bring in a range of other knowledgeable people to contribute to the science discussions."

The third point is one that both scientists see as having added major value to the process. "We had all sorts of people – all the best people from around the world that the industry invited (and paid for) to come and contribute." It was a matter of balance: on the one hand including stakeholders allowed for an open process and access to greater resources; on the other hand there were the inevitable scenarios when parties would push their own agendas. "We knew that the process would be used, that they would try to influence the process. So the only way to really deal with this was to be transparent."

Both scientists agree that this was an important and distinguishing factor of the New Zealand system: the ability to utilise transparency to allow wider participation and a strong critical review process. "There were pros and cons, but overall it had to be a good thing; it improved the quality of the science that we could do." This sentiment nicely encapsulates the evolution of the framework over the years; an organic growth in both the quantity and sophistication of the science input, with the quality of the science as the driving force.

In the years following the opening up of the science meetings, the role of science in fisheries management remained a centrally important component throughout the many changes in structure and environment. TACC setting became a more holistic process, with the wider stakeholder perspectives playing a more prominent role. "The scientific stuff was only a part of the things that the Minister needed to take into account when setting TACs. There were social, recreational, economic, customary and environmental factors". The movement away from exclusively internal funding sources and towards cost recovery drove a desire for industry to play a larger role in research planning, and added new elements to the management priorities. John McKoy highlights that throughout these changes, and as the whole process grew, transparency again emerged as a vital factor. "The only way I believe you can deal with these changes is to keep the whole process transparent and open".

Johns McKoy and Annala agree that the fundamentals of what was initiated 30 years ago remain in place today. The role of the scientists is valued. "It's not the scientists who make the decisions, but they provide the advice for the decision making framework. That's been maintained very strongly since then. Another source of pride is the thorough and readily-available nature of the scientific documentation. "The whole science process, from the beginning and even more so subsequently, was all incredibly well documented...you can track right back to the beginning and see what models were used and all of the steps the science went through."

Interview: Kevin Sullivan – MPI's Stock Assessment Science Manager

Rumour has it Kevin Sullivan has been around for every single Plenary. He can neither confirm nor deny such a statement: "that may or may not be true", he says. Upon further inquiry we find that he has indeed been around for the first 30 instalments, in one way or another. "I suppose I've been around for that long, I'm not sure I'll reach number 40 but, yes." We sit down with Kevin, the current manager of fisheries stock assessment science at MPI, to gain some insight into how his career in fisheries science came about, and learn of his perspective on the first three decades of the Plenary process.

Originally a geology graduate, Kevin entered fisheries science after being exposed to the not so glamorous prospects presented by oil companies. "One wanted to give me a job as a computer programmer and the other as a worker cleaning oil drums". A longstanding love of the ocean, fishing and surfing made marine fisheries a far more attractive prospect.

After completing his PhD in England during the early 1980s, he returned to New Zealand at a critical time for New Zealand fisheries science. "Some inshore fisheries had become depleted and the QMS was on the horizon". These early years (1984–85) were focused on inshore species yield estimates, utilising what was available of the last 30 years of catch data to set best estimates of sustainable yields. "Having the yield estimates on the table made the real difference because then we knew what we could sustain."

Kevin remembers the first Plenary meeting as a more informal affair to today's, with the scientists setting aside a week to get through all of the species. "It wasn't a matter of just turning up for your section; everybody was in the room so there were these massive meetings at Greta Point with 30–40 scientists all talking about each species". The meeting of the time was indeed a full Plenary, with all of the scientists bringing their work together for peer review. "We did have a full Plenary of scientists involved back then, so it was appropriately named".

The Kiwis led the way in Australasian fisheries science, conceiving a Working Group and Plenary process that served as the template for other models around the world. "It was very much a New Zealand effort...the Australians got involved in it in later years but they actually took the model and built their own system around it."

Over the years Kevin has played many different roles in the process, from being an active research scientist to managing the Working Group process. He is philosophical when asked to name his favourite role. "Well I enjoyed initially being an active research scientist, going out on surveys and gathering data. However, as I've moved into the management of the process I've been able to be involved in much more". Being able to work on a range of species has been a highlight. "Each species and each fishery has its own challenges, its own biology and history... it's been really nice to be able to chair a lot of different groups and get involved with a wider range of species and fisheries".

Reflecting on the process and how it has evolved, Kevin highlights the role of the Plenary in strengthening the links between science and management. "People consider the Plenary report as the definitive document on the science; if it's not in there then you can't use it for management." He also describes an important benefit to arise from the Working Group framework, "One of the great things about having people that are in many Working Groups is that there is a cross-fertilisation effect, in that an innovation that develops within one group can then be spread to the others."

This effect is exhibited in one of Kevin's favourite examples of a well managed species: the rock lobster. "We have this management system based on feedback mechanisms that are self-correcting to ensure they reach their target. So we have a situation now where most of the rock lobster stocks are in really healthy shape. It is something that is going to be implemented across more fish stocks." The turnaround of a depleted orange roughy stock is another management highlight, with the closure of the fishery, thorough scientific work and subsequent adjustment of management action proving effective. "We had to reconsider how well we were going managing the resource; the research we have done since has demonstrated recovery of the stock and we've since been able to re-open the fishery. Hoki is another example of a successful stock recovery." It is success stories like these that add to the satisfaction of a career in fisheries science. "It's been good; I've had one career and it's been in fisheries." Who knows, maybe he'll be around for that 40th edition yet..?

Interview: Rosemary Hurst – NIWA's Chief Scientist for Fisheries

As far as we can figure, Rosemary Hurst is second only to Kevin Sullivan in Plenary caps. An important contributor in the original and early rounds and near-constant presence in the decades since, Rosemary believes she has missed "at least one". Rosemary is currently the Chief Scientist of Fisheries at the National Institute of Water and Atmospheric Research (NIWA). Together with the Fisheries Research Division of the former Ministry of Agriculture and Fisheries (MAF), NIWA has provided by far the majority of the fisheries science that underpins the operation of the QMS.

We sit down with Rosemary to discuss her career as a fisheries scientist and the key role NIWA has played in contributing to New Zealand's fisheries science processes over the last 20 years.

A PhD in parasitology allowed Rosemary to study the components of the marine food chain and spend time collecting samples on research vessels. “I always had much more of an interest in the marine side of things; the whole idea of working in fisheries research really appealed to me”. So she left the parasites behind and joined MAF as a fisheries scientist in 1979. The next decade would prove to be an important one. “At that stage they were just starting to get geared up to the idea of being able to estimate potential yields...I was involved in developing quite a few of the original yield estimates for some of those species.”

Rosemary remembers the emergence of the Plenary meetings as a natural progression from pre-existing meetings of the scientists. “That first Plenary report was done because the QMS was going to be introduced, so they wanted all of the background information collated. We’d get together as scientists and have a meeting and then meet with the fisheries managers and discuss the options.” She highlights the evolution of the Working Group process in 1990, when the groups were opened up to outside and often international experts, as an important milestone in improving the peer-reviewed element of the process. “Outsiders ask questions that you don’t necessarily think of because you’ve been so familiar with the species or approach for such a long time. I think that’s been a real boost to the stock assessment process.”

Rosemary moved with the research division of MAF to NIWA in 1995; a move that she recalls as having pluses and minuses for the scientists involved, but that ultimately improved the level of science that could be contributed to the process. “We lost some of the close ties that we had with fisheries observers, fisheries managers and policy makers, but we gained the benefit of working in an organisation that was all about science.” Rosemary also highlights the access to fellow scientists in diverse fields, “NIWA has an extensive range of environmental scientists and some really good collaborations have developed over the years – my first experience being with the climatologists where we looked for causes for gemfish recruitment variation.”

It is this collaborative potential that Rosemary identifies as an encouraging prospect for the future of fisheries science, particularly in the development of ecosystem-based approaches to fisheries. “I think the exciting thing for us over the last couple of years has been having some NIWA core funding that we can put into developing these approaches.” She highlights the value of the NIWA setup in allowing scientists to take a broader, more holistic look at the factors driving marine ecosystem and species health. “NIWA is the ideal place to do that because we’ve got climatologists, oceanographers and benthic ecologists; bringing these disciplines together is essential to developing new insights and understanding of species interactions and ecosystem variability. Consistent with this holistic approach, Rosemary also heralds the recent work done by Jim Roberts and researchers from other organisations investigating the factors affecting sea lion populations; and the move to develop better methods to investigate the sustainability of some of the relatively data-poor by-catch species.

Rosemary is particularly proud of her work with hoki over the years; a species she has had a long association with after chairing the Working Group in the early years. “Right from the very beginning we had a good idea of what we wanted to achieve with the surveys and we developed standardised, statistically-rigorous approaches so that the time series would provide a valuable stock assessment tool”.. The 23 year time series of annual surveys of Chatham Rise hoki, hake and ling is a tremendous achievement and the wealth of data collected has also had enormous benefits for the development of environmental indicators and ecosystem studies.

You can read more about the 23 year Chatham Rise survey time series in Section 6.

Interview Paul Starr – fisheries science consultant

A common question posed in our interviews with contributing scientists has been what they consider to be important moments in the history of the process. It has generally been agreed that the "opening up" of the Working Groups in the early 1990s to allow external scientists and other knowledgeable participants to enter the process was a highlight and important driver of future progress. In our final interview, we sit down with Paul Starr, one of the first of these external scientists, to discuss this transition, and his experiences in New Zealand fisheries when he started out as a full-time science advisor to the New Zealand fishing industry.

After high school in Balboa in the Panama Canal Zone, Paul gained his undergraduate degree from Yale University – quite the launching pad! When he got his degree in 1968, the US government of the day left him with three options: serve in Vietnam, go to jail or emigrate to Canada! A passion for mountaineering and acceptance into the University of British Columbia to undertake a Masters degree, made British Columbia an attractive solution. After that, he took advantage of employment opportunities in fisheries, working 15 years for the Canadian Department of Fisheries and Oceans (DFO) as a salmon scientist. "Salmon are the ultimate migratory fish; it was actually a very cool job." Paul was involved for nearly a decade, first as a science advisor to the Canadian government during negotiations for a salmon sharing treaty between the US and Canada, followed by participation in a joint US/Canada science "Working Group" which provided the science advice used to implement the sharing arrangements, once the treaty was signed in 1985.

This work provided valuable experience in stakeholder management (including other fishery scientists), skills that no doubt came in handy here in New Zealand. Negotiating with the US was complicated because there are many parties that hold varying jurisdictions and frequently have differing interests in how the salmon species will be managed: this often led to conflicting positions within the US delegation. "In the US, jurisdiction inside three miles is given to the States, then you have the federal government for the outside waters, not to mention three or four different Native American organisations, so we were negotiating not just with the US, but with eight or nine groups, all of which seemed to have differing goals."

A recommendation from Paul's good friend and colleague Ray Hilborn led to a move to New Zealand. From Central America, through the Ivy League and via international salmon negotiations may not be the most natural or linear journey to working for the New Zealand Fishing Industry Board (FIB), but this was an interesting time to enter New Zealand's fisheries science scene. "They hired me to come and be a fisheries scientist/ consultant/ advisor. At that time the Science Working Group system was still developing; most who attended the Working Groups at that time were the government scientists. Ray Hilborn and Ellen Pikitch came for three weeks in 1990 and 1991 to do parallel stock assessments for hoki and Max Stocker (also from DFO Canada) came for 11 months, but he left in mid-1991."

The FIB liked having fulltime science advice, so Paul was initially seconded from DFO to New Zealand for two years to replace Max. Paul's approach to adapting to his new environment was immersion. "I went to every single Working Group meeting. I figured that the best way to learn about what was going on in New Zealand fisheries was to go to every meeting."

Paul has fond memories of the following years, collaborating with other external and government scientists, contributing to developments in New Zealand fisheries science throughout the 1990s and into the 2000s. "It was really a nice time...we had what I think was a very active and interesting process. A lot of the real impetus, in my opinion, came from us. It lifted the game. If it hadn't been so dynamic it wouldn't have been so good." Ray would bring his graduate students down to participate in the Working Group process, which exposed the students to tough but valuable learning experiences. "We had these students, some of them were really very good. They were thrown into these meetings, sometimes having to go head to head with top scientists like Chris Francis."

Although cautioning that situations differ greatly between regions and species, when asked to make international comparisons, Paul gives credit to the iterative and inclusive nature of the New Zealand system. "Here you have the Working Groups operating an iterative process...there's an effective feedback system. Over time western Canada has moved towards what we do here."

Paul identifies rock lobster as "my high point, no question". As part of the initial team when the Rock Lobster Industry Council obtained the rock lobster research contract in 1997, Paul along with NIWA scientists and other independent scientists, has been involved in the rock lobster scene ever since. "Rock lobster is probably the New Zealand success story, in my opinion". He is particularly proud of the integration of fisher-collected data with a sophisticated stock assessment model, and the development of "management procedures" (a form of feedback control) which are used to manage the species. "It is an unusual approach, but a good example of how, with science working co-operatively with industry, you can do a lot better."

Since 2000, Paul has been what he describes as a freelance (consulting) fisheries scientist, migrating seasonally between the Canadian and New Zealand summers and providing advice to the fishing industries as well as the governments in both countries.

Paul compares the Science Working Group process in New Zealand with those he has experienced overseas, in his article in Section 8.

Interview: Martin Cryer – MPI's Aquatic Environment Science Manager

Martin Cryer, aquatic environment science manager at MPI, opens our interview with a happy admission of peculiarity. "I'm one of those really weird people who has always known what he wanted to do". From the time of his mid-teens he had a specific direction planned; "I didn't want to be a fish biologist or somebody who worked in the sea specifically, but to work on the human interaction with the fisheries."

Following a semi-vocational degree in applied ecology, which allowed a stint at MAF in the UK, and a PhD in freshwater fisheries, Martin escaped the Thatcher-tyrannised climate of Mother England for the promise of far flung antipodes. "There was a job advertised at the University of Waikato- something I'd never heard of – and that looked interesting. I'd never been to New Zealand before." New Zealand was a perfect fit, and following that first visit Martin spent the next year or so finding a way to come back. "I just realised I'd been born in the wrong country – it was just a revelation; the fishing and hunting opportunities, the state of the fisheries here – even in the 70s and 80s was far better than the UK." He eventually found his way back, and gained a four year contract with the Department of Internal Affairs to do the first two stock assessments on Lake Taupo in the 1980s.

A move to Auckland marked a return to marine fisheries and what was the Ministry of Agriculture and Fisheries (MAF) in 1990, and he has worked at either the various iterations of MAF, or at NIWA, ever since. Martin has played several roles in fisheries science, from stock assessment scientist to fisheries manager. Even in early years the subject of the wider environmental effects of fishing was one he felt strongly about, but it took time for the topic to rise to prominence. "When I started with MAF in 1990 there was a little bit of work being done on the impacts of trawling and dredging but we were told pretty straight out – don't get involved... there's no issue – leave it alone". As the scientific knowledge concerning environmental effects grew, so did the public interest, and by the late 1990s there was an Aquatic Environment Working Group (AEWG).

The modern iteration is chaired by Martin (for protected species issues) and Rich Ford (everything else), and differs from the other Working Groups in design and tone. "It's quite different to the other Working Groups as it is the environmental effects of fishing rather than the fish stock status. It gets a wider variety of attendees and topics than the fish stock Working Groups." Many of the issues dealt with have strong ethical factors to consider, creating passionate discussion within the Working Group and a challenging atmosphere. "When you combine that passion with the uncertainty of the science that's when you have the most dangerous and difficult review issues to deal with." Martin offers a simple answer to dealing with such an environment. "That's where good science comes in, the more science you can have, the more buy-in, and the more likely that better and logical management decisions can prevail."

The Aquatic Environment work has its own annual review document where the impacts of all fisheries combined on a particular seabird or benthic habitat are considered, but the Working Group also contributes to the May Plenary. "What goes in the Plenary is basically the impacts of a fishery for a particular species on the aquatic environment – all of those things that are useful if you are trying to understand a fishery." The role of the AEWG has grown significantly over time, and is now important in providing the fundamentals of ecosystem science within which all other work exists, utilising improvements in tools such as risk assessments. "I think we've got quite a good system, we are on the first rung of a ladder of an ecosystem approach...I think public expectation is that we will move a bit further into a holistic system, and that's what I've focused on over the last five years."

Martin highlights the strength of the wider Working Group framework, and particularly the prominence of the science in the process. "We always try to make decisions based on the best available information...we've got a really good system for making sure the science is as good as it can be. It has definitely evolved over those 30 years and we've become better at it." An achievement of which Martin is particularly proud is the development of a system of recreational fishing estimates for a wide range of stocks. "We've moved over the last 20 years from a situation where we did a nationwide diary survey that could not really be tested, to a point now where we are by quite a long way the best in the world. Even the Australians acknowledge this!"

(You can read more about the development of recreational catch estimates in Neville Smith's article "Marine recreational fisheries research".)

Perhaps a last word to sum up how much Martin has enjoyed his career should concern the two species with which he has worked the most – scampi and scallops. "They are interesting creatures, every time you think you've got a handle on them they'll come up with another twist and a turn... a constant reminder that even when things look fairly well sorted out there is still more to be done and you could be wrong. There are always surprises in this job."

Brief biographies of the people who have made substantial contributions

Adam Dunford has worked as a fisheries acoustics scientist at NIWA since 2000. His work on acoustic target strength and fisheries acoustics methods has supported stock assessments for roughy, hoki, oreos and southern blue whiting.

Adam Langley is a fisheries scientist currently working at Trophia. He has participated in the assessment process over the last 25 years and is currently primarily involved in the monitoring and assessment of a range of inshore finfish species.

Adrian Colman was involved in compiling the 1985 stock assessment and in the assessments of a number of fish stocks in this and subsequent years through to 1997.

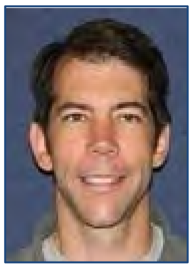
Alan Hart is a fisheries biologist who has been working at NIWA as well as for the Ministry of Fisheries and Ministry of Agriculture and Fisheries since 1987. Alan has provided input into Plenary reports over that time including random trawl survey results, age and growth estimates, orange roughy egg production, and acoustic survey results and target strength results for use in the stock assessments of orange roughy and for black and smooth oreos.

Alan Riwaka has been working for Te Ohu as a senior analyst since 2000. During this period he has had involvement in most of the Science Working Groups run by MPI. In more recent years Alan has focused most of his attention on inshore stocks such as rock lobster, paua, and scallops.

Alicia McKinnon is a Senior Fisheries Analyst working at MPI since 2003. Her primary contribution to the Plenary process has been to provide fisheries management advice for the stock assessment of rock lobster.

Alison MacDiarmid is a marine ecologist working at NIWA since 1987. Her primary contribution to Plenary reports has been to assist in the early stock assessments for red cod and chairing the Middle Depth Stock Assessment Working Group for a period in the early 1990s.

Alistair Dunn is a Fisheries Modeller and Programme Leader, working in Fisheries Stock Assessment and Monitoring at NIWA and has 17 years involvement in statistical analysis and mathematical modelling of fish, fisheries and other biological data for stock assessments, experimental design and, more recently, development of ecosystem approaches to fisheries.



Allan Hicks worked for NIWA from 2001 to 2002 and contributed to deepwater and middle depths stock assessments and research. From 2004 to 2007, he worked with SeaFIC and contributed to orange roughy stock assessments and research.

Allen Fraser has worked in MPI and its predecessors for 20 years and is currently a Team Leader with the Inshore Fisheries Team of MPI. He has participated in shellfish Fisheries Assessment Working Groups and has relied on the Plenary reports to guide decisions on fisheries management interventions.

Andrew Penney was Special Projects Scientist at the Ministry from 2007 – 2011, during which he chaired the Adaptive Management Programme's Working Groups and co-chaired the Rock Lobster Working Group. His contribution to Plenary reports has been reporting on status of species under adaptive management programmes, and developing the Research and Science Information Standard for New Zealand's Fisheries and stock status reporting templates together with the Chief Scientist.

Arthur Hore has worked at MPI (and its predecessors) since 1983 on the management of inshore and highly migratory fish stocks. He has had involvement in domestic and international science processes during that time and more recently has taken an active role in the HMS Working Group and planning research for highly migratory species. International involvement includes participation from time to time in science processes operated by the Western and Central Pacific Fisheries Commission and the Commission for the Conservation of Southern Bluefin Tuna.

Ben Sharp has developed a risk assessment framework for incidental seabird mortality associated with fishing in the EEZ. He has also chaired the Antarctic Fisheries Working Group which carried out stock assessments and evaluated the ecosystem impacts of the Antarctic toothfish longline fishery. He has been closely involved with the bioregionalisation study uderpinning New Zealand's proposal for an MPA in the Ross Sea.

Bob Zuur was Conservation Services Manager with DoC and then Marine Advocate for WWF. Bob sought to ensure that the Plenary reports provided an objective and honest assessment of fish stocks and associated species (which they invariably did!).

Brent Wood is a fisheries technician and GIS and database expert who has been working at NIWA as well as for the Ministry of Fisheries and Ministry of Agriculture and Fisheries since 1975. Brent's primary contribution to Plenary reports over this time has been to take part in trawl and acoustic surveys for inshore, middle depths and deepwater fish species, develop underlying fisheries research database systems and provide maps and plots of data for Plenary reports.

Bruce Hartill is a NIWA Fisheries Scientist who started with MAF Fisheries in 1991. Most of Bruce's contributions to the Plenary have been in relation to kahawai and recreational fisheries.

Cameron Walsh has worked in fisheries research since 1990, firstly with the Ministry of Fisheries, then NIWA and now with Stock Monitoring Services. His contribution to Plenary reports has been primarily in providing information for stock assessments for northern inshore species such as snapper, trevally and tarakihi.

Cath Wallace is an economist and public policy senior lecturer with a particular interest in environmental and fisheries management and institutions. She co-represented the Environment and Conservation Organisations of New Zealand, ECO, at fisheries meetings pressing for ecosystem-based management, for consideration of non-harvest as well as harvest values of fish and for an awareness that we will mostly be better off with more fish in the sea.

Chris Francis, Principal Scientist in the Fisheries Modelling Group at NIWA has been making significant contributions to fisheries stock assessment theory and delivery since he joined the Fisheries Research Division of MAF in 1976, contributing an estimated 70 stock assessment reports before his recent semi-retirement. He designed the concepts and mathematical models used in NIWA's stock assessment tool CASAL.

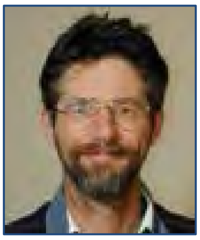
Chris O'Brien was a scientist working at MFish from 1997 to 2004, coordinating the research, assessment and advice processes for a range of programmes including inshore finfish, shellfish, pelagics and the aquatic environment. He was also Chief Technical Officer for Marine Biosecurity from 2000 to 2003.

Clinton Duffy has worked as a marine technical advisor and scientist with the Department of Conservation since 1989. He has contributed to Plenary reports as an early member of the Inshore Fisheries Assessment Working Group, the Science Working Group and through his research on age, growth and reproduction of blue sharks and shortfin mako.

Daryl Sykes has been actively involved in the fishing industry since 1971. During a twenty year career as a professional rock lobster fisherman, Daryl had various industry representative roles including with the New Zealand Federation of Commercial Fishermen and the New Zealand Fishing Industry Board. He was a founding member of the New Zealand Rock Lobster Industry Council and is the current Executive Officer and research programme manager.

Dave Allen began his involvement with the Fisheries Assessment Working Groups in 1989 as a fisheries scientist in MAF Fisheries, and between 1995 and 2009 as a Senior Fisheries Advisor with the Ministry of Fisheries. He has continued his role as an independent contractor for his company Aquatic Natural Resources Ltd. Dave has extensive fisheries management experience in inshore shellfish and finfish fisheries, and freshwater fisheries (particularly eels).

Dave Banks worked since 1979 in fisheries sciences (Fisheries Research Division and NIWA and then more latterly until 2010 at SeaFIC) contributing to Inshore, Middle Depth, Deepwater, Observer, Non-fish Bycatch and Fisheries Data Working Groups, as well as providing science advice (data issues) and occasionally acting as chair of the Rock Lobster WG.



David Gilbert (deceased) was a fisheries modeller, with NIWA and its predecessors with 30 years experience in fisheries population modelling, mark-recapture analysis, applied statistics, snapper fisheries, risk and analysis.

David Middleton is a fisheries modeller who has worked at Seafood New Zealand, and formerly the Seafood Industry Council, since 2004. His primary contribution to Plenary reports has been to provide peer review and oversight on behalf of quota owners.

Derrick Parkinson is a Principal Technician working at NIWA and its predecessors since 1979. His primary contribution to Plenary reports has been in the leading of trawl and dredge surveys to assist in stock assessments for snapper, scallops and scampi.

Di Tracey is a fisheries scientist who has been working at NIWA as well as for MFish and MAF since 1979. Her primary contribution to Plenary reports has been to provide random trawl survey results and biological information, such as age and growth and reproduction, for use in the stock assessments of deepsea fish species, primarily orange roughy, and black cardinalfish. More recently Di has contributed to the Environmental & Ecosystem Considerations sections of various Plenary reports (e.g., Benthic interactions).

Don Jellyman was a freshwater fisheries scientist working at NIWA from 1992 until his retirement in 2012 – prior to that, he worked for the Ministry of Agriculture and Fisheries. His primary contribution to Plenary reports has been to assist in stock assessments for freshwater eels.

Don Robertson has made significant contributions within MAF Fisheries and NIWA since the early 1980s, including working with John Annala and John McKoy on the early development of the Stock Assessment Working Group/Plenary process and the integration of the results into fisheries management. From 1985–95 he was Convenor of the Orange Roughy-Oreo Stock Assessment Working Group and between leading the initiative to design, fund and build the fisheries research vessel *Tangaroa*.

Doug Jones is a Senior Analyst, Freshwater and Marine at Te Ohu Kaimoana and Te Wai Maori Trust since 2011. His primary contribution to Plenary reports has been as a member of Eel Science Working Group.

Elizabeth Bradford joined Fisheries Research as an Applied Statistician in late 1992 and retired from NIWA in early 2012. Her contributions to the Plenary reports involved analysis of data from various Pelagic, Recreational, and Inshore fisheries, including showing the trends over time where there was sufficient data.

Gavin Macaulay was a fisheries acoustics scientist at the Ministry of Agriculture and Fisheries and then NIWA from 1994 to 2009. His primary contribution to Plenary reports has been in the development and application of acoustic techniques to stock assessment surveys of orange roughy, hoki, southern blue whiting, and black and smooth oreos.

George Clement, formerly a management scientist with Ministry of Agriculture and Fisheries, has worked for industry as a scientist and fisheries manager since 1992 and has been an active participant in the Science Working Group processes since they commenced.

Glen Carbines is a stock assessment scientist working at MAF/NIWA since 1992 and for Saltwater Science Ltd since 2010. His primary contribution to Plenary reports has been in the stock assessments for blue cod, but has also assisted with snapper, cockles, scallops and toheroa.

Graeme McGregor is a senior fisheries analyst working at MAF, MFish, and MPI since 1982. His primary contribution to Plenary reports has been to assist in providing a management perspective.

Graham Patchell has been involved in New Zwaland stock assessment programs and Plenary since the first meeting in 1985, working for Fisheries Research Division and contributing to 5/28 papers reviewed that Plenary. Working in the seafood industry from 1987, this involvement continued through the following 30 years, helping to ensure quality science input to assessments.

Greg Johansson has been involved with vessel management with Sanford's since 1991 and has facilitated numerous research cruises and data collection programmes on board commercial fishing vessels.

Greg Lydon was the Science Officer at the New Zealand Seafood Industry Council Ltd (SeaFIC) from 2000 to 2012. His primary contribution to Plenary reports was peer review of inshore fish stocks and freshwater eels and the environmental effects of fishing.

Helen Neil is a geologist and isotope geochemist working at NIWA since 1996. Her primary contribution to Plenary reports has been to assist in age validation and life history across a range of species including paua, bluenose, oreo, snapper, hoki and black cardinal fish

Ian J. Doonan's main contributions have been on orange roughy (since the late 1980s) and smooth and black oreo (since 1995) with work on biology, analyses of catch, stock assessments, and design and leadership of trawl and acoustic surveys. In the 1990s, he worked on Foveaux Strait oyster analyses and the design and running of dredge surveys; Tasman Bay, Golden Bay and Marlborough Sounds scallops analyses and dredge surveys; and also on the design and analysis of surf clam dredge surveys. Ian has also had minor involvement in albacore, kahawai, trevelly, incidental catch of Hooker's sea lion, and scampi bycatch and CPUE.

Ian Hampton is co-director of Fisheries Resource Surveys, of Cape Town South Africa who, in association with the Clement Group, Auckland New Zealand**,** has been working since 2001 on the development and implementation of acoustic survey techniques for the assessment of orange roughy biomass from commercial vessels, primarily on the Chatham Rise and Challenger Plateau.

Ian Tuck is a fisheries scientist working at NIWA since 2006. His primary contribution to Plenary reports has been through conducting stock assessments for scampi, and contributions to the environmental and ecosystem considerations sections, through work related to the Aquatic Environment Working Group.

Ian West worked for the Fisheries Research Division of MAF and then NIWA from 1973 until 1991, and then for the Research Group in DOC from 1995 until 2008. His primary contributions to Plenary Reports have been on catch sampling techniques, fish ageing research and protected species.

Jack Fenaughty ran many of the deepwater trawl surveys aboard research and commercial vessels during the 1980s and early 1990s and was involved in the subsequent stock assessments before leaving the public sector and working on the industry side of fisheries.

Jo Akroyd is involved in the assessment of New Zealand fisheries (hoki, southern blue whiting, hake and ling) as sustainable fisheries certified by the Marine Stewardship Council. This involves reviewing stock status, reference points, harvest strategies and the assessment of stock status since 2001.

John Annala has worked in fisheries since 1974 making significant contributions including working with John McKoy and Don Robertson on the early development of the Fisheries Assessment Working Group/ Plenary process and leading the Science Group at MFish from 1995 until 2004. He was the editor of the Plenary report from 1989 to 2004 and from 2004 until 2014 he was Chief Scientific Officer for the Gulf of Maine Research Institute in Maine. He is currently a Principal Scientist at MPI working on Highly Migratory Species.

John Booth was part of the stock-assessment team for rock lobsters from the early 1990s to 2005, providing biological context for the evaluations. His most important contribution was development of a recruitment (puerulus settlement) index.

John Holdsworth is a founding director of Blue Water Marine Research Ltd (1997). He has contributed to Plenary reports on inshore and high migratory species primarily in regard to catch and effort by amateur fishers.

John McKoy has more than 37 years experience in fisheries, making significant contributions including working with John Annala and Don Robertson on the early development of the Fisheries Assessment Working Group/Plenary processes and being National Research Director of Fisheries at MAF between 1987 and 1995 when he became General Manager of Fisheries Research at NIWA. He now runs his own fishery consultancy company.

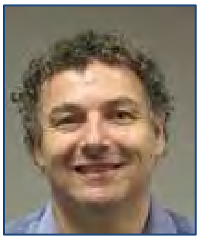
John Taunton-Clark has held various positions in New Zealand's fisheries management agencies since 1996. While primarily a user of the Plenary report information, John has contributed a management perspective to Plenary reports on inshore, deep water, and highly migratory stocks.

Julie Hills is a principal fisheries scientist with the Ministry for Primary Industries. In the last five and a half years Jules has chaired the Shellfish Working Groups and she co-ordinates, implements and manages research that applies to the paua, scallop and oyster fisheries. Her primary contribution to Plenary reports is organising the research that informs the shellfish Plenary reports and ensuring that reports are updated and reviewed

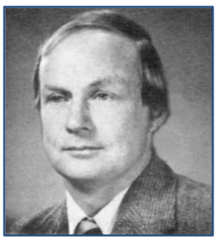
Keith Michael (fisheries scientist NIWA) led and contributed to research projects for the stock assessment of oysters, surf clams, scallops, queen scallops, paua, and blue cod fisheries since 1977. Research contributions mainly focused on biology, ecology, designing and running exploratory and assessment surveys. He also led and contributed to research projects to develop new commercial shellfish fisheries (queen scallops, surf clams, geoducs, and deepwater crabs). Much of this research and research to improve fishing gears and methods was undertaken collaboratively with the fishing industry.

Kevin Stokes was Chief Scientist at the Seafood Industry Council Ltd (SeaFIC) from 2000 to 2009. He contributed to numerous Working Groups in that capacity over those years and as a consultant in following years, as well as all Plenary meetings.

Kevin Sullivan has worked in the research and management of New Zealand's fisheries for over 40 years, working on a wide range of species and fisheries inside and outside the EEZ. For over 22 years he worked as a research scientist involved in the stock assessment of many species including snapper and hoki. For the last 17 years he has worked in a management role for the Ministry of Fisheries and more recently MPI, chairing the Fisheries Assessment Working Groups, reviewing the stock assessment advice from the researchers and managing the competitive tendering process for research contracts.



Kim George has been involved in fisheries research and data management for over 20 years; initially with the Fisheries Research Division of the Ministry of Agriculture and Fisheries (MAF), subsequently with NIWA and the Ministry of Fisheries (MFish) and currently, with the Ministry for Primary Industries. The Data Management team that Kim leads is intrinsically connected with the Plenary report as the team has a data stewardship role for much of the data used in the publication.



Larry Paul was a fisheries scientist at MAF and then NIWA until 2005. He contributed to inshore fisheries stock assessments from the mid-1980s onwards, writing or co-authoring the sections on snapper, groper, and school shark in the pre-Plenary and early Plenary reports. In the 1990s he wrote the Plenary sections for several of the new species introduced into the QMS, and did ageing studies on other QMS species.

Lynda Griggs has worked as a fisheries scientist at NIWA for over 20 years. Her primary contributions to Plenary reports have been provision of information on pelagic species including tunas.

Malcolm Clark is a Principal Scientist (Fisheries) at NIWA. He carried out research on many of New Zealand's orange roughy stocks in the 1980s and 1990s, and more recently has been focusing on deep-sea biodiversity, and the impacts of fishing on seamounts and deep-sea ecosystems.

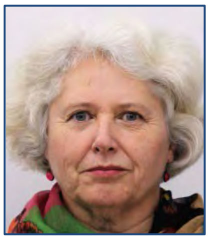
Malcolm Francis is a fisheries biologist who has worked for NIWA and its predecessors since 1981. He has contributed extensively to the stock assessment process for Inshore and Pelagic fishes, and occasionally the Aquatic Environment assessments of protected species, since the inception of the Plenary process.

Marc Griffiths is a stock assessment scientist who has worked for MFish/MPI since 2003. He has been responsible for research planning for inshore finfish and for chairing the following Fishery Assessment Working Groups: Inshore, Snapper, AMP, Northern Inshore, Southern Inshore, Eels.

Marianne Vignaux worked in the mathematical modelling group at MAF Fisheries from 1991 to 1995. She then worked for SeaFIC for a few years, before joining the Research Data Management group at the Ministry of Fisheries until 2011. She now edits the FAR and AEBR series for MPI.

Mark Maunder was a stock assessment scientist working at New Zealand Fishing Industry Board (1993–1995), Trophia (2000-present), and a consultant to various other organisations. His contribution to Plenary reports has been primarily related to stock assessments for snapper and rock lobster, but has been involved with several other species, and as lead programmer for the general stock assessment model Coleraine.

Martin Cryer has been involved in various aspects of fisheries science and management since 1977 (since 1983 in New Zealand). During that time, he has led or contributed to stock assessments for inshore and deepwater shellfish, freshwater and marine amateur fisheries, a wide variety of environmental effects of fishing, and, latterly, comprehensive ecological risk assessments.



Mary Livingston is currently a principal scientist at MPI in the Aquatic Environment (and Biodiversity) team. Her primary contributions to the Plenary reports were through the Hoki Working Group, and included running the Chatham Rise annual trawl survey programme at MAF and NIWA from 1983 to 2004; providing evidence that led to the assessment of hoki as two stocks rather than one; and showing that the proportion of female hoki spawning in a given year can be substantially less than 100%. Nowadays her main contributions are through her role in the Aquatic Environment team (at MPI).

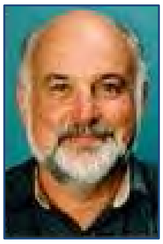
Matthew Dunn received his PhD from the University of Portsmouth (UK) in 1999, and after three years working at the Centre for Fisheries and Aquaculture Science (Lowestoft, UK), he came to New Zealand in 2003 to join the NIWA. While at NIWA, Matt worked on the stock assessment of several deep-water fisheries, and became manager of the deep-water fisheries group and a fisheries programme leader. Matt then joined Victoria University of Wellington in January 2013, as the inaugural holder of the MPI-sponsored Chair in Fisheries Science.

Max Hetherington (deceased) was involved in various aspects of fisheries management and science from the 1970s until his untimely passing in 2006. Max participated actively in Working Group meetings and Plenaries over many years and kept a high profile for his constituents, the recreational fishers and divers of New Zealand. He was a stalwart of the New Zealand Recreational Fishing Council and New Zealand Underwater Association, and was recognised by both organisations as such in the late 1980s with life membership.

Michael Manning (deceased) was a technician with the Seafood Industry, a Stock Monitoring technician and an Inshore Fisheries Scientist NIWA with 10 years experience Fisheries characterisation, CPUE and stock assessment, catch sampling, shark tagging, age and growth.

Michael Stevenson has provided trawl survey and ageing data to reports cited by the Plenary reports for about 25 years (since 1992). He also co-authored six reviews of trawl survey series which have been important to several Plenary reports.

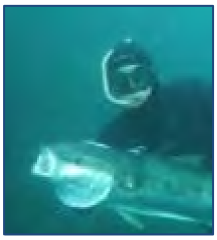
Mike Beentjes is a fisheries scientist working at NIWA since 1995. His primary contribution to Plenary reports has been to assist in stock assessments for freshwater eels, red cod, tarakihi, flatfish, blue cod, jack mackerel, and toheroa.



Murray H Smith was a statistician and fisheries modeller with NIWA working on CPUE analyses, catch at age and mortality analyses, design and analysis of acoustic surveys, and seabird and marine mammal bycatch analyses.

Nathan Walker has been involved in various Working Group meetings over a number of years. More recently Nathan has been more involved in the Aquatic Environment Working Group, including chairing the Working Group when it considers protected species related research.

Neil Bagley is a technician/ scientist with NIWA and its predecessors with 35 years experience with trawl surveys, middle depth species, trawl gear and fish tagging.



Neville Smith is involved in various aspects of fisheries science and management and has been for twenty years, joining the science team at MPI in 1998. He has chaired the Aquatic Environment, Aquaculture, Pelagic, Antarctic and Recreational Fisheries Working Groups, contributed to introducing effects of fishing information to the Plenary reports, developed Working Group reports for a range of pelagic species as they were introduced to the QMS and for toothfish as the Ross Sea fishery developed. Recently he has led work on recreational fisheries and integrating that information across the Working Group reports.

Nick Davies is a stock assessment scientist working firstly with the Ministry of Fisheries since 1986 and then at NIWA until 2008. His primary contribution to Plenary reports has been to undertake stock assessments for snapper.

Nokome Bentley is fisheries scientist at Trophia Ltd. He has contributed to Plenary reports for a variety of species including rock lobster, tarakihi, gurnard and sea perch.

Owen Anderson is a stock assessment scientist working at NIWA (and before that MAF Fisheries) since 1990. His primary contribution to Plenary reports has been in producing stock assessments for orange roughy fisheries.

Pamela Mace is a stock assessment scientist who worked in the Fisheries Research Division of the ex-Ministry of Agriculture and Fisheries during the formative years of the QMS in 1986–89 and then disappeared overseas until 2004 when she joined the then-Ministry of Fisheries. She has chaired Plenary meetings and various Science Working Groups and played a large part in compiling the Plenary reports ever since.

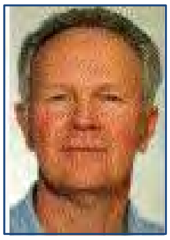
Pat Reid is co-owner and operator of Fisheries Audit Services (New Zealand) Ltd (18 years) and CEO of Area 2 Inshore Finfish Management Company Ltd since 2007. Her interests include inshore mixed fisheries management and increasing the role of fisher's information in stock evaluations.

Patrick Cordue started with MAF in 1987 and left NIWA in 2000 to become an independent consultant. His major contributions to Plenary reports were a decade of hoki stock assessment (pre 2002) and four orange roughy assessments in 2014.

Paul Breen was and is a stock assessment scientist who worked at MAF until 1995 and at NIWA until 2010, and then as a fishery science consultant for a variety of clients including the New Zealand Rock Lobster Industry Council, Deepwater Group, MPI and overseas governments. He has contributed to assessment work for lobsters, paua, geoducs, squid, toheroa, scallops and cockles.

Paul Grimes worked as a biologist at NIWA from 1995 to 2010. His contributions to the Science Working Groups and Plenary processes were to assist in the stock assessments for orange roughy, hoki and southern blue whiting

Paul Starr arrived in New Zealand in late 1991 to work as a Fisheries Stock Assessment advisor to the Fishing Industry Board and served as Chief Scientist for SeaFIC from 1997 to 2000. Paul became an independent contractor in 2000 and has worked continuously in New Zealand since that year for SeaFIC, Seafood New Zealand, various Industry stakeholder groups, MPI (formerly MFish), and NIWA.



Paul Taylor was a fisheries scientist at NIWA (currently with Statfishtics) with 30 years involved in pelagic fisheries biology, ecology, and stock assessments, use of aerial sightings data and surveys for estimating relative abundance indices of schooling pelagic species, and the development of methods relating the distribution of pelagic fish species to environmental features.

Peter Horn is a stock assessment scientist who has worked at MAF, MFish and NIWA since 1984. His primary contributions to Plenary reports have been to assist in stock assessments for hake and ling, and to develop productivity parameters for over 20 QMS species.

Peter (Chazz) Marriott is a principal Technician at NIWA, where he has worked since 1994. Key contributions to the Plenary reports include fish ageing from otoliths, radiometric validation of ageing techniques, fishery research voyages on the RV *Tangaroa, Kaharoa* and industry vessels, and crayfish and paua fishery sampling.

Peter McMillan is a fisheries biologist working at Ministry of Agriculture and Fisheries and then NIWA since 1980. His primary contribution to Plenary reports has been to assist in stock assessments for black oreo and smooth oreo.

Peter Smith was a fisheries geneticist at NIWA with 30 years New Zealand experience in the development and application of biochemical and molecular techniques to stock discrimination of marine fishes, population genetics and taxonomy of aquatic organisms; and the product and species identification of fish and shellfish.

Peter Todd was a scientist at MAF and MFish until 2008 and co-ordinated/ authored/ edited the chapters in Plenary reports for freshwater eels and shellfish.

Phil Kirk worked for MAF as a fisheries management/stock assessment scientist during the mid to late 1980s. He led work on SNA 7 stock assessment and was instrumental in setting up and running the WCSI and ECNI inshore finfish trawl survey series using the *RV Kaharoa*. He was also involved in preparation of the early flounder Plenary documents.

Ray Hilborn worked as a consultant to New Zealand Fishing Industry groups throughout the 1990s and 2000s and participated in Working Groups for many species. Along with other colleagues he developed the first Bayesian stock assessments for New Zealand fisheries, as well as the generalised stock assessment package Coleraine that served as a model for the NIWA program CASAL.

Ray Voller was a fisheries manager at MPI (and its predecessors) between 1973 and 2009. His primary contributions to Plenary reports was to assist in stock assessments for inshore finfish stocks.

Reyn Naylor is a fisheries scientist and has worked at NIWA since 1991. His main contribution to Plenary reports has been the provision of biological data and abundance indices supporting the estimation of biomass projections for paua.

Rich Ford has been working for the Ministry of Fisheries and then MPI within the science team since 2008. His main contributions have been in the aquatic environment and shellfish areas.

Richard Nelson has been an electronics technician at NIWA since 2004. His contribution to the Plenary reports has been in operating and maintaining acoustics and optical equipment for stock assessments of hoki, southern blue whiting, oreo and scampi.

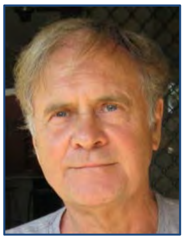
Richard O'Driscoll is the programme leader at NIWA responsible for fisheries monitoring. He has contributed to Plenary reports since 2000, providing data inputs and descriptions for a range of deepwater species including hoki, southern blue whiting, and orange roughy.

Richard Wells is a fisheries technologist working for industry in both operations and management since 1992, latterly for the Deepwater Group. He has provided input towards deepwater and middle-depth stock assessments as well as associated fishery related environmental impacts.

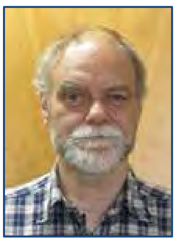
Rick Boyd was a fisheries management scientist with MAF Fisheries in Auckland from 1978 to 1989 and contributed to the Inshore Fisheries Working Group and Plenary reports for the initial setting of TACs at the time of the introduction of the QMS. From 1989 he has been a Consultant. He was a member of the Recreational Fisheries Working Group and involved in recreational fishing surveys in the 1990s.

Rob Tilney, project manager at Clement & Associates Ltd, has been involved in Deep Water Working Group discussions on orange roughy surveys and stock assessments since 2003.

Robin Allen began as a statistician with the Ministry of Agriculture and Fisheries in 1965 and since then has had a variety of roles within MAF (Group director MAF Fisheries Policy 1995) and the Inter-American Tropical Tuna Commission (director 1999–2007) until 2007 when he became Executive Secretary of the (then Interim) Secretariat of the South Pacific Regional Fisheries Management Organisation. He was the Director of Fisheries Research at the time that the annual stock assessment process began.



Roger Coombs moved to New Zealand in 1968 to work on rock lobsters and became leader of the "Population Section" when it was set up in 1972. There he recruited a core group of mathematicians and statisticians to develop methods and models for stock assessments, all of whom came to pay an important role in the stock assessment Working Groups and Plenary sessions. Roger worked on a number of species over the years eventually specialising in acoustic surveys of orange roughy, hoki and southern blue whiting and retiring in 2004.



Ron Blackwell worked as a stock assessment scientist with MAF Fisheries (1987 to 1994), then with NIWA (1995 to 2010). He now works with MPI in Marine Biosecurity. His primary contribution to

Plenary reports has been to assist in stock assessments for red gurnard, alfonsino, bluenose and blue cod.

Rose Grindley was a fisheries manager working at MPI since 1996. Her primary contribution to Plenary reports has been in the area of inshore finfish and shellfish.

Rosemary Hurst is currently the Chief Scientist, Fisheries at NIWA. She has 35 years experience with middle depth and inshore species biology and monitoring (trawl surveys), fish tagging, fish diet, climate relationships and stock assessment and is a current member of the Deepwater, Inshore, and Aquatic Environment Working Groups.

Shelton Harley was a fishery scientist at NIWA during the late 1990s and a member of the Science Team at the then Ministry of Fisheries during the mid 2000s. Shelton contributed primarily to the Plenary reports for the highly migratory and pelagic.

Sira Ballara is a fisheries scientist who has been working at NIWA since 1988. Her primary contribution to Plenary reports has been to assist in stock assessment for hoki.

Stephanie Hill has worked with MPI (and its predecessors) since 2004 as a manager of inshore and highly migratory fish stocks. She has had involvement in domestic and international science processes during that time, including contributions to the Scientific Committee and Ecologically Related Species Working Group of the Commission for the Conservation of Southern Bluefin Tuna.

Steve Brouwer was a Principal Scientist at the Ministry from 2006 to 2014, his primary contribution to the Plenary was to develop Plenary reports, complete the status of the stocks summary tables for HMS and inshore stocks, chair Working Groups to edit and finalise the text and add the environmental sections to the HMS Plenary.

Steve Halley has worked in fisheries policy and management since 1996. Most recently he worked on the development of inshore fisheries plans and associated research planning processes.

Stuart Brodie is a principal analyst in the Inshore Fisheries Management team in MPI. Stuart's work in fisheries dates back to 1998. He co-authored the Harvest Strategy Standard with Dr Pamela Mace.

Stuart Hanchet has been a stock assessment scientist working at NIWA and its predecessors since 1988. His primary contribution to Plenary reports has been to carry out stock assessments of southern blue whiting and to develop and update Plenary reports for toothfish.

Susan Jane (Suze) Baird is a fisheries scientist working at NIWA. Her research has covered aspects of the environmental effects of fishing, including estimation of the incidental capture of protected seabirds and marine mammals, quantification of the nature and extent of mobile bottom fishing methods such as trawling and dredging on the sea floor, as well as fisheries characterisations.

Terese Kendrick started with NIWA in the rock lobster team but since 2002 has been Managing Director of Trophia Limited. She is an analyst who has been involved in monitoring many of the inshore finfish species, providing input for stock assessment or adaptive management.

Vaughan Wilkinson is an oceanographer, fisheries scientist/ manager and commercial fisheries executive who has had a continuing interest in the stock assessment Plenary process since its inception. Vaughan retains a particular interest in the assessment of snapper stocks, and the use mark/recapture methodologies.

Vivian Haist first participated in the New Zealand Working Group process in 1993, when she came down from Canada to help with the southern blue whiting stock assessment. Vivian has since made major contributions to the assessment of hoki, blue cod and particularly rock lobster, where Vivian has been contributing since 2004.

Other people without photos who have also made substantial contributions

Andrew Branson
Andy McKenzie
Anthony Brett
Barry Weeber
Bob Beggs
Brian Jones
Brian Saunders
Carol Scott
Colin Sutton
Crispin Middleton
Dan Fu
Dan MacGibbon
Dane Buckthought
Darren Parsons
Darren Stevens
Dave Gibson
David Thompson
Dean Stotter
Debbie Hulston
Ed Abraham
Emma Jones
Eric Graynorth
Helena Armiger
Jacques Boubee
James Williams
Jeff Forman
Jeremy McKenzie
Jim Drury
John Cranfield
John Jameson
Karen Field
Kim Duckworth
Kim Walsh
Kirsty Woods
Malcolm Haddon
Marg McVeagh
Mark Geytenbeek
Martin Cawthorn
Matt Pinkerton
Matt Smith
Mike Claudatos
Paul Sagar
Pete Dawson
Peter Notman
Ralph Coburn
Richard Bian
Rob Mattlin
Seam Handley

Shannan Crow
Sophie Mormede
Steve Mercer
Steve Parker
Susie Iball
Talbot Murray
Todd Sylvester
Tom Chatterton
Warrick Lyon

MPI and Ministry of Fisheries Science Officers over the years

Shelton Harley (1998)
Rachel Garthwaite
Jolene Key
Warrick Lyon
Amelia Connell
Shane Grayling
Ellen Garland
Rebecca Lawson
Michelle Brock
Rebecca Edmonds
Te Puoho Katene
Tiffany Bock
James Dare
Michelle Beritzhoff
D'Arcy Webber
Will Arlidge
Adele Dutilloy (2014)

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