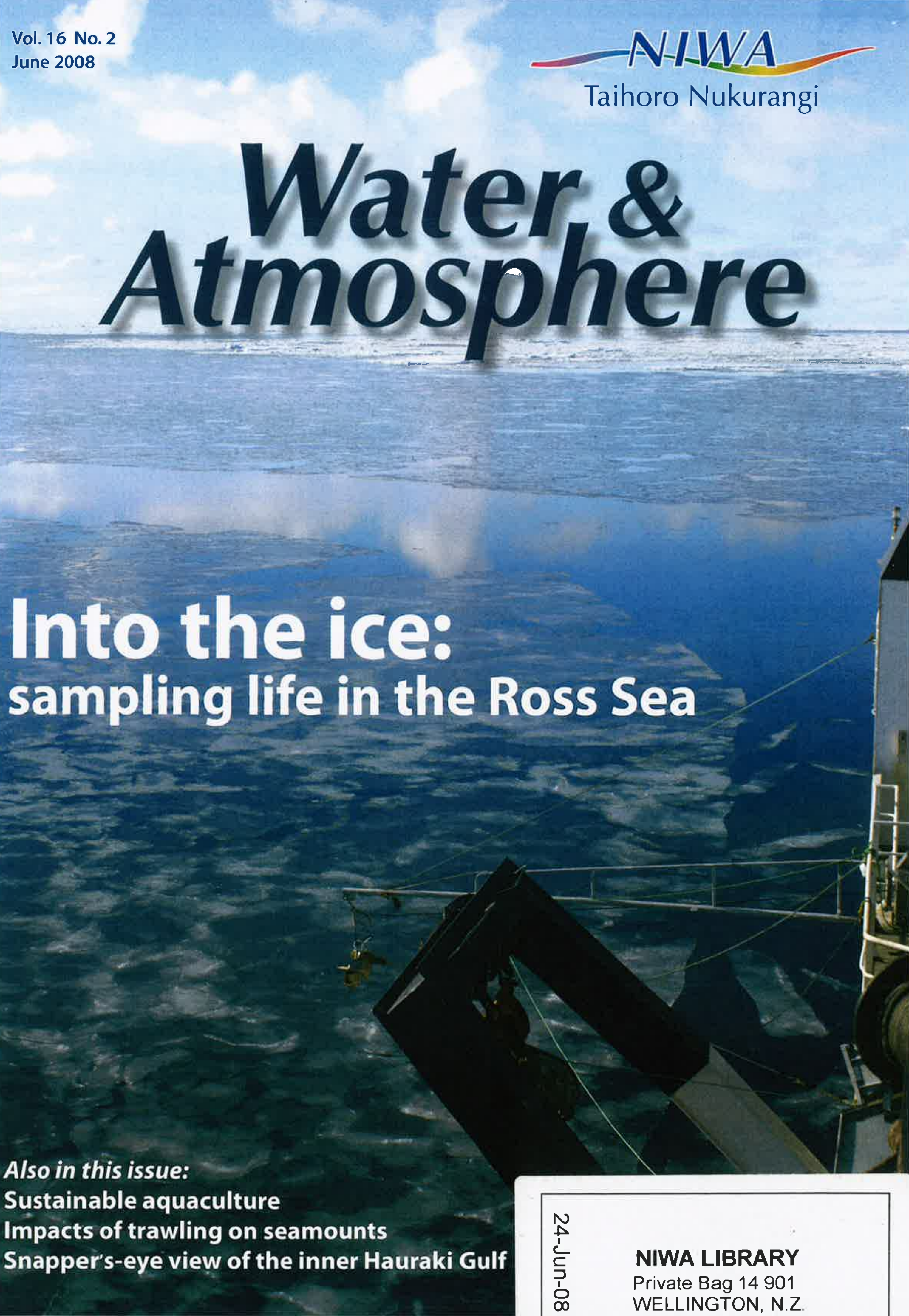
Vol. 16 No. 2
June 2008

NIWA
Taihoro Nukurangi

Water & Atmosphere



Into the ice: sampling life in the Ross Sea

Also in this issue:
Sustainable aquaculture
Impacts of trawling on seamounts
Snapper's-eye view of the inner Hauraki Gulf

NIWA, the National Institute of Water & Atmospheric Research Ltd, is a New Zealand Crown Research Institute. Our work contributes to the sustainable management and development of New Zealand's atmospheric, marine, and freshwater systems and associated resources.

NIWA's Māori name Taihoro Nukurangi – where the waters meet the sky – describes our work studying the waterways and the interface between the earth and the sky. Our rainbow logo also reflects the intersection of air and water.

For more information about NIWA, visit our website:
www.niwa.co.nz

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We welcome comment on articles in *Water & Atmosphere* and on any matters relating to NIWA's research endeavours.

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Covers

RV *Tangaroa* in newly formed ice in the northern Ross Sea. Scientists from NIWA and other institutions travelled for seven weeks and covered more than 7000 nautical miles to sample Antarctic marine life. The back cover shows the ship's track and sampling stations. Read about the voyage and see some of the finds on pages 14–15.

Images courtesy of NZ IPY-CAML
Photo: John Mitchell; Map: Arne Pallentin

News from NIWA

Teacher feature

A day in the field

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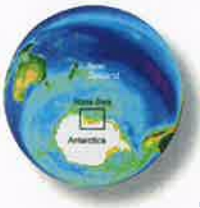

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Archive/Index

Water & Atmosphere is available online and can be searched by key word, author's name, etc.
See **www.niwa.co.nz/pubs/wa/archive**

Recent publications by NIWA staff

For more of NIWA's work, see the list of recent papers in refereed journals, proceedings, books, chapters, presentations, and popular articles at **www.niwa.co.nz/pubs/list**

News from NIWA

Natural hazards in 2007

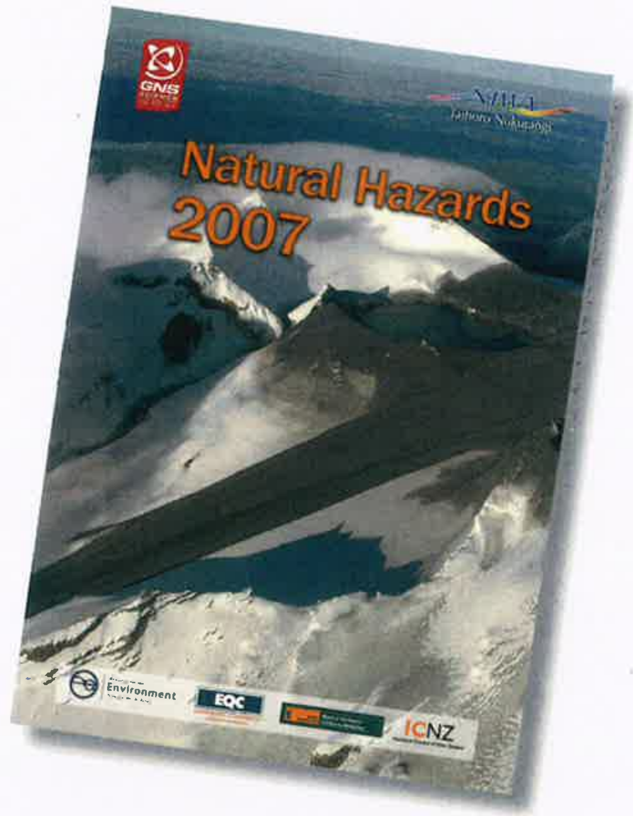
From volcano and earthquake to flood, drought, tornado, and tsunami, 2007 was one of the most costly years on record for natural hazards in New Zealand. For the insurance industry, it's projected to be the second most expensive year for natural hazard payouts since 1968, the year of the *Wahine* storm (exceeded only by the 2004 Manawatu floods). And the Earthquake Commission received three times the number of claims as for the previous year.

The Natural Hazards Centre, a collaboration between NIWA and GNS Science, produces an annual review that describes the major hazard events of the year and the research that goes into reducing the risks and mitigating the damage of natural hazards.

The 2007 review includes:

- hazards summaries, with graphics and analysis of key events
- reports from the Insurance Council and Earthquake Commission
- hazard planning reports from Ministry of Civil Defence and Emergency Management and Ministry for the Environment
- research summaries from NIWA and GNS Science on weather-related hazards forecasting, geological hazards and society, and a regional RiskScape model.

Copies of the review are available online from the Natural Hazards Centre at www.naturalhazards.net.nz or from Harriet Palmer, 0-4-386 0604, h.palmer@niwa.co.nz



For further information, contact:
Doug Ramsay, 0-7-859 1894, d.ramsay@niwa.co.nz
John Callan, 0-4-570 4732, j.callan@gns.cri.nz

Volcanoes:

- Mt Ruapehu lahar, 18 March: 1.3 million cubic metres of warm acidic water, entraining five times its weight in rock debris.
- Mt Ruapehu 'blue-sky' eruption, 25 September: a boulder seriously injured a climber in Dome Hut about 700 m from the centre of the crater lake.
- Seismic unrest at Mt Ngauruhoe: the volcano has not erupted since 1977, but seismic unrest began in 2006 and is continuing.

Earthquakes:

- 26 earthquakes of magnitude 5.0 or greater: this is about average for NZ
- Gisborne earthquake, 20 December, magnitude 6.8: the year's worst earthquake and the most damaging since March 1987 Edgecumbe quake (magnitude 6.6).

Landslides:

- Over 100 significant landslides, including a rockfall that killed a climber in Mt Cook National Park in March.

Heavy rain & floods:

- Northland, 28–29 March: now confirmed as a 1-in-150-year event. The heaviest rain fell for over 8–10 hours, with over 40 mm an hour falling in some places.
- Nelson & Taranaki, 22–23 May: schools and business closed; houses evacuated.
- Hawke's Bay, 17–18 July: up to 300 mm rain fell within 48 hours. The army evacuated children from two flooded country schools.
- South Canterbury & Otago, 30 July: heavy rain; state of emergency declared.

Coastal hazards/ tsunami:

- East coast South Island & Cook Strait, 25–26 June: gale-force southerlies with 6 m swells forced ferry cancellations; 8 m waves at Banks Peninsula.
- Oamaru, June: storm conditions caused localised erosion; factory destroyed.
- Four tsunami recorded, but no resulting damage.

Other weather-related hazards & events:

- Extraordinary swarm of damaging tornadoes in Taranaki, 4–5 July, cut a 140-km-wide swath of damage; state of emergency declared.
- Driest year on record in many areas. Annual rainfall less than 75% of normal in the east from Wairarapa to Otago, eastern Bay of Plenty, Taranaki, Gisborne, Manawatu, Wellington, and Nelson.
- Lightning strikes on a single night (13 March) cut power to about 40 000 homes in Wellington.
- For the first time since 2001, Central Otago curlers were able to play their sport on the frozen Idaburn Dam (where temperatures fell as low as minus 10 °C, 17 July). This is despite the fact that the national average temperature for the year as a whole was slightly above normal.

How could climate change affect us?

NIWA has just released new projections of climate change in New Zealand. The projections are the combined result of regional climate modelling and statistical 'downscaling' (producing results for New Zealand from global projections by using what we know about how New Zealand's climate relates to broader climate patterns).

"The evidence of climate change continues to mount, climate models are becoming more sophisticated, and scientific knowledge of the climate is improving all the time," says David Wratt, NIWA's General Manager Climate Change.

What's happening already

- Increasing temperatures: about 0.9 °C over the past 100 years.
- Reduced frost frequency over most of the country: Canterbury and Marlborough experience about 20 fewer frosts per year now than in the early 1970s.
- Retreat of major South Island glaciers: volume of ice in the Southern Alps reduced by almost 11% in the past 30 years. Twelve of the largest glaciers are unlikely to return to their earlier lengths without extraordinary cooling of the climate.

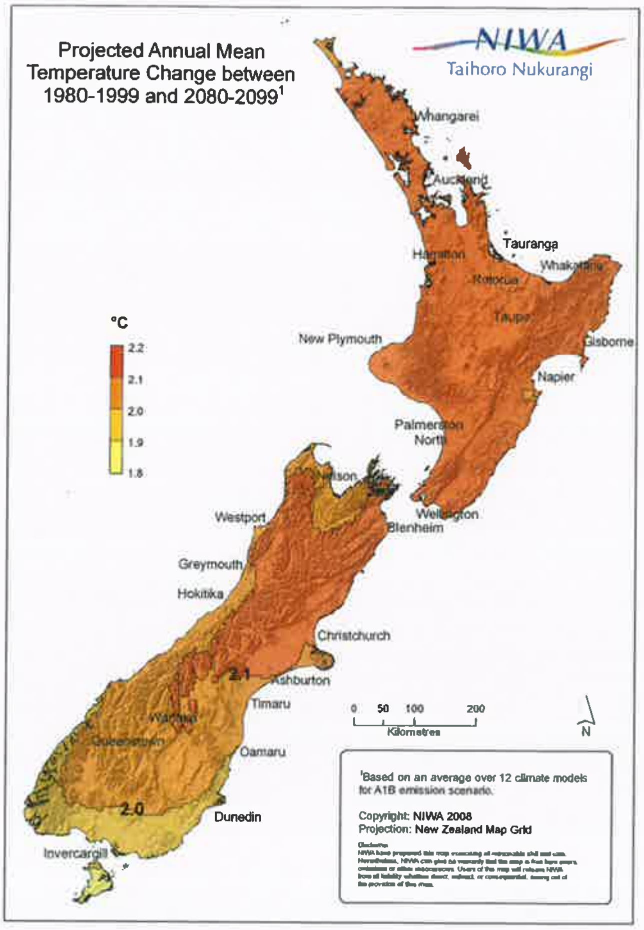
The projections

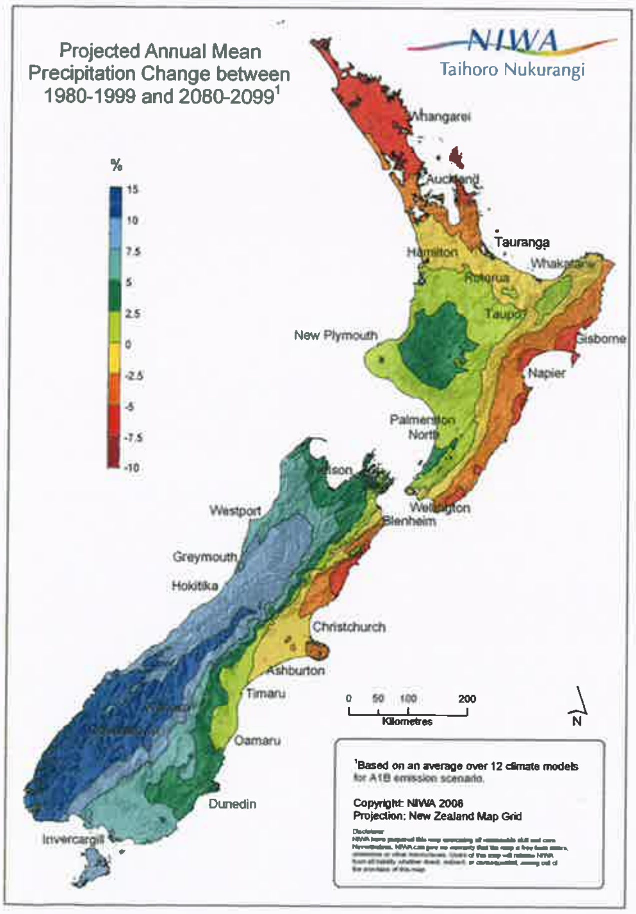
Future climate change depends partly on how much extra greenhouse gas goes into the atmosphere. For this reason, NIWA scientists used six different scenarios of how the world might develop over the rest of this century, but mostly focused on a middle-of-the-road scenario.

Temperature

Temperature is projected to increase by about 2 °C by 2090 for a mid-range scenario.

This is about the difference in the annual median temperature between Wellington and Auckland.





Extreme temperature

We can expect fewer frosts and more hot days.

Rainfall

As the map (*left*) shows, the overall picture is for a drier climate in most of the east coast and north of the North Island, coastal Canterbury, and coastal Marlborough, and for a wetter climate in the west and south of the South Island.

NIWA scientists also produced rainfall projections for each season:

- **winter & spring:** all 12 global climate models used by NIWA for this study point to increased westerly winds, especially over the South Island. This means drier in the east & north, but more rain in the west of both islands.
- **summer & autumn:** different models point in different directions, but the average pattern is that westerlies decrease slightly over almost all of New Zealand. NIWA scientists have less confidence in this result than in the annual, winter, and spring projections. If these projections are borne out, less frequent westerlies would mean drier summers and autumns in the west of North Island, and possibly wetter in Gisborne and Hawke's Bay for those seasons.

Extreme rainfall

Heavy rainfall is likely to get heavier and/or more frequent. For a mid-range scenario, what is a 1-in-100-year event now could become a 1-in-50-year event by the end of the century.

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Dr Brett Mullan, 0-4-386 0508, b.mullan@niwa.co.nz

Fisheries scientist K. Radway Allen, 1911–2008

The Allen Building, home to marine fisheries research at NIWA's Wellington campus, was named after Kenneth Radway Allen, who died recently in Australia, aged 97. I think we can rank Allen as the first professionally trained fisheries biologist employed by the New Zealand Government.

A native of Great Britain and graduate of Cambridge University, Allen came to New Zealand in 1938 to work for the Marine Department, which managed all fisheries in New Zealand apart from freshwater angling, an activity controlled by the acclimatisation societies. The Marine Department had turbulent relationships with the acclimatisation societies; Allen would have known little about this before coming to New Zealand, though he would quickly have found out.

Allen set to work on the trout population in the Horokiwi Stream, north of Wellington. He attempted to understand energy flow from the stream insects to the trout population that preyed on them and to develop an energy budget. It was an ambitious project, and there are stories of Allen and his wife dragging nets through the pools in the Horokiwi. The outcome, a book-sized bulletin published in 1951, remained Allen's major work. He found that there wasn't enough energy in the food web in the Horokiwi to support the stream's trout population, a situation that would later become known as 'Allen's paradox'.


Photo: NIWA

K. Radway Allen.

By the 1960s, Allen had become research director at the Fisheries Laboratory of the Marine Department. During his New Zealand career, he was a founder of the New Zealand Ecological Society and its first president, and was elected Fellow of the Royal Society of New Zealand in 1961.

In 1964, utterly frustrated by unhelpful senior bureaucrats in the Marine Department, Allen left for Canada, eventually becoming director of the fisheries research station in Nanaimo, British Columbia. In 1972, he shifted to Cronulla, New South Wales, as Director of the CSIRO Division of Fisheries and Oceanography, a position he held until retirement in 1977. He also became involved in management of international whale fisheries and was Chairman of the International Whaling Commission's Scientific Committee from 1974 to 1979.

Following his departure to Canada, Allen's New Zealand connections were slight, though he was marginally involved in a repeat study of the Horokiwi (now Horokiri) Stream. This study showed that the stream's trout population was defunct, owing to the effects of the management of the stream's catchment. The report on this work in 2000 was probably his last publication.

Bob McDowall

Allen, K.R. (1951). The Horokiwi Stream – a study of a trout population. New Zealand Marine Department. *Fisheries Bulletin 10.* 231 p.

For further information, contact:
Dr Bob McDowall, 0-3-343 7861, b.mcdowall@niwa.co.nz

Time to wet the whistle: researching Waikato drought

From February to June, NIWA in Hamilton hosted two visiting professors from Waterloo, Ontario: Dr Sherry Schiff (University of Waterloo) and Dr Michael English (Wilfrid Laurier University). This husband and wife team combines his expertise in hydrology and hers in biogeochemistry. They chose to spend their sabbatical in the Waikato because of ready access to the nearby Whatawhata Research Centre, where NIWA has, for many years, been running experimental work on rainfall effects and streams in hilly catchments. Whatawhata offers an infrastructure of experimental treatments, weirs, and monitoring structures supported by a decade of data.

Taking advantage of the unusual climatic conditions, they successfully monitored for nitrogen losses from the first storms after the extended Waikato drought and compared these among various land-use treatments. This research will provide information on the importance of catching the drought-breaking 'first flush' for accurate nitrogen (N) load measurement from rural catchments. Samples for N isotopes in water and vegetation will be analysed in Canada to help unravel the sources and flowpaths of N entering the streams under storm and baseflow conditions.

Says their NIWA host John Quinn, "Sherry and Michael have been a real pleasure to work with. Not only are they a self-supporting research team, but they even supplied lab work through their home institutions. Now we're getting sampling devices constructed based on their designs that we'll use at other catchment study sites at Toenepi and Lake Taupo. We're also making plans for longer-term collaborations, potentially involving their graduate students doing research at our sites."

Michael and Sherry comment, "Our NIWA visit has been greatly facilitated by the excellent NIWA staff. Many thanks to John for hosting us and to everyone who made our visit so productive and enjoyable. Working at NIWA and exploring New Zealand has been an amazing opportunity for ourselves and our children. New Zealand is a beautiful, fortunate country and there is much that we will miss about its people and its landscape."

For further information, contact:
Dr John Quinn, 0-7-856 6735, j.quinn@niwa.co.nz


Photo: John Quinn

Michael English and Sherry Schiff await the end of the golden weather at the Whatawhata field site.

Queen's Birthday honour for Dr Wendy Nelson

Wendy Nelson, an expert in marine macroalgae (seaweeds) and coastal ecology, was named a Member of the New Zealand Order of Merit for services to the marine environment. This well-deserved award marks many years of distinguished algal research as well as her passionate advocacy for the marine environment, especially through her membership of the New Zealand Conservation Authority, where she has served for eight years.

Wendy, who is a science leader in aquatic biodiversity, is based at NIWA in Wellington. During her three decades of research, she has established a notable track record of publications, especially on algal biosystematics and taxonomy. Her publications reflect her strong links with researchers in other institutions, both in New Zealand and overseas.

Photo: Alan Blacklock

Wendy Nelson holds the bronze she received last year as part of the New Zealand Marine Sciences Award.

NIWA also extends congratulations to Professor Martin Manning, for many years a science leader in climate research at NIWA in Wellington. Now at Victoria University of Wellington, Martin has been made an Officer of the New Zealand Order of Merit for services to climate change research.

For further information, contact:
Dr Don Robertson, 0-4-386 0572, d.robertson@niwa.co.nz

Giant squid joins its colossal mate

Te Papa's now famous colossal squid has been joined by another frozen/thawed companion – a giant squid, netted by *Tangaroa*.

The giant squid (*Architeuthis dux*) was caught during a fish trawl off the Snares in 650 m of water during a 2007 subantarctic trawl survey. It is well travelled, as it stayed on the ship throughout the IPY Antarctic voyage and was only lifted out of *Tangaroa*'s freezer when the ship returned from that voyage in March 2008.

The squid is now at Te Papa and awaiting thawing, dissection, and/or display. The specimen is a very intact example, so it's acceptable for Te Papa's high-quality collection.

Photo: Lindsay Battersby

The giant squid lies on *Tangaroa*'s deck, shortly after it was trawled up from the depths. The large white tube, or mantle, is 1.5 m long and this specimen weighs about 150 kg.

We believe the specimen is a female sub-adult (or juvenile), so by no means a fully grown adult. Giant squid this size are commonly caught and are thought to be about 1–2 years old, based on examination of the 'rings' in the statoliths, the animal's balance organ.

These giant squid are so elusive, hardly anything is known about their natural history, and there is disagreement over how many species exist and how abundant they are, though they are thought to be widespread throughout the world's oceans. Judging from squid beaks found in toothfish and whale stomachs in the Antarctic, it is apparent that they must be hugely abundant in the Southern Ocean.

They are fierce predators and are known to hang around areas of upwellings, such as seamounts, where they hunt their prey – mostly small fish and other squid.

For further information, contact:
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Dr Lianos Triantafillos, 0-4-386 0517, l.triantafillos@niwa.co.nz

Sobering news for beer drinkers

In Auckland in April, NIWA climate scientist Jim Salinger delivered some sombre news to a convention of the Institute of Brewing and Distilling: in the decades to come, climate change will have serious effects on the cultivation of malting barley – a key ingredient in beer.

Warned Salinger, "It will mean either there will be pubs without beer or the cost of beer will go up."

Malting barley crops will be affected globally, but Salinger's remarks were specifically about New Zealand and Australia. As soon as 30 years from now, rising temperatures and drier conditions could spell dramatic decreases of the crop in areas presently growing the grain – in Canterbury in New Zealand and in four states in Australia: New South Wales, Victoria, South Australia, and Western Australia. The picture is less dire for New Zealand, however, as the same climate changes may render parts of Southland and Otago more suitable for growing malting barley.

Brewers in Australasia will face "a lot of challenges", including the necessity of developing new strains of heat- and drought-resistant malting barley, or varieties that can mature in a shorter season.

For further information, contact:
Dr Jim Salinger, 0-9-375 2053, j.salinger@niwa.co.nz

Photo: Janice Meadows

Workshops & symposia

Fourth International Symposium on Deepsea Coral Research

1–5 December 2008, Victoria University of Wellington

Understanding deepsea corals – their ecology, function, and value – has become a priority for marine resource agencies and managers around the world.

NIWA is hosting the 4th International Deepsea Coral Symposium, the first time the symposium has been held in the southern hemisphere. It is is designed to bring together scientists, resource managers, students, and policy-makers who are actively involved in research and management of deepsea corals and other deepsea habitats as well as the animals associated with them.

This international event will focus on scientific exchange, establishing collaborative partnerships, and help provide an understanding of the critical factors for conserving deepsea corals and cold-water coral reefs.

The deadline for submitting abstracts and early-bird registration is 31 July. The programme and registration details are on the conference website:
coral2008.niwa.co.nz

For further information, contact:
Di Tracey, 0-4-386 0866, d.tracey@niwa.co.nz
Dr Helen Neil, 0-4-386 0375, h.neil@niwa.co.nz

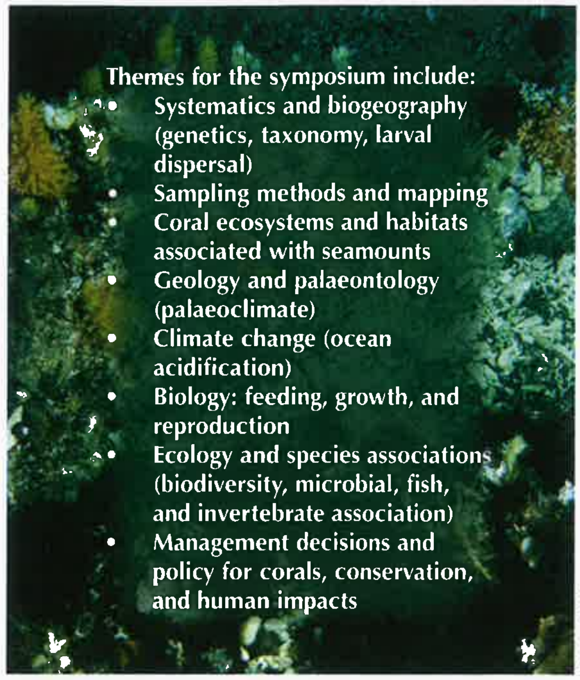


Photo: NIWA

Gorgonian and stylasterid corals on Macquarie Ridge.

Image: MODIS Rapid Response Project at NASA/GSFC

Satellite image of Te Waipounamu, captured December 2007, illustrates the snow fields at the heart of South Island water resources.

Ngāi Tahu–NIWA Water Resources Workshop

12–13 March, Christchurch

Ngāi Tahu rūnanga members and kaumātua from around the South Island joined NIWA and other key stakeholders to discuss water resource issues in Te Waipounamu and find out about NIWA's research in this area.

Declining freshwater quality, uncertainty over access to water resources, degradation of traditional values, and inappropriate freshwater management structures were highlighted as major concerns within the Ngāi Tahu rohe.

The workshop was organised by Ngāi Tahu and NIWA's National Centre for Water Resources. More than 80 people attended the two-day event, including senior management from NIWA, Ngāi Tahu, Environment Canterbury, Irrigation NZ, and Fish & Game NZ.

Mark Solomon, Te Rūnanga o Ngāi Tahu kaiwhakahaere, summed up the value of the workshop, saying that the scientific presentations from Ngāi Tahu whānui, NIWA staff, and other invited scientists and stakeholders provided Ngāi Tahu with information that will underpin the tribe's move to increase direct involvement in water resource management within their rohe.

For further information, contact:
Dr Clive Howard-Williams, 0-3-348 5548, c.howard-williams@niwa.co.nz

Carbon: Global Cycle to Regional Budget

14–15 April, National Library, Wellington

The challenge of 'decarbonisation' – or carbon constraint – following an era of cheap fossil fuel energy is undoubtedly the largest single environmental issue of the 21st century. It will require major shifts in energy sourcing and a significant change in the day-to-day functioning of commerce and society. Internationally, policy is looking ahead to a framework for comprehensive global agreement following the first commitment period (2008–2012) of the Kyoto Protocol. Domestically, policy is centred on the development of an all-sector Emissions Trading Scheme.

In order to accurately predict the future greenhouse effect, we must first understand the relationship between emissions and atmospheric concentration, or the 'airborne fraction'. And to predict this fraction, we must understand how the global carbon cycle functions, including its response to anthropogenic change and potential feedbacks with global climate change. Two major concerns are the current trend of increasing atmospheric CO_2 (which goes hand-in-hand with current global trends of increasing carbon emissions) and the increase in carbon intensity of economic activity (which can be seen as the amount of carbon consumed per unit of Gross World Product).

This workshop focused regionally on New Zealand, Australia, and the Southern Ocean. It brought together about 100 researchers and policy analysts to review and look ahead at future needs for carbon-cycle research and policy development.

There were two keynote speakers. Dr Pep Canadell summarised the work of the Global Carbon Project, which was established in 2001 as a framework for integrated study of human, economic, and biogeochemical aspects of carbon. Dr Martin Manning, Victoria University of Wellington, looked ahead at the emerging nexus between science and policy in understanding and managing carbon emissions. The papers and posters that followed addressed three main topics:

- Global/marine/carbon capture
- Terrestrial research
- Policy-related research, including the development of integrated economic/biophysical models.

The meeting was testimony to the high degree of cross-disciplinary interaction and cooperation that characterise the New Zealand (and wider Australasian) science and policy communities. The meeting was jointly sponsored by NIWA, GNS Science, Landcare Research, Ministry of Agriculture and Forestry, Ministry for the Environment, and the Royal Society of New Zealand International Geosphere–Biosphere Programme (IGBP) committee.

Work presented at the workshop will be published in a special issue of the journal *Biogeochemistry* under the guidance of guest editors Martin Manning and Troy Baisden (GNS). The RSNZ IGBP committee will facilitate development of further educational resources.

For further information, contact:
Dr Mike Harvey, 0-4-386 0308, m.harvey@niwa.co.nz

Useful links

The workshop programme and presentations are available at:
www.rsnz.org/advisory/igbp/carbon
Global Carbon Project: www.globalcarbonproject.org

Training at NIWA

NIWA offers courses on a range of topics. They are presented at a number of venues according to need and level of interest, and in some instances can include in-house training at your premises. Though the schedule for 2008/09 has not yet been confirmed or posted online, there are two electric fishing courses planned for September:

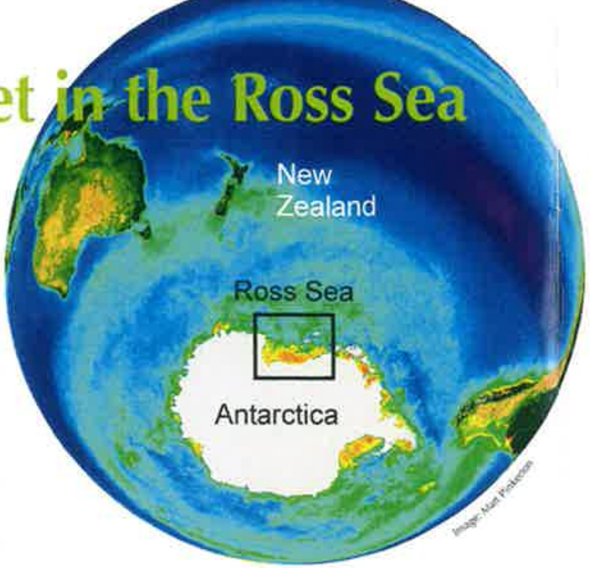
Electric fishing for machine operators, 9–10 September, Christchurch
Electric fishing for machine operators, 16–17 September, Palmerston North

If you are interested in booking a training course for yourself or your team, keep an eye on
www.niwascience.co.nz/edu/training
or contact :
NIWA Training Coordinator
phone 0800 RING NIWA (0800 746 464
or email training@niwa.co.nz

Marine Ecosystems

Making ends meet in the Ross Sea

***Matt Pinkerton, Janet Bradford-Grieve,** and **Stuart Hanchet** are developing a mass-balance model to learn how animals fit together in the Ross Sea ecosystem.*



Based on data from NASA satellites, this image shows the phytoplankton concentration in the Ross Sea. High concentrations are shown in green and red, lower concentrations are blue and purple. (Data used courtesy of NASA.)

After braving some of the worst sea ice in decades, NIWA scientists returned in late March from a seven-week voyage to the Ross Sea region of Antarctica. Among our goals for the voyage was to learn more about the region's predator–prey links and the abundance of some important and poorly understood species.

Antarctica's unique ecosystems

Compared to temperate regions, the waters of the Southern Ocean have low primary productivity – the production of organic matter by plants that is the basis of marine food webs. In temperate waters, like those around New Zealand, phytoplankton grows during most of the year. But in the Ross Sea there's a long period between late May and mid July when the region is in 24-hour darkness and no plants can grow. The year's entire primary production happens in brief events in the spring and summer, and these bursts of high productivity are often very localised. Another challenge for Antarctic animals is the dramatic change through the year to the available environment, as sea ice forms in the autumn and then melts in the spring.

These special conditions seem to be associated with particular characteristics in Antarctic animals and plants. Animals living in Antarctic waters have a relatively low number of species and many are endemic to the region; that is, they don't live anywhere else and are highly specialised to the Antarctic conditions. Some species of fish have developed antifreeze in their blood that allows them to survive in freezing conditions. And Antarctic organisms are often larger and slower-growing than similar animals in warmer waters.

Survival strategies

Animals living in the Ross Sea have developed various strategies for survival when food is scarce. Entire populations of some of the larger, mobile animals leave the region completely during winter, including minke whales, most seals, petrels, and Adélie penguins. Some larger animals tough it out, relying on having built up enough reserves to see them through. Emperor penguins, for example, incubate their egg over winter to take advantage of the plentiful food in the spring and summer when it's time to feed the newly hatched chicks. This is a risky strategy: while incubating the egg through the winter, the males lose more than 40% of their body weight and come close to starvation. Other less mobile organisms store oil in their body during the summer and use this for energy while in a quiescent (low-energy) stage during winter. Still other animals have expanded the things they can eat, live slower but longer, or can adjust their breeding cycles to take advantage of occasional peaks of food availability.

Finding a balance

- The animals, plants, and microbes of the Ross Sea ecosystem have unique survival strategies to meet the particular challenges of their environment.
- NIWA scientists are fitting together what is known about the Ross Sea ecosystem to model a mass-balance food web.
- The 2008 research voyage will add vital pieces to the puzzle, especially on the biomass and feeding relationships of larger animals that are difficult to catch.

Modelling a mass-balance food web

At NIWA we're fitting together what's known about the Ross Sea ecosystem into a consistent picture. Data about the ecosystem have been produced over many years by a number of nations and it has been a mammoth task to pull all this information together and make sense of it. We have particularly been interested in data that measure the quantity of organisms (biomass), the amount of food an animal needs to survive and grow, the rate at which it grows, and how the numbers of predators and prey affect each other.

To confirm our understanding of how the food web works, we're developing a mass-balance model of the Ross Sea. The model is based on the balance between growth and death in various groups of animals over time. We know that no more production can come out of the Ross Sea system than is put in by the primary producers, and that there will be losses in biomass at each link in the food web.

Some aspects of the ecosystem are quite well known, while other pieces need new data or, failing this, force us to make educated guesses. New research becomes available all the time, so this is a constantly shifting target. The model checks that the available numbers make sense when put together.

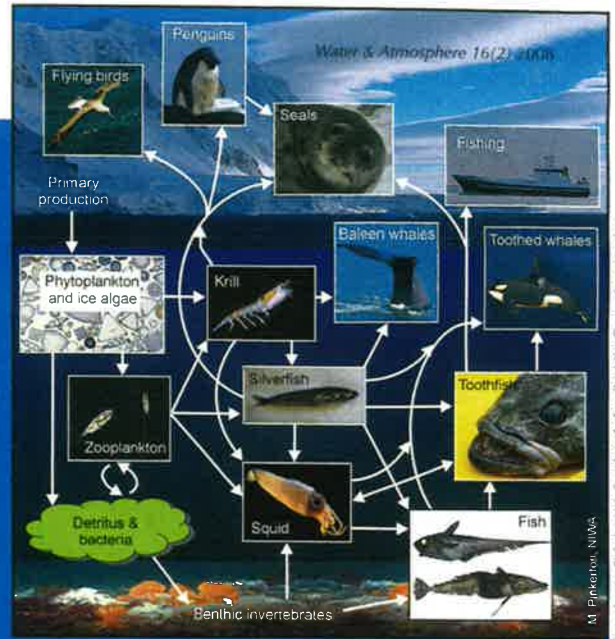
Last year we presented a preliminary balance model to CCAMLR (the commission that implements the Convention on the Conservation of Antarctic Marine Living Resources), who regulate fishing in the Antarctic. We're using our model to help investigate how the organisms fit together in the ecosystem and to decide which are the important questions for future research. The model should also suggest potential impacts on the Ross Sea ecosystem of fishing, climate variability, and climate change. W&A

The big picture: a simplified Ross Sea food web

Growth of phytoplankton makes up the largest contribution to primary production in the region, though there is some primary production by sea-ice algae and macroalgae (seaweed). Bursts of growth occur in the spring and summer along the coast, in polynya (large open-water areas within the sea ice), and in the waters left as the sea ice melts. Primary production is channelled through copepods, the most common type of zooplankton, and a number of smaller species of zooplankton. Algae that are not consumed and waste products can fall to the seafloor, often in large amounts. This food source, and the growth of macroalgae in coastal regions, provides nutrition for the benthic (bottom-dwelling) invertebrates. These benthic animals have varied feeding strategies and include:

- grazers, such as urchins, sea cucumbers, and snails
- predators, such as the Antarctic whelk and seastars
- filter-feeders, such as Antarctic scallops, bivalves, anemones, soft corals, and sponges
- scavengers, such as large worms.

Two species of krill are found in the Ross Sea: the larger Antarctic krill north of the Ross Sea proper, and smaller crystal krill in waters over the continental shelf to the south. Krill abundance tends to be much lower in the Ross Sea than in other parts of the Southern Ocean, and Antarctic silverfish fill the gap as key species in the food web. Silverfish grow to a length of about 30 cm, occur throughout the Ross Sea, and are found in the diet of almost all large predators. They, in their turn, feed on the smaller copepod crustaceans. Other fish in the Ross Sea include the 2-m-long Antarctic toothfish, 'cryopelagic' fish that live on the underside of sea ice (cryo=freezing, pelagic=open waters), as well as grenadiers (or rat-tails), skates, deepsea and moray cods, dragonfishes, and icefishes. A number of species of squid and octopus live in the Ross Sea, including the colossal squid that can grow to more than 4 m long.



The arrows show the energy flow through the food web. They go from the prey species (these get eaten) to their predators (the hunters).

In the Ross Sea region, there are an estimated 40 000 breeding pairs of emperor penguins and about 1 million breeding pairs of Adélie penguins (38% of the world population). Several other species of birds breed in the region, including Antarctic petrels, snow petrels, and the south-polar skua, which preys on penguin chicks. Many other birds visit in summer, including two albatross species.

Seals are the most common marine mammals in the Ross Sea in summer, with more than 200 000 crabeater seals, 40 000 Weddell seals, 8000 leopard seals, and 5000 Ross seals. Baleen whales in the outer Ross Sea include dwarf minke whales, Antarctic minke whales, and smaller numbers of fin, humpback, sei, and blue whales. Toothed whales sighted in the Ross Sea include orca (killer whales), sperm whales, southern bottlenose whales, and Arnoux's beaked whales.

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Dr Matt Pinkerton is a specialist in remote sensing and modelling food webs, and Dr Janet Bradford-Grieve is a marine biologist and ecologist. They are based at NIWA in Wellington. Dr Stuart Hanchet is a fisheries scientist based at NIWA in Nelson.

This project is supported by the Ministry of Fisheries programme on 'Ecosystem Effects of Fishing in the Ross Sea' and the Foundation for Research, Science & Technology 'Ross Sea Sustainability' programme.

Marine Biodiversity

Mapping biodiversity in New Zealand's Exclusive Economic Zone

Sending the DTIS cameras over the side to film the seabed below.

Though the deepsea floor around New Zealand may look like a desert, initial results from a wide-sweeping new survey point to a surprising abundance of life. ***Scott Nodder, Don Robertson,*** *and* ***David Bowden*** *describe how the results were gathered in this important investigation of New Zealand's EEZ.*

Life in the deep
- Ocean Survey 20/20 is a major, multi-agency programme to survey biodiversity in New Zealand's EEZ by the year 2020.
- Initial results are in for the first component of the programme: an investigation in 2007 of Chatham Rise and Challenger Plateau.
- Scientists are now analysing over 4 tonnes of biological samples brought back from two voyages.

It's one of the largest habitats on earth, but the muddy sediments of the deepsea floor still hold many mysteries, and the factors driving habitat and biodiversity variability in these environments are poorly known. The animals at the bottom of the deep sea inhabit an environment that's entirely inhospitable from a human perspective: it's perpetually dark, cold, and under crushing water pressure. Despite the barren appearance of the deepsea sediments, we're learning that there's greater biological diversity on the ocean floor than once was thought.

Ocean Survey 20/20

Last year, we began the first systematic survey of such deepsea habitats in New Zealand's Exclusive Economic Zone (EEZ) as part of Ocean Survey 20/20 (OS 20/20). Over the next 15 years, this ambitious government-funded programme, will map the seafloor habitats and biodiversity of New Zealand's marine environment across large areas of the EEZ. To achieve its goals, OS 20/20 draws on expertise from several government departments and crown research institutes, including Land Information NZ (LINZ), Ministry of Fisheries (MFish), Department of Conservation (DOC), NIWA, and GNS Science.

The initial OS 20/20 project focused on two large, deep-ocean domains: Chatham Rise to the east of the New Zealand landmass, and Challenger Plateau to the west. These voyages revealed diverse and abundant biological communities living in a range of environments – from rugged seamounts and reefs to plains of muddy sediment and current-scoured sands at depths of over a kilometre.

The Chatham–Challenger project kicks off

The Chatham–Challenger project involved three separate voyages of NIWA's research vessel *Tangaroa*. The first, in August 2006, was to get the lie of the land. Using a multi-beam echo-sounder, we mapped a number of transects (lines) across recognised physical, chemical, and biological gradients. These echo-sounder data gave us a detailed picture of seafloor bathymetry (contours) and composition (hard or soft surfaces) from which we were able to identify broad habitat differences (such as steep versus low slopes, rock versus mud sediment types). We used these data to plan for two voyages in April–June 2007 in which we sampled the biological communities associated with the different habitats.

Deciding where to sample

We developed our sampling strategy by combining the multi-beam data from our initial seafloor survey with environmental variables, including surface chlorophyll *a* concentrations (an indicator of primary productivity in the ocean) from satellite observations and modelled tidal currents. This data analysis gave us a number of environmental categories representing distinct seafloor habitats.

Then we sampled these distinct habitats at three levels of intensity. At every sampling site we used NIWA's deep-towed imaging system (DTIS) camera platform, which records continuous high-definition video of the seafloor and high-resolution still images at regular intervals. In conjunction with the DTIS, we used our 'seamount sled', a device that collects samples of organisms as we tow it short distances along the seafloor. In the trade, this is known as an epibenthic sled (epi=near, benthic=bottom); the samples it collects confirm what we see in the video images. At some of the sites we deployed a broader suite of sampling gear. And for at least one site in each habitat, we sampled with a full range of equipment, including DTIS, the epibenthic sled, a hyperbenthic sled to collect macroscopic fauna just above the seabed (macroscopic=large enough to see without a microscope), and sediment corers to sample organisms, bacteria, and physical properties of the sediment itself.

Onboard *Tangaroa*, we identified the samples as far as possible, and counted, labelled, and preserved them for future taxonomic and scientific study. For marine biological expertise and scientific knowledge onboard the ship we had 25–30 researchers from several New Zealand institutions, including NIWA, MFish, DOC, University of Waikato, and University of Otago.

Photo: Scott Nodder

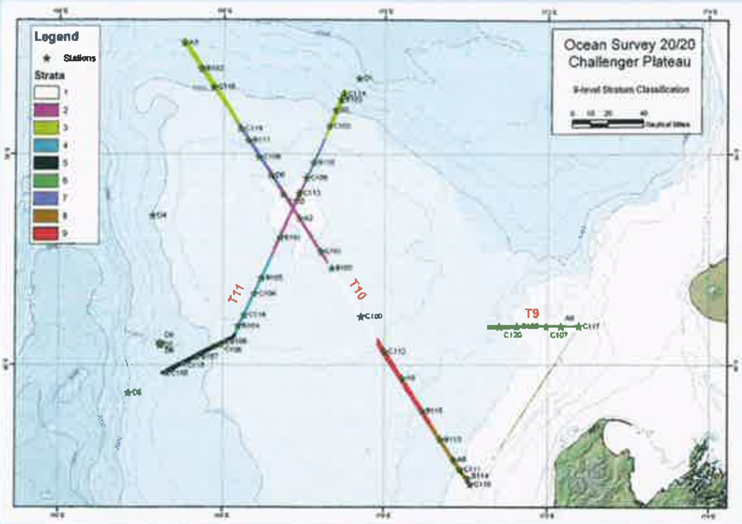
We sorted over 11 tonnes of samples during the voyages. Prime specimens and material that we couldn't readily identify were retained for further work back in the laboratory.

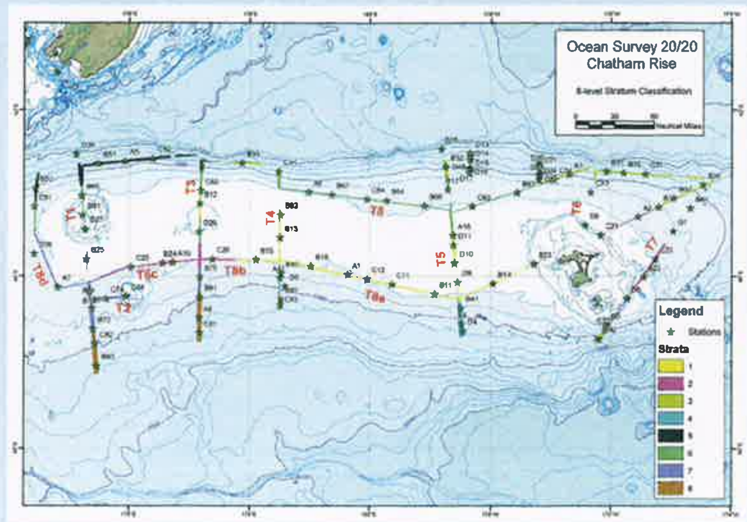
A survey based on intensive sampling

During the voyages in 2007, we made nearly 300 gear deployments at 104 different locations on Chatham Rise, and 140 deployments at nearly 50 sites on Challenger Plateau. We sorted over 11 tonnes of seafloor material, and retained almost 4 tonnes of biological specimens sorted into over 4000 individual sample lots for taxonomic identification.

	Chatham Rise	Challenger Plateau
Total number sites sampled	103	53
Total number sample lots	3430	1849
Total weight (sorted)	10471 kg	1405 kg
Total weight (kept)	3450 kg	approx 500 kg
Total number of taxa	445	219
Most common phyla found	Arthropods (489)	Echinoderms (298)
2nd most common	Echinoderms (452)	Arthropods (296)
3rd most common	Molluscs (397)	Molluscs (221)

Sampling statistics, including the total number of taxa (order, family, genus, or species) and the top three phyla from each region (total lot numbers in brackets).





Station locations and multi-beam coverage of Challenger Plateau (*above*) and Chatham Rise (*right*). We compared these two regions, in part, because in a physical environmental modelling study they share similarities despite differences in their physical, biological, and chemical characteristics. The colours along the transects indicate the different habitats ('strata') sampled in each study area. (Note: numbering and colouring of strata differ between the two study areas.)

Initial results

It will be at least a year before the samples from these voyages are identified and only then can we begin the full analyses of biodiversity and distribution. However, some broad-scale patterns are clear from the raw data. For instance, we can begin to visualise relationships between habitat type and faunal biodiversity based on the nearly 170 one-hour camera transects across both study areas (see example below). From real-time observations like this, it's clear that the Chatham Rise has more diverse substrate types than the Challenger Plateau. The diversity of biological communities is often correlated with habitat complexity and we might, therefore, expect the Chatham Rise to harbour greater biodiversity. However, habitat complexity operates on many scales, and what first appeared to be a uniform expanse of soft muddy sediments across much of the Challenger Plateau turned out to be covered by a dense and finely structured mosaic of animal tracks and burrows. These signs of life indicate high abundance – and potentially high diversity – of benthic animals within the sediment.

Photos: Peter Hill and Peter Marriott

Images from the DTIS camera.
Typical carbonate-rich sandy substrate with Dell's spider crab and a salp.
Site C102, Transect T10, Stratum 2, top of Challenger Plateau, 480 m water depth.

Coral- and mollusc-dominated encrusting fauna on seamount crest, east of Chatham Island. Site D6, Transect T7, Stratum 2, eastern Chatham Rise, 85 m water depth.

The way ahead

We'll spend the next three years analysing the Chatham–Challenger OS 20/20 samples. Our research will concentrate on mapping biodiversity in relation to substrate type across the study areas and will explore the potential for using higher-level remote sensing methods such as multi-beam mapping for predicting the distribution of seafloor biological communities. The OS 20/20 data will also be used to develop and refine the Marine Environment Classification (MEC), another government-funded NIWA initiative, and thus will be an important contribution to future resource-management strategies for New Zealand's EEZ. W&A

Dr Scott Nodder is a marine geologist, Dr Don Robertson is NIWA's General Manager for marine biodiversity, and Dr David Bowden's expertise is in benthic ecology imaging. They are all based at NIWA in Wellington. *They are indebted for the success of this project to Neville Ching (NIWA contracts manager), and John Mitchell (ocean geologist), and to the rest of the OS 20/20 project team.*

The authors particularly thank the OS 20/20 Steering Group (especially Dr Mary Livingston at MFish) and management of the core agencies for funding: MFish, LINZ, DOC, and NIWA. They gratefully acknowledge the hard work of all voyage participants as well as the many NIWA staff who contributed technical and scientific expertise.

Marine Biodiversity

Back from the ice bearing scientific treasure

Tangaroa working in heavy pack ice in the Ross Sea.

Running the numbers

- Ship's company included 44 scientists, technicians, and crew.
- Travelled 7140 nautical miles in 50 days.
- Brought back more than 37 000 specimens.
- Recorded 55 hours of video and 12 500 still images
- For a blog from the voyage and useful links, see: www.niwa.co.nz/rc/antarctica/ipy-caml

NIWA's research vessel Tangaroa *has battled extreme sea-ice conditions to bring back the goods: thousands of specimens and images of Ross Sea biodiversity.* ***Fiona Proffitt*** *reports on some of the finds.*

With a ceremonial send-off by the Prime Minister, they left Wellington on 31 January, bound for the Ross Sea. Fifty days and 7140 nautical miles later, *Tangaroa* and her 44-strong crew returned home. Despite encountering the worst sea-ice conditions witnessed in the region in 30 years, they successfully sampled 39 sites from the shelf, slope, abyss, and seamounts, including areas and habitats that had never been sampled before.

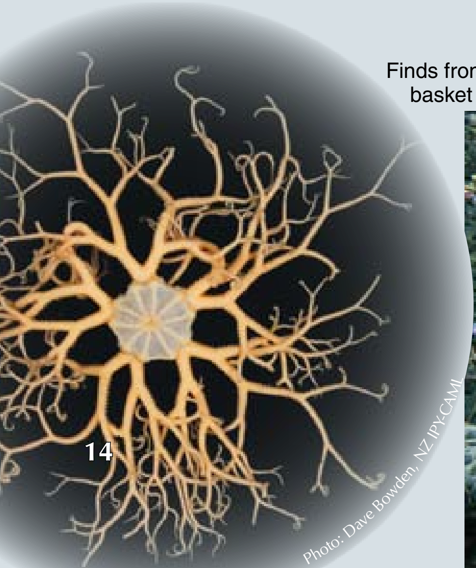
The ship's scientific contingent included 25 researchers from NIWA, Ministry of Fisheries, Te Papa, Victoria University of Wellington, University of Waikato, NOAA (USA), and Università di Genova (Italy). Eighteen ship's crew operated the vessel and assisted with deploying the sampling gear, while a Natural History New Zealand filmmaker documented the entire voyage.

Known as NZ IPY-CAML, the voyage was part of New Zealand's principal International Polar Year project and was a collaborative effort between government agencies and research providers throughout New Zealand. It also formed part of the Census of Antarctic Marine Life, an international circumpolar survey effort. Its focus was to survey biodiversity to provide a picture of the Ross Sea ecosystem, both for fisheries management purposes, and as a baseline for monitoring the effects of climate change and human activities.

The scientists returned with more than 37 000 specimens. The invertebrate specimens, which cover some 51 groups, are being processed by the NIWA Invertebrate Collection team in Wellington, while the fish have gone to Te Papa for identification and curation. The process of formally identifying, describing, and naming them will take several years. Many of these species will turn out to be new to science, including potentially nine 'new' fish species, several new deep-sea molluscs, and a new and particularly large species of hydroid (a coral-like organism).

The team successfully deployed NIWA's deep towed imaging system (DTIS) down to 3500 m – almost the height of Mount Cook – capturing 55 hours of video and 12 500 still images of the seabed and its inhabitants. This bonanza of imagery will reveal new insights about seafloor habitats, and species distribution, behaviour, and interrelationships. Studies of plankton, microbes, ocean colour and physical properties, fisheries acoustics, and multibeam sampling will also yield a wealth of information about the Ross Sea and Southern Ocean environment.

As well as the scientific achievements, the voyage supported a successful education programme hosted by the Science Learning Hub (www.sciencelearn.org.nz), and featured in news media around the world. W&A



Finds from the seabed beside Scott Island, a seamount in the northern Ross Sea: basket star collected at 500 m depth and abundant sea pens and brittle stars photographed at 150 m.

Photo: DTIS, NZ IPY-CAML

Adélie penguins

Photo: Dave Bowden, NZ IPY-CAML

Photo: Richard O'Driscoll, NZ IPY-CAML

Peter 'Chazz' Marriott (NIWA) prepares to photograph a fish specimen and (*below*) the midday-to-midnight shift sort samples of organisms collected from the seafloor. Left to right: Stu Hanchet, Kareen Schnabel, Darren Stevens (all NIWA), and Matt Knox (University of Waikato).

Photo: Peter Marriott, NZ IPY-CAML

Tangaroa Master Andrew Leachman studying an ice map on the bridge and (*below*) the vessel penetrates pack ice to get into the Ross Sea.

Photo: Dave Bowden, NZ IPY-CAML

Photo: Glen Walker, NZ IPY-CAML

Dr Fiona Proffitt is a science journalist based at NIWA in Wellington. The voyage was led by NIWA, supported by new government funding from Land Information New Zealand (LINZ). The overall NZ IPY-CAML project was led by the Ministry of Fisheries, with additional governance provided by LINZ, Antarctica New Zealand, Ministry of Foreign Affairs and Trade, and NIWA.

Photo: Richard O'Driscoll, NZ IPY-CAML

Sadie Mills (NIWA) with a sea cucumber known onboard as a 'sea pig'.

Photo: Glen Walker, NZ IPY-CAML

Right: Crewmen work through a snow storm to retrieve sampling gear.

Below: The ship's complement of scientists and crew gathers at the bow in the Ross Sea.

on a newly formed ice floe, northern Ross Sea.

Photo: John Mitchell, NZ IPY-CAML

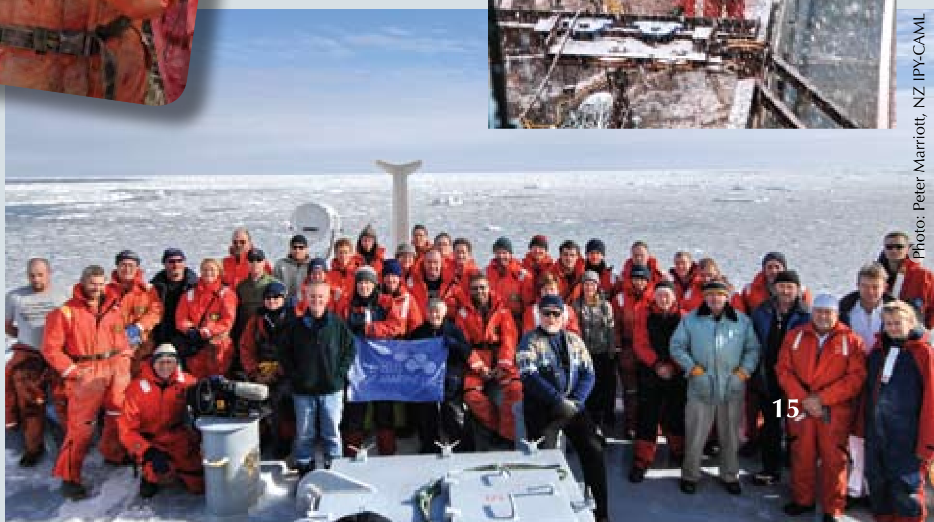


Photo: Peter Marriott, NZ IPY-CAML

Resource Management

Seamount fisheries: understanding the impacts of trawling

Malcolm Clark recounts how scientists at NIWA are investigating the effects of commercial trawl fishing on some of New Zealand's most productive submarine landscape.

Counting the cost

- Seamounts and other raised features in the sea are highly productive and home to many commercial species of fish.
- Trawling can damage the diverse deepwater habitats that may support the fish stocks.
- For almost a decade, NIWA scientists have been surveying and measuring the effects of trawling on habitat and fish.

Photo: DTIS, Malcolm Clark

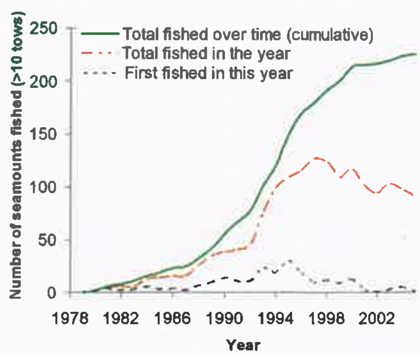
The light band shows a deep gouge in soft sediment near the summit of a seamount; this was probably made by a trawl door.

Lying beneath the waters around New Zealand are over a thousand seamounts, knolls, and hills. They are often sites of flourishing sea life, with spectacular reefs of cold-water corals and large sponges, and have become the focus of important commercial fisheries for such deepwater species as orange roughy, oreos, black cardinalfish, and alfonsino. However, the benthic (seabed) habitat can be fragile, and heavy bottom-trawl gear can easily damage the coral. Because these corals may be long-lived and slow-growing, their recovery from trawling could take many years, if not decades. Knowing the environmental effects of fishing on the seafloor habitat is an important component of fisheries management.

Since 1999, NIWA scientists have been studying the effects of trawling on seamounts, looking at a number of aspects of seamount fisheries and ecology. Using NIWA's extensive bathymetric database and recent multibeam surveys, first we determined where seamounts are found, and their physical characteristics. Then we looked at fisheries data to see the extent of trawling on these seamounts. We ran compare-and-contrast surveys on a small group of fished and unfished hills to determine the likely nature of impact, and began a series of surveys on a previously fished seamount to examine recovery over time from trawling. Finally, we've investigated age and growth of corals to understand their likely resilience to disturbance by trawling.

How much trawling and where?

We used data from MFish to determine which seamounts have been fished, how often, how heavily, in which direction, and for what species. Based on these data, we've developed several combined indices to describe the importance of a seamount to fisheries, and the relative amount of fishing (and hence impact) on a seamount. The main fisheries that target seamounts are those for orange roughy, black cardinalfish, and oreos (especially smooth oreo).

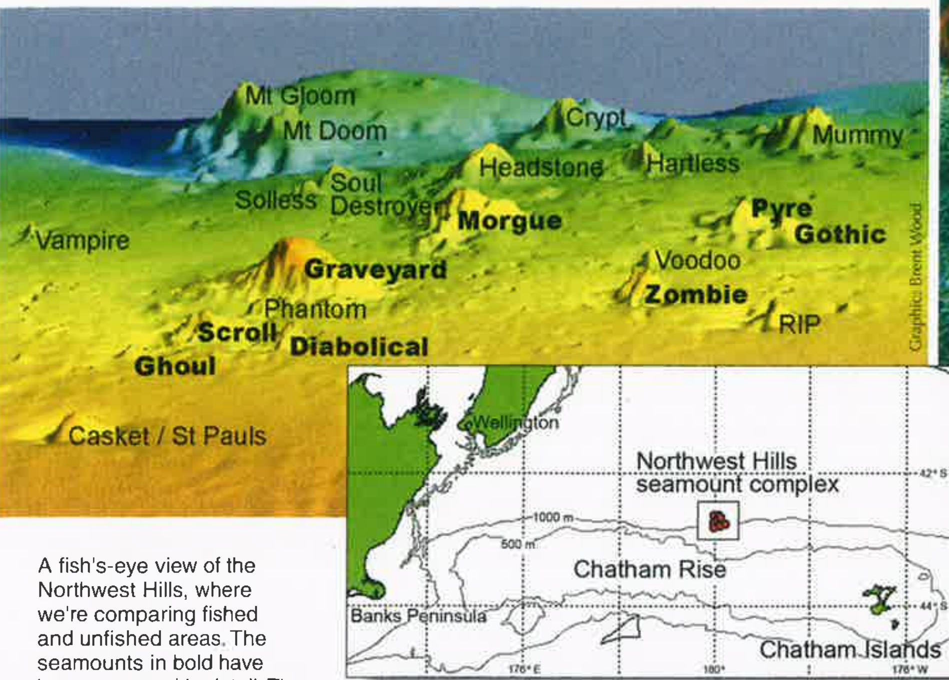


Changes over time in the number of seamounts fished by bottom-trawl commercial fisheries.

The number of seamounts fished has changed over time. Fisheries on seamounts around New Zealand first developed in the early 1980s, but the amount of fishing on them increased rapidly in the early 1990s as the association between some species and seamounts became clear, and as navigational accuracy improved dramatically, for example through the introduction of GPS. The number of seamounts fished each year is now around 100, or 10% of the known number. However, the percentage of seamounts that are fished in particular depth ranges – such as depths suitable for orange roughy – can be much higher.

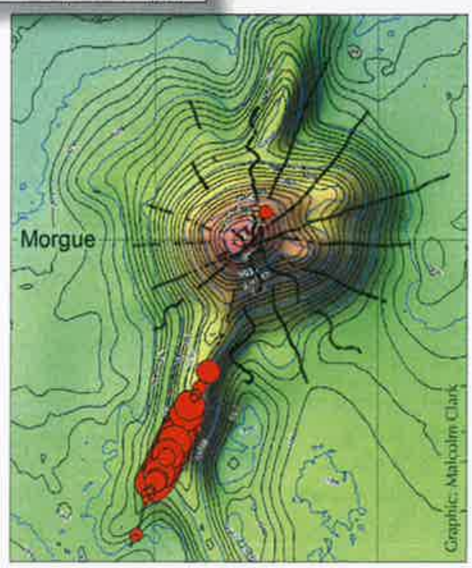
Comparing fished and unfished seamounts

There are two common approaches to investigate the effects of fishing. The first is to experimentally trawl or dredge in areas that are not commercially fished and then compare the communities before and after. The second is to compare fished and unfished areas with similar habitat, which is the more common as it doesn't involve deliberately destroying habitat. We have been carrying out such a study on a group of small seamounts on the northern Chatham Rise, commonly known as the Northwest Hills. This region has been heavily fished over the last 10 years, but effort has focused on just a few of the seamounts. This gives us a natural setting to examine seamounts in very close geographic proximity, of a broadly similar size, depth range, and elevation, that have been fished to varying degrees. In 2001 we completed a survey to describe the biodiversity of seamount fauna and study the effects of fishing. We found a strong contrast in the extent of coral cover between fished and unfished seamounts, distinct differences in the composition of species communities, and physical evidence of previous trawls in the form of gouges and scours on the seabed.



A fish's-eye view of the Northwest Hills, where we're comparing fished and unfished areas. The seamounts in bold have been surveyed in detail. The seamounts are 100–400 m high, rising from the seafloor at about 1200 m depth. They lie roughly 500 km east of Kaikoura, about halfway to the Chatham Islands.

Above: Stony coral covering the seafloor along the undisturbed ridge on Morgue. Other animals in the picture are crinoids (sea lilies), orange brisingid starfish, and orange roughies.



Left: Distribution of stony corals in seafloor photographs on Morgue. The photos were shot along the black transect lines. The size of the red circles is proportional to percentage of the image covered by erect coral. Most of the coral is growing on a ridge that has never been trawled, while there is very little coral elsewhere.

Age and growth of coral

One strand of study has been determining the age and growth rates of bamboo corals which are regularly found on seamounts in New Zealand waters. Some of this work was reported in *Water & Atmosphere* in 2003. We used ring counts from thin sections, electron microscopy images, and radio-isotope analysis. The study indicated that these corals could be at least 50 years old, and have a relatively slow growth rate of 2–3 cm per year, which could mean large corals are several hundred years old. Their resilience to fishing may be low. Now we're beginning the challenging task of resolving ages of reef-forming and multi-branching stony corals.

Monitoring changes over time

We undertook a second survey of the Northwest Hills in 2006, covering the same fished and unfished hills from the 2001 survey. One of the important changes since the earlier survey is that three of the hills have since been closed to trawling; one of these, called Morgue, was heavily trawled in the past. Fisheries data show that commercial fishing trawls have run in many directions on Morgue, with the exception of south to southwest. During the 2006 survey we made intensive photographic transects in a radial pattern around the hill, including one in a south-southwest direction down the line of a ridge-like lava flow, where trawling has not been reported. We recorded dense stands of a cold-water coral similar to those found on the nearby unfished seamounts. This indicates that, despite heavy fishing, the rugged slopes on this one side had provided a refuge for corals which were likely to have been much more widespread before fishing began. The survey also revealed a patchy distribution of small stylasterid corals (also known as hydrocorals) that appear to have colonised areas of the seamounts between the two surveys. We plan further surveys to monitor changes in the sea life after trawling has ceased. W&A

Further reading

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Dr Malcolm Clark is a fisheries scientist who studies seamounts and their biodiversity. He is based at NIWA in Wellington.

NIWA's seamount research is funded by the Foundation for Research, Science & Technology's 'Seamount Fisheries' programme and complementary Ministry of Fisheries projects.

Resource Management

Snapper's-eye view of the inner Hauraki Gulf

***Mark Morrison, Ude Shankar, Darren Parsons, Glen Carbines,** and **Bruce Hartill** describe a multi-layered investigation into fish and their habitat.*

Fishing for answers

- Recreational fishing and other human activities are putting increasing pressure on coastal ecosystems.
- NIWA scientists are using a range of tools and techniques to study the interactions between snapper, recreational fishing, and seafloor habitats.
- Our findings about snapper in the Gulf will help in moving towards ecosystem-based fisheries management.

Marine recreational fishing is a passion for many New Zealanders, providing both food and entertainment. It also generates significant economic activity, including the purchase of fishing gear, bait, boats, fuel, and holiday accommodation. However, increasing levels of recreational fishing have direct and indirect effects on marine fish populations. The most obvious direct effect is that more fish are caught. 'Indirect' fishing effects include anchor, chain, and gear damage to the seafloor, and changes to the food web caused by adding food (the bait) and removing higher-level predators (the fish). In addition to actual fishing, other human-induced pressures on coastal fisheries include increasing sedimentation and water turbidities, and loss or degradation of important biogenic (living) nursery habitats, such as sea-grass meadows, horse-mussel beds, and sponge gardens. The emerging challenge for resource management is to maintain productive and healthy fisheries by looking after the coastal ecosystems that effectively underpin them. This is known as 'ecosystem–based management'.

A model fishery

The inner Hauraki Gulf snapper fishery is a logical place to start looking at the interactions between recreational fishing and marine ecosystems. Ministry of Fisheries (MFish) figures for December 2004–November 2005 estimate a recreational harvest of 674 tonnes of snapper from the inner Gulf, or about 28% of all snapper caught recreationally between North Cape and East Cape. This means that around 761 000 snapper, weighing on average 0.84 kg each, are caught each year in the inner Hauraki Gulf by recreational fishing.

Knowing this, we focused our FRST-funded 'Marine Recreation' research programme in the inner Gulf to better understand the inter-relationships between the recreational snapper fishery, snapper populations, and the underlying seafloor habitats, including the invertebrate animals living there. We divided the inner Gulf into eleven zones representing areas of either higher recreational fishing catch (for example, Rangitoto, Motiuhe Channels) or lower catch (Bean Rock area, Tamaki Strait). Then we began a range of field projects to collect the data needed to 'populate' each of these eleven zones.

To manage these datasets, we turned to a geographic information system (GIS) – a software programme designed to store, display, and analyse spatial data. We based RECFISH, our GIS database, on the Marine Data Model developed by NOAA (US National Oceanographic and Atmospheric Administration).

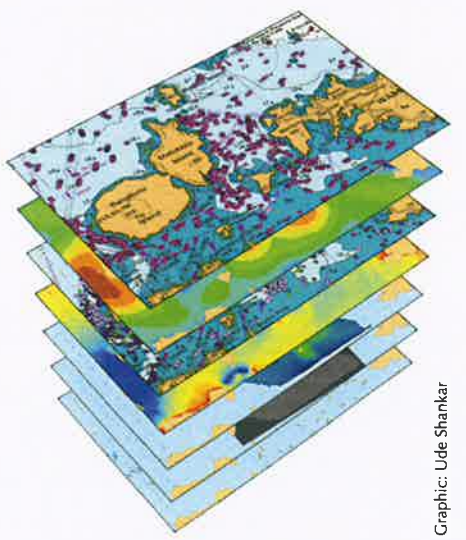
The range of data we have collected has been quite broad. In the following sections we describe some of these data, how we collected them, and what they mean.

Broad-scale habitat mapping

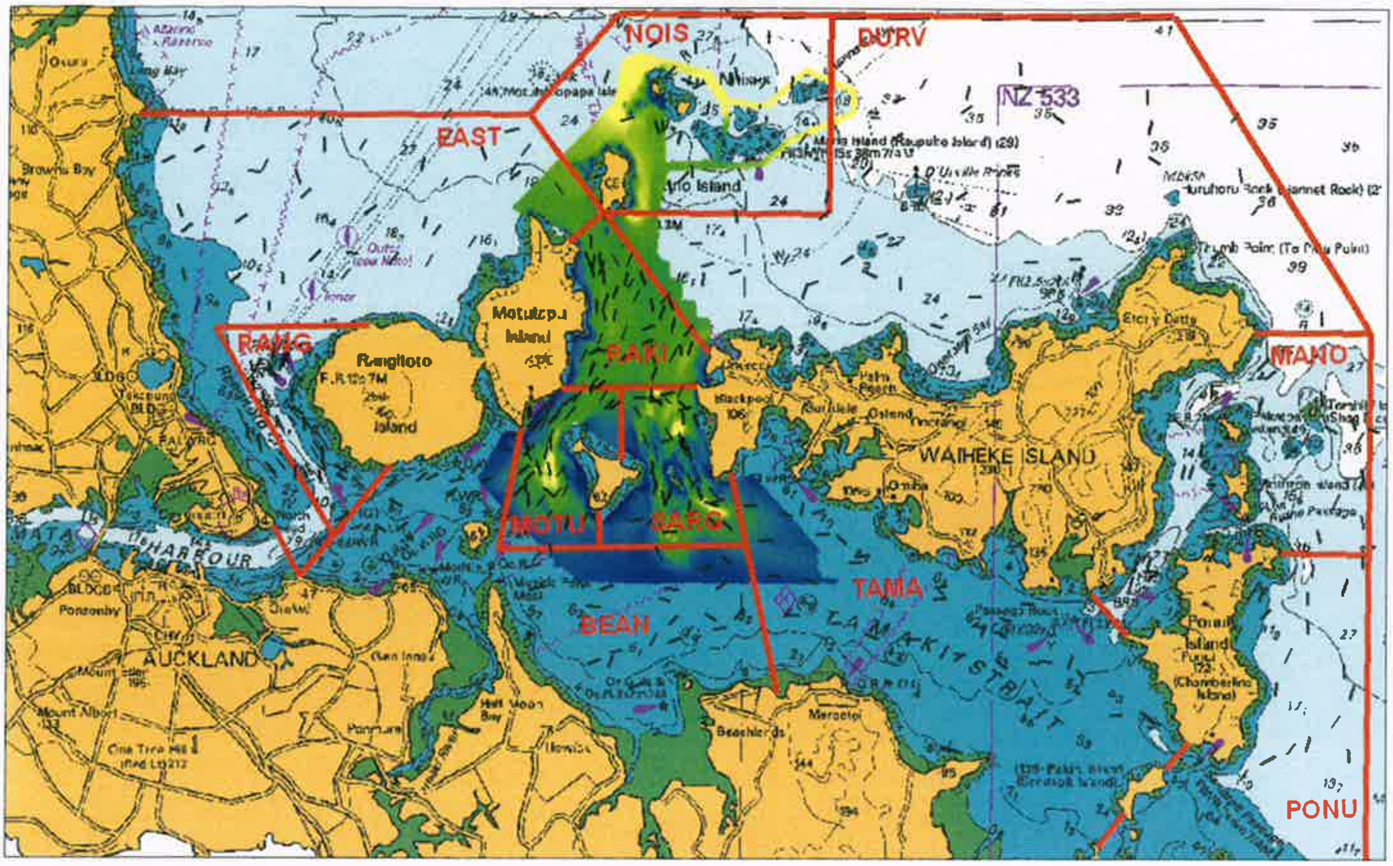
We used advanced mapping technologies (multi-beam, side-scan sonars) to map the seafloor bathymetry (contours) and texture, at very high resolution, in the middle part of the overall study area. From these data, we're using software tools to identify seafloor features such as plateaus, holes, ridges, slopes, and channels. These tools use the same basic principles as those for producing land topographic maps, such as the ones you might use for tramping. Along with such 'big' features, we've also identified smaller habitat components, such as patch reefs, sand/shell waves (like dunes), and regions with lots of pits and mounds. Overall, this information lets us create broad-scale seafloor habitat maps. In the surrounding, unmapped area, we've used existing marine chart information. We've also used an Auckland Regional Council hydrological model for the Hauraki Gulf to predict tidal current speeds, providing an additional layer of habitat information.

Finer-scale seafloor habitat types

Mapping technologies such as sonar are good for identifying different physical elements of the seafloor, but they don't tell you what the elements actually are, though an experienced operator can make a pretty good guess. They also cannot



Components of the RECFISH GIS data scheme.



The inner Hauraki Gulf survey area marked with our eleven sampling zones.

detect individual plants and animals on the seafloor, unless they are so dense that they literally form a living cover (for example, high-density beds of green-lipped mussels or horse mussels). We used a dropped underwater video (DUV) to determine what the different physical features from the remote mapping actually were – a process called 'ground-truthing' – and to count individual plants and animals of reasonable size. A DUV is a forward-facing video camera attached to a lead 'torpedo' with stabilising fins, that is towed along just above the seafloor. Small lasers attached to the DUV are aimed at the seafloor, with a 20-cm gap between them. This 20-cm scale-bar is captured in the video, so we can estimate the size of individual objects on the seafloor, such as fish.

We used the DUV to identify seafloor type and count animals living on the seafloor at more than 400 locations spread across the eleven zones. At each location, we towed the DUV along a line, or 'transect', for a distance of about 400 m, with a transect width of 0.5–2 m, depending on water clarity. Back at the office, we viewed each video transect and determined the seafloor type, such as mud, sand, shell grit, shell 'armouring', or rocky reef. At random points along each transect, we counted and measured all the biogenic habitats (horse mussels, sponges, sea-squirts, scallops, large dead shells), as well as physical features like ripples, pits, and burrows. These data are being used to describe what the different habitats are, what lives in them, and how this varies across the study area. Many of these features are potentially important components of 'good' snapper habitat.

Fishery catch-and-effort dynamics

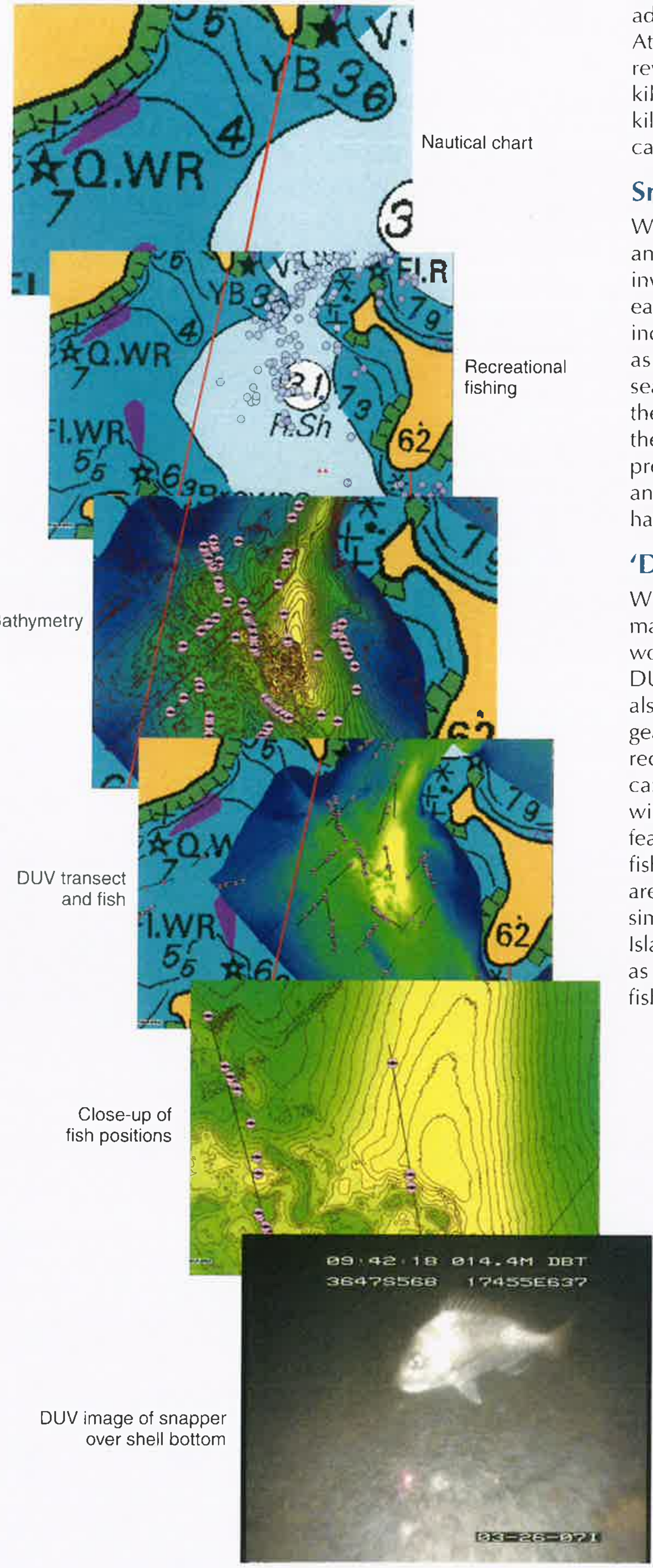
We're using survey techniques we developed in earlier work for MFish to estimate how many snapper (and other species) are caught, and at what sizes, in each of the eleven zones. Observers in small planes count the number of recreational boats fishing in each zone; on the same day, we interview fishers as they return to nearby boat-ramps, measure their fish catches, and ask questions such as how long they had fished that day. We ran these surveys on 45 randomly selected days throughout the year.

Snapper population dynamics

Previously, we discovered that snapper and other species can be counted during the night as they sleep on the seafloor, using either divers or DUV. For this programme we took advantage of this behaviour to estimate how many snapper, and at what sizes, were present in each of the zones, and how that changed through the year. From the 400+ DUV transects, we counted and measured every sleeping fish seen, a 'catch' of more than 2200 snapper, ranging from 2 to 75 cm in size. We also noted the habitat associated with each individual fish. From these observations we are quantifying what habitats snapper prefer, and how they vary across the survey area.

We also wanted to know more about snapper movement patterns, and how popular fishing areas, such as Rangitoto and Motiuhe Channels, were linked by snapper movement to other places that were much less fished, such as East Coast Bays to Rakino, Tamaki Strait, north of Waiheke Island. To

RECFISH: example of data layers from the Motiuhe Channel.



do this, we tagged snapper throughout our study site and in adjacent areas: around 9300 fish in the summer of 2006/07. At last count, more than 560 tags have been returned, revealing patterns ranging from strongly resident (less than a kilometre movement) to migratory (moving tens to hundreds of kilometres). The extremes of movement include a snapper re-caught off the Hokianga Harbour, and another off Gisborne.

Snapper habitat usage

While snapper are found across all habitat types, their numbers and sizes vary considerably with bottom habitat type. To investigate possible reasons for this, we selected five locations, each containing a specific type of bottom habitat. These included the fine muds north of Rangitoto (known to fishers as the 'worm beds'), sands, shell gravel, and shell-armoured seafloor (dog-cockles). At each location, we sampled both the benthos (invertebrate animals) and snapper (to see what they had been eating). From these data we are assessing what prey items snapper are targeting versus those that they are not, and how this relates back to the different kinds of seafloor habitats.

'Derived' spatial maps and models

With the various datasets described above, we're creating new maps that incorporate multiple data sources. For instance, we're working on fish–habitat suitability models, using data from DUV, remote sensing, and our current-speed model. We're also looking at the relationships between anchoring/fishing gear intensity and biogenic habitat densities on the seafloor, recorded across fishing intensity gradients (using DUV, drop cameras, and boat counts summed over time). These models will enable us to go to other places, rapidly assess the habitat features, and then predict the relative values of those places for fish and fishers, and likely threats to those values. Many places are under increasing environmental and human pressures, similar to the inner Hauraki Gulf; these include the Bay of Islands, Kaipara Harbour, Coromandel, and Tauranga, as well as more southern regions of New Zealand where recreational fisheries target colder-water species such as blue cod.

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Photo: Sam Mossman

Photo: Jarrod Walker

Images of the real world.

Left: Recreational fisher with large snapper tagged at the Noises Islands and later re-caught (and released) at Kawau Island, 30 km away.

Material from a benthic core sample from the 'worm beds' north of Rangitoto Island.

Below: Examples of biogenic seafloor habitat elements valued by snapper and vulnerable to fishing damage and sedimentation. Top to bottom: an ascidian (sea squirt), a wandering anemone, and a sponge (with resident hermit crabs).

Fishy preferences: emerging patterns and implications

As we analyse our data, we're seeing the emergence of strong spatial and temporal associations. For instance, snapper in general show a strong preference for habitat patches and areas of higher structural complexity, such as beds of horse mussels, sponges, and sea squirts, and pits and burrows. Juvenile snapper especially are almost always observed very close to, or on top of, such structures (a pattern also seen in estuarine nursery environments). The two most likely reasons for this are that the structures provide shelter from larger predators (John dory, kahawai, and coastal sharks), and/or better foraging opportunities.

In turn, while we found such biogenic structures right across the inner Hauraki Gulf study area, these habitats are more common, and larger, in areas of coarser soft-sediment habitats (such as shell grit, gravel, shell 'armouring') and stronger tidal flows. It's no coincidence that such places are also where recreational effort and catch are most concentrated, for example Rangitoto, Motiuhe, Rakino, Seargant's, and Ponui channels. Unfortunately, such biogenic structures are also vulnerable to fishing impacts, such as being dislodged or crushed by anchors and chain, being physically removed by lines and hooks, or clogged by re-suspension of bottom silts. As most of these species are filter-feeders, they are also affected by more generic threats, including higher sedimentation rates to the seafloor, which smothers them, and suspended sediment in the water, which makes them spend extra energy to extract their food. These degraded conditions also affect the smaller species living in and on the soft sediments, such as marine snails, polychaete worms, and bivalves, which provide food for snapper.

While these habitats and areas have some natural resilience to such disturbances, there is probably a threshold beyond which natural regeneration processes, such as recruitment and regrowth, cannot counter the continuing loss of suitable habitat. Resiliency and thresholds will vary across different habitats, depending on the kind of disturbance. We can see historical examples of such thresholds being reached and exceeded in less resilient – or perhaps more stressed – areas; witness the extensive expanses of dead (and presumably old) relic shell beds in Tamaki Strait and the inner Firth of Thames, along with the complete loss of once extensive, and dense, green-lipped mussel beds growing on soft sediments. These beds were commercially dredged from the 1920s to the 1960s for the Auckland market, until the fishery completely collapsed; forty years on, the beds have never returned. Such areas are now dominated by large expanses of soft mud and silts; there is little emergent structure, and the snapper catch is modest compared to other areas.

All things considered, the inner Hauraki Gulf recreational snapper fishery is still in a pretty good state. This current research programme is quantifying the likely magnitude of, and the mechanisms behind, some of the potential problems outlined above. Our findings will give us a much better understanding of how this coastal ecosystem supports its fisheries, how human behaviour affects these relationships, and what new approaches might be developed to proactively manage our impacts on this and similar systems. Ultimately, ecosystem-based management will not only support the value and pleasure of recreational fishing, but also maintain a healthy and functional ecosystem, with all its wide and wonderful diversity of habitats and species. W&A

Photo: Matt Smith

Photo: Jarrod Walker

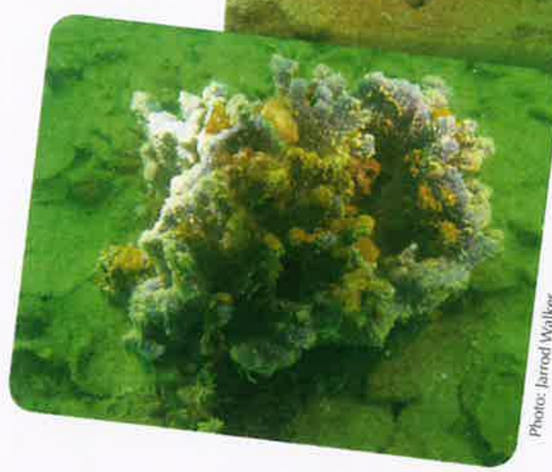
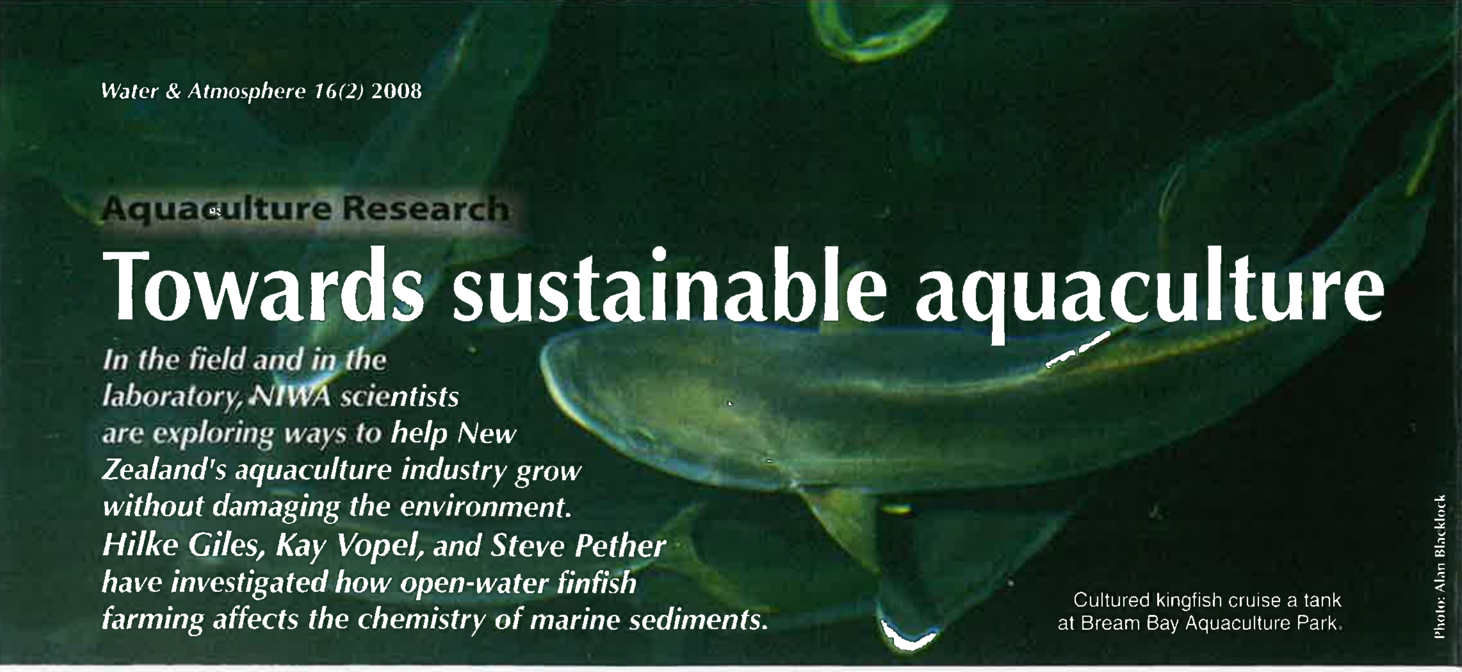


Photo: Jarrod Walker

Dr Mark Morrison, Dr Darren Parsons, and Bruce Hartill study fisheries ecology; they are based at NIWA in Auckland. Dr Ude Shankar is a GIS specialist based at NIWA in Christchurch. Dr Glen Carbines, formerly of NIWA, is now a fisheries scientist with Stock Monitoring Services Ltd.

The authors thank the Foundation for Research, Science & Technology for funding 'Marine Recreation' and DOC for funding (and permitting) snapper tagging within Hauraki Gulf marine protected areas. MFish granted a special permit for the sampling and fish tagging in this study.

We are grateful to many people for their involvement with this programme, including colleagues at NIWA and at Leigh Marine Laboratory, University of Auckland, numerous boat ramp interviewers, the pilots of Christian Aviation, and the skippers and crews of the commercial long-line vessels. Finally, we thank all those many fishers at the ramp who kindly gave their time to answer questions about their fishing, and allowed us to measure their catches.



Aquaculture Research

Towards sustainable aquaculture

In the field and in the laboratory, NIWA scientists are exploring ways to help New Zealand's aquaculture industry grow without damaging the environment. Hilke Giles, Kay Vopel, and Steve Pether have investigated how open-water finfish farming affects the chemistry of marine sediments.

Cultured kingfish cruise a tank at Bream Bay Aquaculture Park.

Photo: Alan Blacklock

Aquaculture is a rapidly growing industry in New Zealand with plans to raise annual production from today's $300 million to $1 billion by 2025. New Zealand aquaculture is dominated by products with high quality but moderate value, such as Greenshell™ mussels, Chinook salmon, and Pacific oysters. Some of the industry's planned growth can be met through improvements of these species; however, the greater opportunity lies in new higher-value species, such as kingfish (*Seriola lalandi lalandi*).

NIWA has made great progress in breeding kingfish. A remaining obstacle to large-scale commercial cultivation is the potential effect on the marine environment. One way of learning about these impacts is by simulating them in the laboratory.

Environmental effects of fish farming

The main concern about developing a new marine fish farm is usually how it may affect water quality. The key to understanding these effects lies with the processes that take place in the sediment.

Fish are typically farmed in coastal areas in cages near the water surface. Fish faeces and uneaten feed sink to the seafloor, where they enrich the sediment with organic material. Fish farms also have other effects on the ecosystem, but this enrichment is the most significant effect.

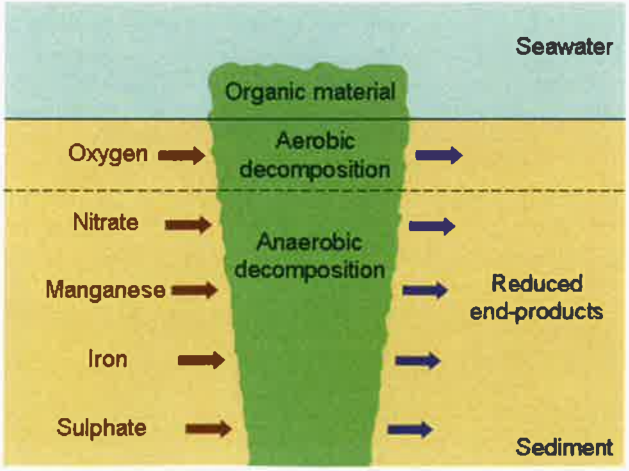
In the sediment, organic material is broken down by a complex network of microbial **reduction–oxidation** (or **redox**) reactions. This process provides food for microbes and therefore increases their activity. Microbes that live in the upper few millimetres of sediment use oxygen as a source of energy to break down organic material and thus create an **oxygen demand** in the sediment.

Below this upper sediment layer, organic matter is broken down by microbes that use other sources of energy, mainly nitrate, iron and manganese compounds or sulphate. This process is called **anaerobic** decomposition and produces reduced end-products. These end-products are mobile in the sediment. They diffuse within the water between the sediment grains (**porewater**) and are redistributed if the sediment is mixed, for example by burrowing animals or by **resuspension** of the sediment by strong currents. If these reduced end-products enter the upper sediment layer they are oxidised by oxygen and this also creates an oxygen demand in the sediment.

Commercial success one step at a time

- **NIWA has successfully bred kingfish in tanks; now we need to understand the environmental impacts of raising them in open-water cages.**
- **With laboratory experiments we're measuring how the fish faeces that fall from cages affect the chemistry of the sediments below.**
- **Our results so far suggest that sediment oxygen levels are depleted under fish cages and also indicate that this is less of an issue where strong water currents help mix the sediments.**

The large amount of organic matter deposited below fish cages changes the rates of almost all redox reactions. It also changes the **flux** of reaction products between the sediment and the overlying seawater. These fluxes can have important consequences for the seawater quality. For example, fish farming can result in the release of nutrients from the sediment that support the growth of algae in the water. It can also result in the release of toxic hydrogen sulphide. The effects of fish farming on ecosystem functioning thus depend on redox reactions in the sediment.



Graphic: Hilke Giles

The microbial processes at work in the sediment beneath a fish cage during decomposition of organic material, such as fish faeces. The energy source for microbes in the upper sediment layer is oxygen. Below this upper layer, nitrate, manganese, iron, and sulphate provide the energy. The reduced end-products are mobile in the sediment and can be oxidised by oxygen if they enter the upper sediment layer.

Clockwise from top left:
Four cores in the lab experiment:
S = sediment (no treatment)
SR = resuspended sediment
SF = sediment with faeces
SFR = resuspended sediment with faeces.

A close-up of the layer of fish faeces on one of the sediment cores.

Hilke Giles measures oxygen in the cores during the laboratory experiment. The black instrument is an automated microelectrode porewater analyser.

Simulating kingfish farming in the laboratory

To find out what happens when fish faeces are deposited on sediment, we set up an experiment in the laboratory. We submerged cores of coastal sediment in seawater tanks. To some cores we added faeces from kingfish living in tanks at NIWA's Bream Bay Aquaculture Park, while some sediment cores were left untreated.

In the coastal environments typically used for aquaculture, tidal currents resuspend the sediment surface, lifting the top sediment layer so it mixes with seawater before settling down again when the currents weaken. We also wanted to investigate if this process modifies the effect of fish farming on the sediment. To simulate resuspension, we vigorously stirred the surface sediment of some sediment cores before adding faeces.

Glossary
aerobic – in the presence of oxygen
anaerobic – in the absence of oxygen
biogeochemistry – field of study combining biology, geology, and chemistry
flux – exchange of reaction products between the sediment and the overlying water
oxygen demand – consumption of oxygen during microbial activity
porewater – water between the grains in sediment
redox – short for reduction–oxidation
reduction–oxidation – microbial processes that remove (**reduce**) and add oxygen molecules
resuspension – mixing of the top layer of sediment into the water above

Our results

As we expected, adding fish faeces to the sediment increased the sediment oxygen demand significantly. We found that:

- Oxygen in the sediment decreased more rapidly with depth in the cores where fish faeces were added, due to the high oxygen demand by microbes.
- Oxygen demand was less when sediment was resuspended before fish faeces were added.

Implications for fish farming in New Zealand

Our experiment suggests that fish farms in areas where sediments are periodically resuspended by tides and currents may have less effect on the sedimentary environment than fish farms in calm areas. We'll learn more about these effects with more detailed analyses of our results.

We're on the brink of understanding the connections between fish farming, environmental parameters, and processes in the sediment and seawater, and soon we'll be able to give better advice regarding the ecosystem effects of fish farming. W&A

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Dr Hilke Giles is a sediment biogeochemist who works on measuring and modelling aquaculture effects on sediment processes; she is based at NIWA in Hamilton. Dr Kay Vopel, formerly at NIWA, is now a senior lecturer at Auckland University of Technology. Steve Pether is an aquaculture technician at NIWA's Bream Bay Aquaculture Park.

Hazards Research

Facing natural hazards with Māori environmental knowledge

Over the centuries, Māori have recorded a litany of natural hazards and catastrophic events in their stories, songs, and place names. Now ***Darren King, James Goff,*** *and* ***Apanui Skipper*** *are investigating how this wealth of information can complement scientific studies and management of natural hazards.*

Applying MEK to hazards
- Māori stories, songs, and place names record many generations of experience in New Zealand.
- Researchers have compiled and mapped those that carry information about natural hazards.
- Hazards managers can take advantage of Māori environmental knowledge by acknowledging these sources of local information and involving the Māori community in hazards planning.

In New Zealand, we're exposed to a range of natural hazards. Why should the relatively short record since European settlement be all that we know about these things? Obviously it isn't: we have geology, geophysics, and other branches of Western science to look further back in time. But we also have Māori environmental knowledge (MEK), or *Mātauranga taiao*. It's a cumulative body of knowledge that is part of a wider understanding of the natural and spiritual world, or *Mātauranga Māori*. This form of knowledge is regarded as both 'traditional' and contemporary, representing the experiences of generations of Māori in New Zealand.

We have reviewed a wide range of written records (which are based on oral recordings and traditions) to compile details of past natural hazards as remembered through a variety of forms: *pakiwaitara* (stories), *mōteatea* (laments), *pepeha* (quotations), *whakataukī/whakatauākī* (proverbs), and *waiata* (songs). They tell about catastrophic events, such as earthquakes and volcanic eruptions, and areas of high hazard risk, such as flood-prone rivers; and they forewarn hazardous environmental conditions, such as storms and drought. We discuss this research in greater detail in our article 'Māori Environmental Knowledge and natural hazards in Aotearoa–New Zealand' (*Journal of the Royal Society of New Zealand*). For more about the use of environmental indicators, see 'Understanding local weather and climate using Māori environmental knowledge' (*Water & Atmosphere*).

Storms, floods, and taniwha in oral tradition

Many stories tell of the impacts from great waves caused by storms, inundation caused by incantations, and land or marine phenomena – known as *taniwha* – causing death, destruction, and peril for people living near water. It's likely these stories were told to explain the causes of natural hazards, to record loss of life, and to serve as warnings about the nature of particular places.

In a story from the northern South Island, a taniwha living in a cave at Cape Campbell attacked people travelling along the coast between Cape Campbell and the Wairau River. (A similar story places a taniwha at Wairau River mouth.) The taniwha would approach the land with such force that the sea would rise up in front of it and sweep people off the land and into the lagoon behind. Eventually, it was killed by a great warrior who made the coast safe for subsequent travellers.

In another story, a group of Ngāti Tara from Taranaki were fishing off the coast of Wai-iti on the north Taranaki coast when they were caught in a large storm that drove them south to Rangitoto (D'Urville Island) in Tasman Bay. Eventually settling with their families at Moawhitu (Greville Harbour), they lived there until the community was wiped out by a wave. It is said the wave swept into the harbour, drowning almost everyone and "tumbling their bodies into the sand dunes". According to the oral tradition, this disaster would have occurred around the 16th century. While there's been no tsunami-related research at this site, early work in the area hints that there may be some geological evidence of such a tsunami-like event.

Photo: Alan Blacklock

Devastation from a flash flood at Matata, Bay of Plenty, in May 2005.

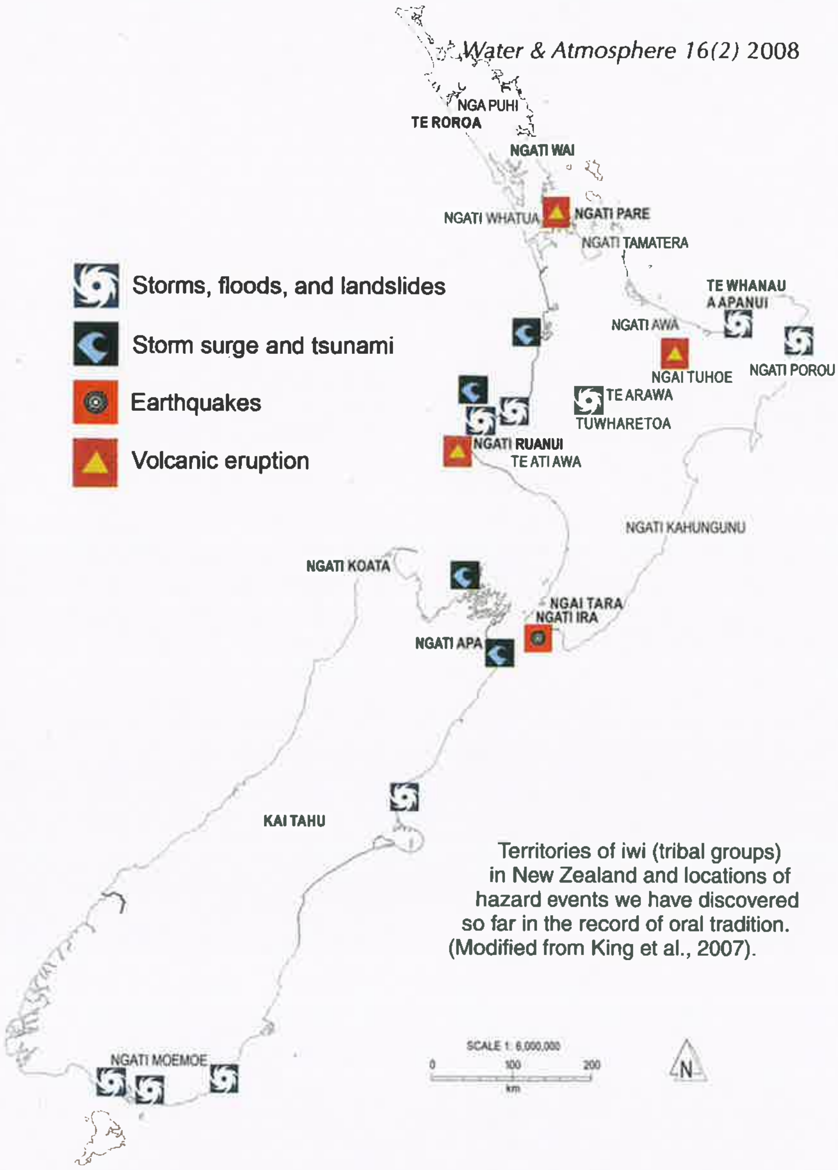
Environmental history in place names

We also looked at place names and their meanings, which can frequently provide clues about the local history, geography, biology, hydrology, and climate. Waikino, near Waihi, for instance, designates a point on a narrow river channel known to cause a dangerous torrent. In a similar manner, the name 'Rangipo', given to the barren tephra plain downwind of Ruapehu, Tongariro, and Ngaruahoe volcanoes, means 'place of darkness'. While there are many examples like these, one must be careful when attributing significance to place names, as meaning can be confused through varying use of language and personal interpretations.

MEK and natural hazard management

Given the diversity of natural hazards faced by various Māori communities in the past and today, we can gain important insights from their experiences. MEK's contribution to natural hazards science and management can include:

- raising community awareness about the hazard histories of local areas and the range of events that are possible
- providing important baseline information against which to compare environmental change
- helping to set research questions about local hazards and environmental processes,
- reconstructing time-lines of past hazards to help estimate the return periods of specific hazards events
- informing discussions about natural hazards preparedness, response, and recovery.



Territories of iwi (tribal groups) in New Zealand and locations of hazard events we have discovered so far in the record of oral tradition. (Modified from King et al., 2007).

While there may be other valuable contributions that MEK can make to hazard management in New Zealand, it's important to recognise that incorporating MEK into the process of hazard management does not end with documenting that knowledge. Rather, the process should actually involve Māori people, their knowledge, and expertise. By letting Māori share responsibility for hazard preparedness, response, and recovery, we can apply all the knowledge that Māori possess – not just traditional knowledge – to local hazards management and mitigation. Civil defence and local authorities tasked with hazards management should actively facilitate this knowledge-sharing to ensure that MEK is incorporated into the decision-making process; without it, New Zealanders are at greater risk than they need be. W&A

He kupu whakamutunga

Ko aku kupu whakamutunga ko ēnei e whai ake nei.
"Ka pūwaha te tai nei, hoea tahi tātou".
Me hoe i te waka kia tika kia kore ai e tahuri.
Nō reira e aku nui, e aku rahi, e aku toka tumoana tēnā hoki tātou katoa.

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Darren King (Ngāti Raukawa) is based at NIWA in Auckland, where his work focuses on climate variability and change. Dr James Goff is a coastal scientist specialising in tsunami, working for NIWA in Christchurch. Apanui Skipper (Te Whānau-a-Apanui, Parehauraki) works with Te Kūwaha, NIWA's Māori Research and Development Unit, from his base in Hamilton.

Teacher Feature

Using *Water & Atmosphere* in your classroom

One of NIWA's aims with this magazine is to contribute to science education in New Zealand. To this end, we distribute *Water & Atmosphere* without charge to New Zealand high schools. Articles are assigned 'Curriculum Connections' to indicate which of the NZ NCEA Achievement or Unit Standards they can complement as a classroom resource. These links are assigned by NZMST Teacher Fellows who are working with NIWA scientists.

The magazine and the Curriculum Connections are also available online at **www.niwa.co.nz/pubs/wa** There you'll find an archive of back issues. All online articles include a pdf of the printed version and the articles are indexed via the website's search engine. The Curriculum Connections are compiled at **www.niwa.co.nz/pubs/wa/resources**

Curriculum Connections for this issue

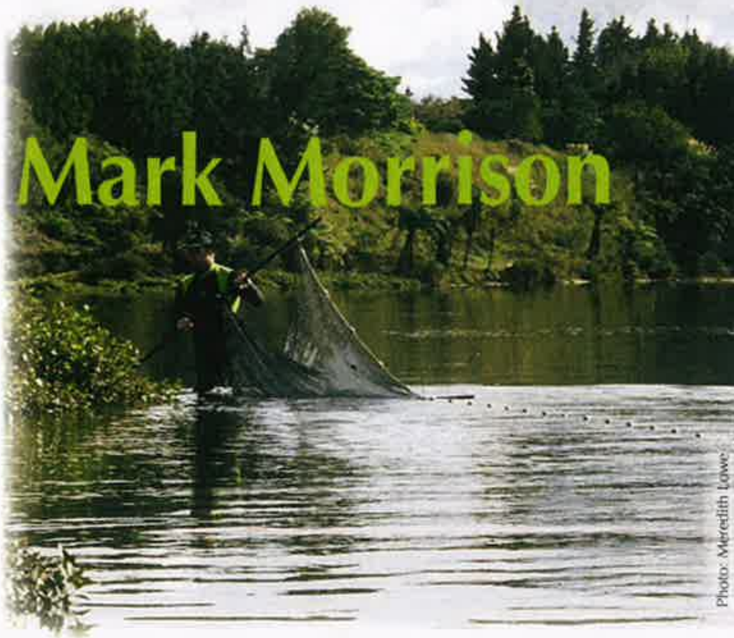
Pages	Article	Relevant NCEA Achievement Standards (AS) and Unit Standards (US)	Brief summary
10–11	Making ends meet in the Ross Sea	Biology Level 1 US18970, Level 2 AS90461, Level 3 AS90716	NIWA scientists are fitting together information about productivity and food webs to develop a mass-balance model for the Ross Sea.
12–13	Mapping biodiversity in New Zealand's EEZ	Biology Level 2 AS90162 Science Level 1 US6349	Ocean Survey 20/20 is exploring the waters around NZ to discover the extent of our living marine resources.
14–15	Back from the ice bearing scientific treasure	Biology Level 2 AS90461	Pictorial spread on a 7-week exploration of Antarctic marine biodiversity.
16–17	Seamount fisheries: understanding the impacts of trawling	Biology Level 2 US6309, Level 3 US6319, AS90714 Education for Sustainability Level 2 AS90811, AS90813 Science Level 2 US6352, Level 3 US21613, US6355	Studies over the past decade have inventoried the biodiversity on seamounts and compared the benthic communities found in trawled and untrawled areas.
18–21	Snapper's-eye view of the inner Hauraki Gulf	Biology Level 1 US6309, Level 2 US8925, AS90461, AS90769 Education for Sustainability Level 2 AS90811	An extensive study of recreational fishing and snapper habitat is a step toward 'ecosystem-based management'.
22–23	Towards sustainable aquaculture	Aquaculture Level 3 US16674, US19772, Level 4 US19773 Biology Level 2 US6309 Geography Level 1 AS90204 Education for Sustainability Level 2 AS90811 Science Level 1 AS90188, Level 2 US6352, Level 3 US21613, US6355	NIWA research is is exploring ways to help the NZ aquaculture industry grow without damaging the environment.
24–25	Facing natural hazards with Māori environmental knowledge	Education for Sustainability Level 2 AS90812 Science Level 2 US6352, Level 3 US21613, US6355	Māori stories, songs, and place names record traditional knowledge that can help in hazards planning.

Colour key to Achievement and Unit Standards

Aquaculture Biology Chemistry Earth Science Economics Education for Sustainability Geography Mathematics Physics Science

A day in the field

On the water with Mark Morrison



Mark sets a fyke net to sample small fish in mangroves.

Fisheries ecologist Mark Morrison balances his desk job writing research proposals, reports, and journal articles with liberal doses of fieldwork in estuaries and coastal waters all around New Zealand. Mark gained his post-undergraduate degrees from the University of Auckland. For his research on rocky reef fish ecology and scallop ecology and enhancement, he was based at the University's marine field station at Leigh.

Since 1996, when he joined the fisheries team at NIWA in Auckland, Mark's research has encompassed several broad-scale surveys of coastal fisheries and habitat throughout the country. In this issue of *Water & Atmosphere*, he's written about an extensive survey of the recreational snapper fishery in the inner Hauraki Gulf (see pages 18–21).

Mark's days in the field can be quite varied, depending on the research objectives. We asked him to describe some of the fieldwork involved in an earlier project.

Tell us about your big coastal habitat survey.

For this project we sampled by dragging a small seine net in selected estuaries along the entire coastline of New Zealand, including Stewart Island. It's taken us five or six years to do the whole country, and we're still completing the data analysis. Our purpose was to see what small fish are living in the different habitats that are found in estuaries, from the lower channels or seagrass meadows at the mouth, up through the muddy reaches, and right up into the saltmarshes. We're especially interested in small fish – juveniles in particular – and habitats such as seagrass beds, and in recording how these environments change around the country.

Logistics must be a major part of this kind of fieldwork.

We ran the surveys by working two sampling teams in convoy. Typically we had two-person teams and sometimes iwi, locals, or people from DOC helping us out. These teams would travel in a 4-wheel-drive vehicle, towing a small inflatable boat. We'd leapfrog down the country, with each team doing an estuary a day. We'd be on the road for a couple of weeks at a time, sometimes coming back to the same motel, sometimes checking into a new motel each night. We covered each area as efficiently as possible.

Did you sample every estuary?

We knew we couldn't cover every estuary, so we picked our harbours for various reasons: sometimes because the estuary was typical, or unusual, or, sometimes because it was unspoiled by humans. Some of our estuaries were practically inaccessible and we'd end up dragging our boats over farmers' fields, through gates, and down banks to get to the water. And sometimes we simply couldn't get a boat into the site and had to seine the whole estuary on foot. The locals were especially good about helping us get into remote places and they also provided a rich local history. In all, we covered more than 70 of New Zealand's 300-plus estuaries, including all the bigger ones.

Can you describe your schedule for a typical day?

Each day's schedule was different, depending on how far we had to travel from the motel to the estuary and the timing of low tide for that day. In each esutary we aimed to drag our nets at eight sites ranging from the entrance to as far up as we could reach. To do this we planned on 5 to 6 hours on the water, split either side of low tide. With driving to our site, sampling, and then driving back (or else to our next accommodation), we worked 10 to 12 hours a day.

What happened to the samples you collected each day?

During the fieldwork, we identified, measured, and released the larger fish. We bagged the smaller stuff, carried it out, and froze it when we got back to the motel, and later shipped it back to our lab in Auckland by refrigerated freight. In the field, we also recorded all sorts of environmental data about the water, the sediments, the plants, and so forth.

What's the worst and the best your fieldwork can offer?

The absolute worst is the mud. In the shallows, the fine-mesh nets can occasionally fill up with it until we may end up hauling 200–300 kg of mud. And in some parts of the estuary we're literally up to our waists in it. By the end of the day we look like the 'Creature from the Black Lagoon'.

The really great parts about this fieldwork are the camaraderie and humour of the field crew and some of the amazing places we get to go to: remote, scenic, pristine, as close to a natural landscape as possible. It's like you're the first person there. And because we work throughout New Zealand, there's a lot of variety – from Northland's Rangaunu Harbour (which I think of as the hidden harbour, even though it's a hundred square kilometres) to remote estuaries in Stewart Island.

Further reading

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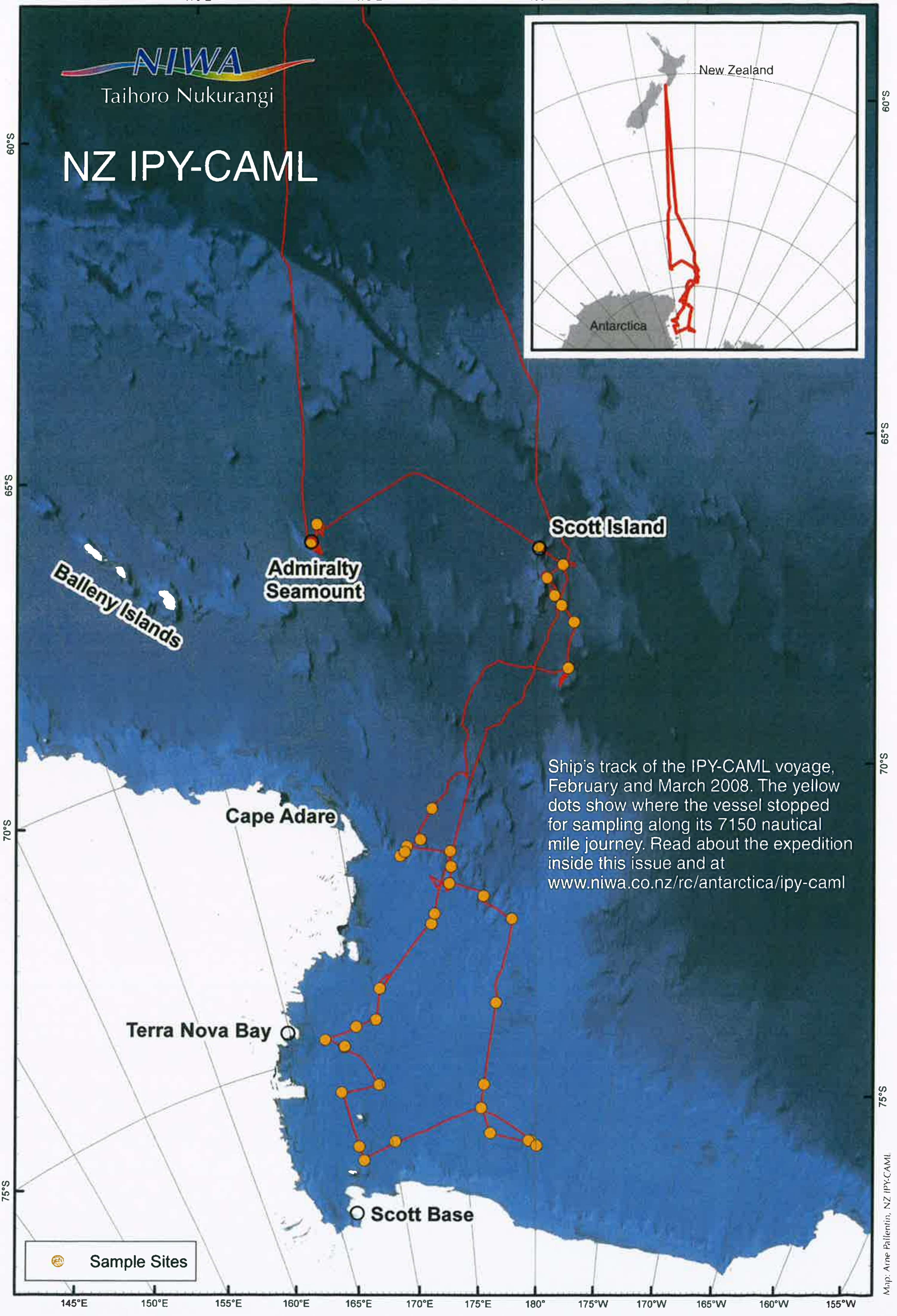

Ship's track of the IPY-CAML voyage, February and March 2008. The yellow dots show where the vessel stopped for sampling along its 7150 nautical mile journey. Read about the expedition inside this issue and at www.niwa.co.nz/rc/antarctica/ipy-caml