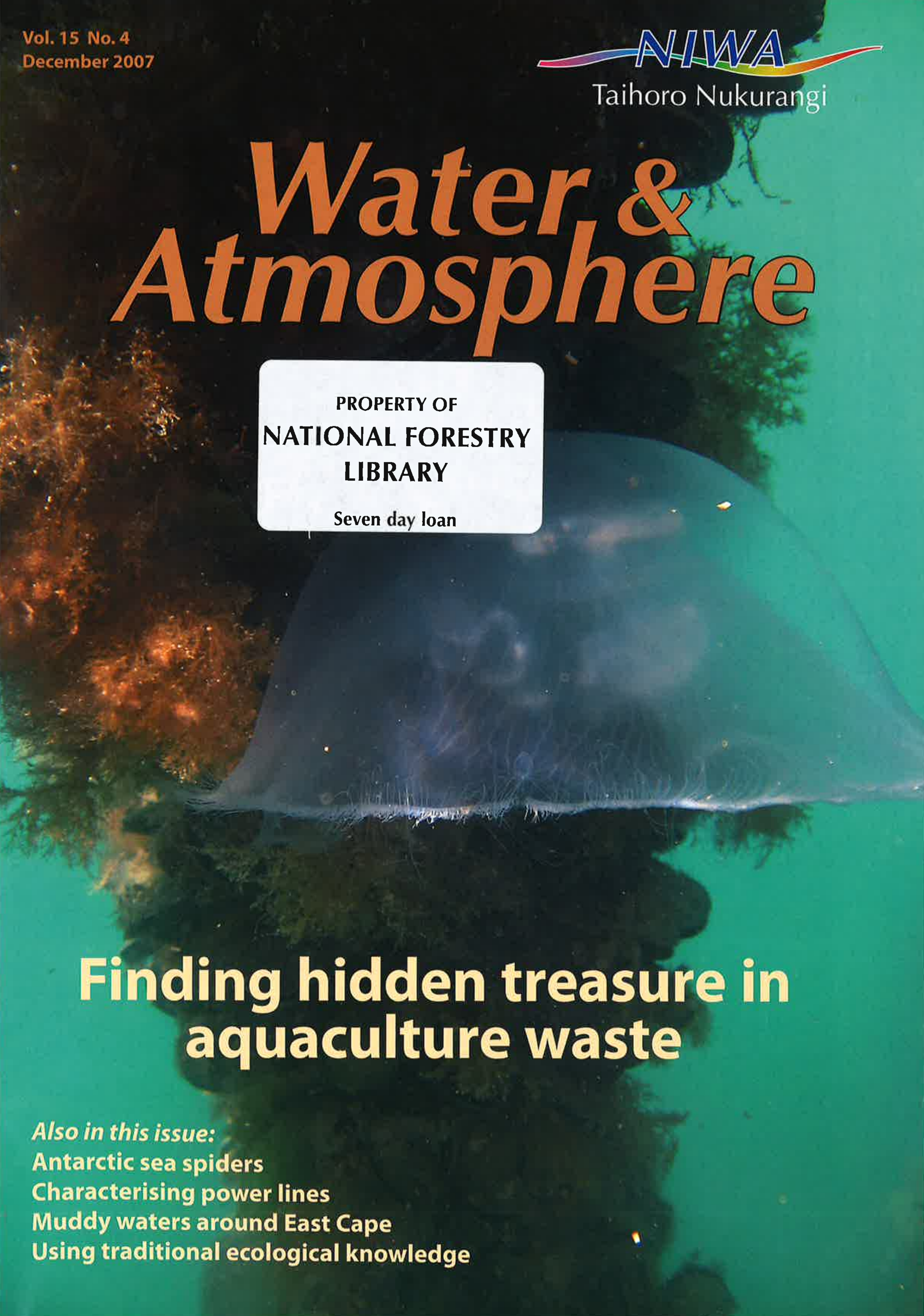
Vol. 15 No. 4
December 2007

NIWA
Taihoro Nukurangi

Water & Atmosphere



Finding hidden treasure in aquaculture waste

Also in this issue:

Antarctic sea spiders
Characterising power lines
Muddy waters around East Cape
Using traditional ecological knowledge

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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Cover

A moon jelly drifts past a line of cultured mussels while NIWA scientists set up experiments nearby. They are exploring the benefits of integrated co-culture, where the waste from one species is food for one or more other cultured species. Read more on pages 10–12.

Photo: Chris Woods

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Profile

NIWA
Taihoro Nukurangi

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News from NIWA

Marine Bioblitz finds new species

NIWA marine biodiversity scientists played a major role in the world's first Marine Bioblitz, held on Wellington's south coast in the proposed Kupe/ Kevin Smith Marine Reserve. Held during October, the blitz recorded over 550 species, including five that are new to science.

One of these, a graceful anemone with 32 tentacles, was found by NIWA scientist Malcolm Francis during a night dive. "We were swimming around with torches, and I wanted to take a look over the sand, because we often neglect sand as a habitat," says Malcolm, an expert underwater photographer. He spotted several of the anemones as they emerged from their sand burrows, and quickly photographed them. They are 5 to 10 cm long, pale, and sand-coloured, with delicate spots on their tentacles. Subsequent examination revealed that the organism is a tube anemone, or cerianthid. "I've discovered new fish species before, but it was a big thrill to find this elegant creature," says Malcolm.

Other new species discovered during Bioblitz were a bryozoan (a tiny animal that builds a stony skeleton), a diatom (a single-celled phytoplankton), a tiny red and green nudibranch (sea slug), and a scarlet flatworm that represents a group (Acoela) with no named species in New Zealand.

The Marine Bioblitz was a big success, not only in finding a huge number of species, but also in getting lots of Wellingtonians involved with their coastal environment. Guided kayaking, rock-pool hunts, walks, beach clean-ups, and public talks were all part of the month-long programme.

"The whole event was terrific," was the opinion of Shane Ahyong, one of the NIWA team which spent each Bioblitz weekend identifying and cataloguing species, and talking to the public. "There was lots of interaction between the public and the scientists, and it was great to see how people react when they're shown things they've never seen before. It was surprising that we found so many species over just four weekends. But we know that there are still many more species out there. We're already making plans for a second Bioblitz, once we've all recovered from this one!"

The Marine Bioblitz was supported by a host of organisations and local businesses, and the NIWA team was led by Wendy Nelson.

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Heather Anderson, 0-4-801 2218, h.anderson@forestandbird.org.nz
or visit the website: www.marinebioblitz.wellington.net.nz

Photo: Malcolm Francis

A new species of tube anemone discovered during the Bioblitz.

Photo: Fiona Proffit

Wellingtonians of all ages came out to see what lives in the proposed marine reserve.

Photo: Nicola Rush

NIWA divers inspect and photograph the hull of a visiting yacht.

Taking border patrol one step further

The spread of non-indigenous marine species through New Zealand's coastal ecosystems is an ongoing concern. There are several mechanisms by which non-indigenous organisms are spread domestically; however, marine shipping is the single most important way these species get to New Zealand in the first place.

Since 2004, NIWA has been involved in a project for MAF Biosecurity New Zealand (BNZ) that assesses the quantity and diversity of non-indigenous species transported to New Zealand as 'fouling assemblages' on the hulls of vessels arriving from overseas. The research is being carried out by several providers, each addressing a different type of vessel (for example, merchant, passenger, fishing, recreational).

NIWA has two roles in the overall project. First, we're examining the types of organisms brought to New Zealand on the hulls of private yachts. Then, during the final stage of the research, we're analysing the data collected by NIWA and other providers and developing statistical models that quantify the relative threat to New Zealand's marine biosecurity of different vessels. This is the first project worldwide to compare comprehensively the relative importance of all vessel types in introducing non-indigenous species.

Sampling has been completed and all biological specimens have been examined and identified by expert taxonomists. Hundreds of species from more than a dozen marine phyla have been collected from approximately 500 vessel hulls, and it has become apparent that some areas of a ship hull are more likely to harbour fouling species than others. Unfortunately, 'niche areas' like rudder and propeller shafts, recesses in the hull, the keel bottom, and other hard-to-get-to places are particularly popular with marine organisms, including non-indigenous species.

This research, which concludes in the middle of next year, will help BNZ understand the rate of influx of non-indigenous species into New Zealand via vessel fouling and provide a framework to prioritise management efforts toward higher-risk vessel types. We hope to get New Zealand one step closer to a predictive tool for identifying high-risk vessels – based on their maintenance and travel history – before they enter the country.

For further information, contact:
Dr Oliver Floerl, 0-3-343 8056, o.floerl@niwa.co.nz

Revised guide to deepsea invertebrates

The Ministry of Fisheries has published a revised edition of *A guide to common deepsea invertebrates in New Zealand waters*, compiled by NIWA staff Di Tracey, Owen Anderson, and Reyn Naylor, with input in each chapter from several taxonomic experts. The guide amalgamates the first edition of the deepsea invertebrate guide and a crab guide, and incorporates a further 98 species. It provides identification sheets for over 200 invertebrate species, each with an improved colour image and a description of the key diagnostic features.

Most of the species in the guide are commonly encountered when trawling in water depths of more than 200 m.

By supporting more accurate identification, the new guide will improve monitoring of trends in the capture and distribution of incidental bycatch.

For a free CD of the manual, contact:
Beatrice Stewart, Ministry of Fisheries,
PO Box 1020, Wellington
0-4-819 4265, beatrice.stewart@fish.govt.nz

Upskilling for NIWA technicians

As recipients of QEII Technicians' Study Awards, NIWA technicians Karen Thompson and Kristel van Houte-Howes have recently been to the UK for advanced training.

Sampling and identifying freshwater algae

Karen works in Hamilton with NIWA's Blue-Green Algal Monitoring Service, identifying and counting a wide variety of freshwater algal species from a range of different water bodies. For her award, Karen attended two courses at the University of Durham taught by Professor Brian Whitton and Dr David John, recognised leaders in the field of algal identification. The courses provided training in the ecology, sampling, and identification of all freshwater algal groups, and included lectures, field trips, and laboratory-based microscopic analysis.

New Zealand is physically isolated from experts in this ever-developing field; new and revised classifications are introduced as techniques and equipment improve. The training experience was very beneficial for Karen, who explains, "In New Zealand there is a shortage of well trained and skilled freshwater algal taxonomists. The new skills and knowledge I obtained have given me a lot more confidence as an ecologist and taxonomist and will not only benefit me and NIWA in the on-going monitoring of lakes and rivers, but also help contribute to the protection and restoration of our New Zealand waterways."

Dr David John demonstrates sampling techniques to Karen's class.

Photo: Gordon Beakes, University of Newcastle upon Tyne

Crustacean behaviour and physiology

Kristel's work at NIWA in Hamilton involves identifying chemical signals in crab communication. She took her award at the University of Hull, learning specialist skills in crustacean laboratory trials and behavioural studies from European researchers who are at the forefront of marine chemical ecology. Through one-on-one tuition and direct involvement in laboratory assays, Kristel was able to pick up techniques and skills that will help advance crustacean science in New Zealand.

Photo: Nicola Fletcher, University of Hull

Kristel prepares to extract urine from a crab specimen, the first step in isolating the pheromones by which the crabs communicate.

Recent work by Dr Jörg Hardege and his team at Hull has identified the pheromone used by the shore crab *Carcinus maenas* to attract mates. Their studies have also compared seasonal influence on decision making (sex versus food) in the crab, pheromone complexity, receptor function, and environmental control of reproductive behaviour. While at the university, Kristel gained in-depth knowledge about this work, the behavioural trials involved, and how these were developed into reliable bioassays.

As Kristel notes, "This training has also enabled NIWA to foster relationships with researchers at the University of Hull involved in chemical ecology work, and we are embarking on some collaborative work in the near future."

For further information, contact:
Karen Thompson, 0-7-859 1895, k.thompson@niwa.co.nz
Kristel van Houte-Howes, 0-7-859 1870, k.vanhoute@niwa.co.nz

To learn more about the QEII Technicians' Training Awards visit the Ministry of Education website: www.minedu.govt.nz

This large Fulton Hogan in-situ recycler will be used in the field trial for a new approach to reconstructing roads contaminated with coal tar.

Photo: Christchurch City Council

Learning from the Taranaki tornadoes

In early July, a swarm of tornadoes cut a 140-km swathe of destruction across the Taranaki region. The first tornado hit the New Plymouth CBD on the 4th, damaging several businesses, a few residential dwellings, and a racecourse. However, much more dramatic events were to follow on the next day, when a swarm of several – possibly more than 20 – tornadoes struck locations throughout Taranaki and devastated the small coastal town of Oakura. Roughly 50 houses suffered major damage, some of it irreparable, when two tornadoes ripped through the town.

In response to the tornadoes, NIWA organised a multi-agency reconnaissance team to assess the vulnerability of different types of New Zealand buildings (domestic and commercial) to high winds. Besides making visual observations and detailed measurements of the level of damage, we interviewed eyewitnesses, property owners, and local emergency managers. We used GPS equipment to record the exact location of the surveyed buildings, and prepared survey forms to ensure a consistent and objective assessment. After collating the damage for each tornado path, we estimated the tornado category (F-scale) and the likely wind speeds.

Our objective for the survey is to develop wind fragility or vulnerability curves that match a given wind exposure (gust velocity) to a realistic level of damage to different types of New Zealand buildings (for example, timber, masonary, or brick veneer). A report on this survey will soon be available on the Natural Hazards Centre website: www.naturalhazards.net.nz

For further information, contact:
Dr Stefan Reese, 04-386 0564, s.reese@niwa.co.nz

This beachfront house in Oakura lost its upper storey when a tornado swept through on 5 July. That tornado had maximum wind speeds of 60–70 metres per second, so was an F2–F3 event. When it made landfall and hit the house, wind speeds were probably in the range of 50–55 m/s.

Photo: Stuart Thurston, BRANZ

Dealing to contaminated Christchurch roads

Chemists at NIWA are working with Fulton Hogan roading contractors in a project to immobilise and remedy coal-tar contamination in the city's network of streets. We're trialling an innovative solution using established in-situ recycling methods.

Gas works are well known for being highly contaminated sites, and recently the problem of how to deal with contaminated fill material from gas works has emerged. However, it's less well known that similar coal tar products were widely used for tar sealing New Zealand roads before the 1970s. Compared to the bitumen used in road construction today, coal tar contained about 5000 times greater concentrations of the carcinogenic contaminants polycyclic aromatic hydrocarbons, or PAHs.

Approximately half of Christchurch's streets are contaminated with coal tar. Many are nearing the end of their operational life times and will require complete reconstruction within the next 20 years. However, excavating and disposing of the many thousands of tonnes of contaminated roading material will be prohibitively expensive.

Our research project is examining the feasibility of using established in-situ recycling methods to solve the problem of coal tar legacy in older roads. The method we're testing involves milling the road surface and base material, while simultaneously adding 'foamed' bitumen. The resulting pulverised (or milled) road is shaped and compacted to form the new road base material, which is then overlaid with a new bitumen surface seal.

A key component of the research is to establish whether the in-situ method can adequately immobilise the PAH contaminants from the coal tar. To this end, we'll run leaching and toxicity tests on stabilised road millings prepared with specialist equipment that mimics the exact process used in the large recycling/stabilisation machines operated by Fulton Hogan. The project will culminate next year in a full field trial on an 80-m section of Burke Street in Christchurch.

Funding for the project comes from Land Transport New Zealand and Christchurch City Council.

For further information, contact:
Dr Craig Depree, 0-7-856 1750, c.depree@niwa.co.nz

You can read more about this research in 'Environmental forensics: cracking the case of the contaminated streams', Water & Atmosphere 15(3)*: 8–9.*

Removing representative roading materials for experimental work back in the laboratory.

Photo: Craig Depree

Hauraki Gulf snapper – stay-at-homes, or wandering tourists?

You can help us better understand snapper movements

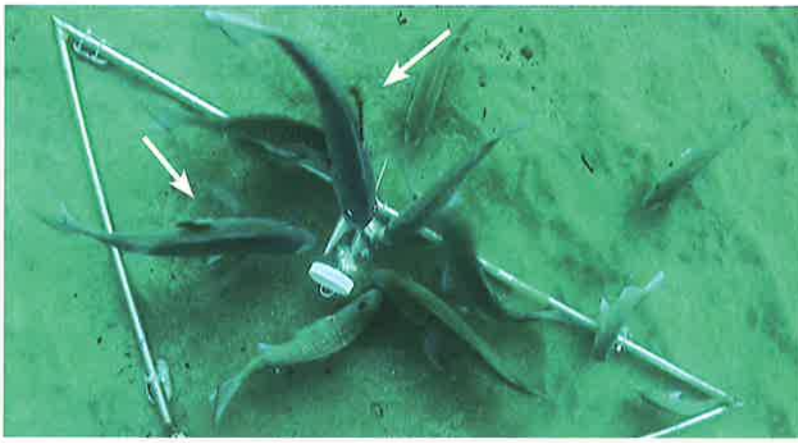
Snapper are an important finfish species in northern New Zealand. Our understanding of their movements – both for individuals and for populations – remains relatively poor, with important implications for fish and habitat management. To address this gap, last summer we tagged almost 10 000 snapper across the greater Hauraki Gulf, using external yellow dart tags.

To date, over 250 tags have been returned, and we're beginning to see a range of different movement behaviours. For instance, although all snapper were tagged in the Greater Hauraki Gulf, some 6% of returns have come from the Bay of Plenty, ranging from Cape Colville to Whale Island (about 230 km away), along with places in-between, such as Cuvier, Great Mercury, Alderman, and Slipper Islands, and off Tauranga Harbour. In the winter months, snapper have been turning up farther north around the rocky reefs of Great Barrier Island, and in deeper waters (70–100 m) off Little and Great Barrier Islands. In stark contrast to these long-distance movers, other snapper have remained at 'home', effectively being re-caught where they were released in the Hauraki Gulf.

We expect many tagged snapper will move inshore again over the summer, and it will be very useful to assess whether they return to the location at which they were tagged (homing behaviour) or, alternatively, randomly re-assort themselves across inshore locations. The key to successfully answering such questions will be getting sufficient numbers of tag returns from fishers. So, if you are lucky enough to catch a tagged snapper, please contribute to this research programme; it will be much appreciated!

This project is supported by the Foundation for Research, Science & Technology and the Department of Conservation.

For further information, contact:
Dr Mark Morrison, 09-375 2063, m.morrison@niwa.co.nz



These snapper have been attracted to a baited underwater video station in the outer Hauraki Gulf. The arrows point to two snapper with tags, which are trailing a light growth of filamentous algae.

What to do if you catch a tagged snapper

If you catch a tagged snapper, you can make a valuable contribution to this research by ringing the phone number on the tag and providing these important details:

- tag number
- date
- location
- depth
- fish length
- whether the fish was caught over reef or over soft sediment.

If the fish that you catch is undersized and therefore cannot be landed, simply measure its length, cut off the tag, and release the fish. All tags returned (with associated data) go into a monthly prize draw to win a rod-and-reel combination valued at $350.

The phone number to ring (weekdays, 9 to 5) is 09-375 2050.

Muddy waters international

Marine ecologist Drew Lohrer has recently returned from a three-month exchange at Nagasaki University in southern Japan. In consultation with the Royal Society of New Zealand, the Japan Society for the Promotion of Science (JSPS) awarded him a prestigious Invitation Fellowship to work with Professor Akio Tamaki, one of Japan's foremost authorities on intertidal sandflat ecology. Together with Professor Tamaki and his students and colleagues, Drew examined the effects of sediment deposition on populations of commercially important bivalves.

In Japan, rivers swollen by monsoon rains deliver terrestrial sediments to coastal waters, and estuarine tidal flats are damaged by the muddy deposits that result. In 2002 and 2006, Professor Tamaki documented catastrophic events where mud deposits up to 30 cm thick smothered whole populations of bivalves before they could be harvested. Drew timed his 2007 visit to coincide with the monsoon season and was able to sample a significant deposition event on the Shirakawa tidal flat (Ariake Sound, Kyushu) in mid July. After the peak rains, a homogenous layer of mud more than 10 cm thick extended for almost 2 km^2. The impacts of terrestrial sediment deposition were clearly evident for the sandflat's three dominant bivalve species.

The results of this research project complement the ongoing interdisciplinary investigations of Professor Tamaki and his coastal engineering colleagues who study sediment-transport dynamics. They are progressing towards an understanding of complicated ecological interactions mediated by complex physical forces, such as salinity gradients and wave and tidal hydrodynamics. Terrestrial sediment deposition is a significant problem in New Zealand and throughout the Pacific Rim, and Drew's Invitation Fellowship has planted the seeds for an enduring collaborative relationship. Professor Tamaki plans to visit Drew at NIWA in Hamilton next April.

For further information, contact:
Dr Drew Lohrer, 0-7-859 1803, d.lohrer@niwa.co.nz

Drew (in shorts) and his Japanese colleagues sample bivalves smothered by extensive mud deposits.

Photo: Drew Lohrer

Photo: Fumihiko Yamada, Kumamoto University

NZMST Teacher Fellow studies carbon dioxide levels – and more!

Shirley Dudli will always remember 2007 as the year she took the plunge into the world of NIWA science as a New Zealand Science, Mathematics and Technology Teacher Fellow. After 10 years teaching secondary school science and biology, Shirley found a year immersed in the diverse world of NIWA science both challenging and invigorating. The bells and timetables of Hamilton's Fairfield College were replaced by a quiet office at NIWA Hamilton, spiced with visits to other NIWA sites and various remote field locations throughout New Zealand.

During her project, 'Carbon dioxide in the atmosphere and ocean', Shirley was busy learning about the development of carbon dioxide measurement and monitoring, both in New Zealand and internationally, and improving her understanding of the impact of changing CO_2 levels on the earth system.

Early in the year she travelled to Dunedin to learn about NIWA's work in measuring CO_2 in the ocean; unfortunately, poor weather conditions meant the ocean-going leg of this trip had to be cancelled and her work was confined to laboratory-based demonstrations of pCO_2 (partial pressure of CO_2), pH, and alkalinity testing. She got the real ocean-going experience in August when she spent 10 days working with scientists collecting and analysing seawater and ocean sediment samples on NIWA's research vessel *Tangaroa*. While at NIWA in Wellington, she visited the Baring Head Clean Air Station and spent time at the Greta Point gas analysis facility, where she discovered the complexities of gathering and analysing atmospheric samples for a range of different gases. To complete her work on increased CO_2 levels, she spent a week with AgResearch in Palmerston North, where scientists are working on the impact of elevated CO_2 levels on pasture growth.

Photo: Karen Thompson

Photo: Lisa Bryant, Victoria University

All at sea: on board *Tangaroa*, Shirley filters seawater in the lab and gets down and dirty with a sediment core on deck.

To add to her experience, Shirley got involved in some of NIWA's other projects, including river sampling in field trials for treatment of didymo in Princhester Creek, Southland, and sampling sediment from Lake Okaro. She also helped out with *Water & Atmosphere* by providing the curriculum links to go with each article.

Shirley says of her year at NIWA, "I'm looking forward to sharing my experiences and new knowledge with students and colleagues when I return to school in 2008. My thanks to all the NIWA staff for their collegiality and patience, the Royal Society of New Zealand for their on-going support and guidance, the New Zealand Government for funding such a fantastic scheme and the Fairfield College community for their continued encouragement and moral support."

For futher information about Teacher Fellows at NIWA, contact: Dr Julie Hall, 07-856 1703, j.hall@niwa.co.nz

Cool conference for kids

When Mireille Consalvey was 10, she decided that she wanted to be a marine biologist – the idea planted by her mum after Mireille announced she wanted a job involving snorkelling. Though she is rarely submerged in water these days, her current post as a seamount scientist proves that from small acorns mighty oaks may grow.

In 2001, teacher Nik Edwards and his class at Raumati South School had a Eureka! moment and decided to organise a careers conference for kids, profiling a wealth of career options with experts talking directly to children about what they do. Alongside fellow scientists Kareen Schnabel and Craig Stevens, Mireille participated in this year's conference, which profiled over 200 career choices ranging from bomb disposal to caring for animals at the SPCA. They were each given an hour-long slot and free rein to introduce the children, aged 11 to 13, to what it means to be a scientist at NIWA.

Kareen and Mireille both talked about the biology of New Zealand's underwater environment. Kareen highlighted some of the weird and wonderful creatures that she collects and catalogues as part of her role as manager of the NIWA Invertebrate Collection. Meanwhile, by the wonders of modern technology and using footage from NIWA's Deep-Towed Imaging System, Mireille took the children down to 1000 m to see some of the marine life that lives on New Zealand's underwater mountains. Proving that physics really is fun, Craig put a real face to the often imagined caricature of a physics boffin. Against a backdrop of marine physics, Craig discussed how ocean exploration has changed over the centuries, from trade and migration, to exploitation, to conservation and sustainability. And, with one child announcing at the end of Craig's talk that he too wanted to be a marine physicist, it could be that our successors are already lining up.

For further information, contact:
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Kareen Schnabel, 0-4-386 0862, k.schnabel@niwa.co.nz
Dr Craig Stevens, 0-4-386 0476, c.stevens@niwa.co.nz

Show and tell with Mireille, Craig, and Kareen.

Photo: Alan Blacklock

Training at NIWA

NIWA offers a wide range of couses each year. 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. Courses offered in the next six months include:

Identifying wetland sedges and rushes, 29–30 January, Hamilton

Identifying algae in rivers and lakes, 13–14 February, Christchurch

Identifying aquatic macrophytes, 19–20 February, Christchurch

Introduction to stream invertebrates, 14 March, Hamilton

Advanced flow regime analysis, March (3 days), Hamilton

General environmental data logging, 19–20 March, Christchurch

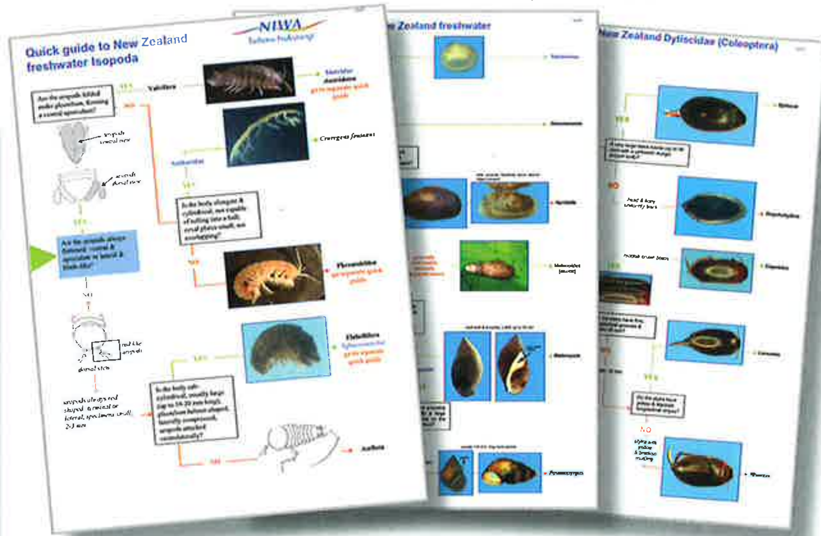
Identifying marine macroalgae, April (2 days), Wellington

Optimising data quality from environmental monitoring stations, 16 April, Christchurch

Scientific diver training course, June (8 days), Rotorua

For further information, contact:
NIWA Training Coordinator
phone 0800 RING NIWA (0800 746 464
or email training@niwa.co.nz

www.niwascience.co.nz/edu/training



New 'Quick guides' to freshwater invertebrates

We've added a dozen new guides to NIWA's successful series of pictorial identification keys for New Zealand's freshwater flora and fauna. These include two guides to mites by Dean Olsen (Cawthron Institute), three to the crustaceans (Amphipoda, Copepoda and Isopoda) by Graham Fenwick and Anna John (NIWA), and six guides to adults and larvae of freshwater beetle families (including Dytiscidae and Hydrophilidae) and one to common freshwater snails by Brian Smith (NIWA). These new keys were produced with funding from the Department of Conservation Terrestrial and Freshwater Biodiversity Information System (TFBIS) programme.

All 'Quick guides' can be found on the NIWA website: www.niwa.co.nz/rc/prog/freshbiodiversity/tools#id

For further information, contact:
Brian Smith, 07 856 1756, b.smith@niwa.co.nz

Bringing IPY into the classroom

The third International Polar Year runs from 2007 to 2009. In February and March 2008, NIWA's research vessel *Tangaroa* will be in Antarctic waters as part of the IPY, specifically with CAML, the international Census of Antarctic Marine Life programme. The scientists on board will be studying the biodiversity and ecology of the marine environment and reporting directly back to the classroom via the Internet.

The Science Learning Hub, an educational website, will host reports from the ship. These reports will focus on eight themes chosen to provide the best links between the science being undertaken on the voyage and the New Zealand science curriculum for years 9 and 10. They are:

- the research vessel
- life on board
- fish
- benthic organisms
- seamounts
- ocean currents
- plankton
- food webs.

The themes will be added to the website sequentially over the eight weeks of the voyage. Each theme will include an introductory article, a daily blog from the ship, images, sound files, videos from the ship, a section for students to ask questions of scientists and crew onboard, and links to related teaching resources and student activities. The IPY material will remain on the website as a teaching resource after the voyage has been completed.

Tangaroa in the Ross Sea, 2006.

For further information, go to www.niwa.co.nz/edu/ipy
Or contact Dr Julie Hall, 07 856 1709, j.hall@niwa.co.nz

Marine Aquaculture

Finding hidden treasure in aquaculture waste

Niki Davey checks the sea cucumber feeding cage at the mussel farm research site.

Mix and match

- Mussels contribute 90% by weight and 64% by value to New Zealand's aquaculture annual production. How do we move up the value chain from here?
- Co-culture is a way to mix species from different feeding groups in the same space, where the waste of one is food for the other.
- Collaborative research is confirming the suitability of mixing and matching seaweed and sea cucumbers with mussels and salmon.

Waste not, want not. Jeanie Stenton-Dozey explains how waste from marine farming offers a way to increase production without enlarging the environmental footprint. The key is integrated co-culture.

The backbone of the New Zealand aquaculture industry has been the longline culture of green-lipped mussels on small coastal farms scattered mainly throughout the Marlborough Sounds. Over the last three decades, farming space has increased more than 30-fold to meet demand for the Greenshell™ brand. In 2006, 97 000 tonnes of mussels, worth $224 million, were harvested from 4747 ha of water space; this represents 90% by weight and 64% by value of New Zealand's aquaculture production.

But where can the industry go from here? More space for mussels? More mussels per hectare? New species?

The need to boost aquaculture growth beyond an industry dominated by mussel production has been recognised in the New Zealand Aquaculture Strategy (2005), which sets a goal of $1 billion sales by 2025. How? Mussels are a low value product; the price has fluctuated little around an average of $5.10 per kg for annual export returns over the last 20 years (see 'Valuing seafood'). Stocking densities on existing farms are optimal, so increased profitability can only come from creating more farming space or culturing higher-value species – or by finding innovative ways to increase production per hectare without enlarging the environmental footprint.

Dense clusters of marine farms (shown in pink) line the Pelorus Sound coast in the western sector of Marlborough Sounds.

Future growth thus lies in making better use of existing space to produce high-value sustainable products for export. However such intensification must not be at the expense of the enviable clean, green image of New Zealand seafood. Together with our industry partners, NIWA has taken up this challenge to increase production and value per ha. We're pioneering the culture of new species and exploring mechanisms to make better use of existing mussel and salmon farming space through integrated co-culture.

What is integrated co-culture?

It's the scientifically based culture of complementary feeding groups in close proximity for the benefit of the cultured species, the environment, the economy, and society. Integrated co-culture is based on an ancient concept that has been the pivot of aquaculture in China for centuries: the waste from one cultured species is recycled to feed another species.

In recent years, Western nations have been experimenting with co-culture, especially around finfish farms where adding feed has the potential to alter the nutrient pathways in local marine food chains. In Canada, for instance, co-culture research is an integral part of the national Aquanet Research Program, data from which have shown that kelp grows 46% faster and mussels twice as fast when co-cultured with salmon. Research projects underway in Scotland and Denmark show similar results

Integrated co-culture in New Zealand

NIWA's co-culture research is in collaboration with the Yellow Sea Fisheries Research Institute in China. Through this relationship we've built a multidisciplinary team with expertise in research, economics, regulations, and societal concerns. We aim to develop and implement

Valuing seafood

All prices per kg are for FOB – Free on Board: the value of export goods, including raw material, processing, packaging, storage, and transportation up to the point where the goods are about to leave the country as exports.
Source: NZ Seafood Industry Council, from Statistics New Zealand

methods for the cost-effective, sea-based culturing of multiple species of high market value. They should be ecologically complementary and able to recycle aquaculture waste. We're combining mussels with high-value Chinook salmon ($9.20 per kg), sea cucumbers ($15–25 per kg), and two species of seaweed ($ variable per kg) at two research sites in the Marlborough Sounds, one based on salmon as the key culture species and the other on mussels.

Schematic shows how the waste from one species feeds the other.

Experimental set-up

We monitor the environment and growth of culture species along transects lines around the farms. The water column is analysed for dissolved nutrients and suspended material, and the amount of material falling to the sea floor is calculated by collections in sediment traps. We determine the influence of the tidal cycle on these parameters from current speed and direction, which are continuously monitored with current meters. Seaweed growth is enhanced by dissolved nitrogenous waste from extraneous fish feed and animal excretion, while the mussels filter particles that are suspended in the water column. Sea cucumbers living on the seafloor feed on deposits that have settled from farm waste.

Seaweeds grown from spores in NIWA's Mahanga Bay aquarium are planted out on longlines at our research sites. To understand how the seaweeds benefit from farm waste, we experiment with their growth and nutrient uptake rate using different concentrations of dissolved nutrients. Mussels of 20 to 30 mm, provided by industry, are seeded out on ropes using cotton stocking and buoyed longlines. Preliminary data from the salmon farm indicate advanced growth of both mussels and seaweed.

Branching into ranching

Our research on sea cucumbers as a marketable species is based on the premise of sea ranching (where an area is seeded with young animals for future harvest), so we must first ascertain whether these animals concentrate around farm deposits. We've placed tagged sea cucumbers under a mussel farm and in areas with no farms; every six weeks NIWA divers return to count the number of tagged animals remaining. Although we've had some problems with tag retention, the data clearly show long resident times for sea cucumbers under farms, an excellent result in support of benthic ranching.

At this stage, we're not sure whether the animals remain under the farms because of food availability or for refuge from predators – or a combination of both. We've begun behavioural and feeding experiments to ascertain the relative importance of shelter and food. Mesh cages are placed over the sediment under the farm and hungry sea cucumbers are left in the enclosures for 48 hrs to graze the surface. Then we collect sediment cores for nutrient analysis. These feeding studies are complemented by assessments of feeding behaviour with and without shell debris to see if providing a shelter influences residency time. All these data will be incorporated into ecological and economic models to assess the long-term feasibility of integrated co-culture on small coastal farms in New Zealand.

Co-culture species in our experiments

Chinook salmon: *Oncorhynchus tschawytscha*
mussels: *Perna canaliculus*
seaweed: *Gigartina atropurpurea* and *Ecklonia radiata*
sea cucumbers: *Stichopus mollis*

Clear benefits for the future

Integrated co-culture will yield two clear economic benefits for the aquaculture sector. Firstly, it's an attractive pathway for diversifying the industry into higher-value species. Secondly, maximising use of natural food, coupled with minimising environmental impact, endows the sector with a significant international marketing opportunity: the market increasingly demands products with low environmental impact, and such products command higher premiums. Co-culture provides a way for New Zealand to capitalise on the global demand for seafood and on the opportunity to increase export earnings through introducing high-value species where we have established networks and market profiles. W&A

Further reading and useful links

AquaNet: Canada's aquaculture research network www.aquanet.ca/English/index.php

Chopin, T. Seaweed and Integrated Multi-Trophic Aquaculture (IMTA) Research Laboratory: www.unbsj.ca/sase/biology/chopinlab

Farming seaweed – a growing industry. Page on the Industrial Research Ltd website: www.irl.cri.nz/newsandevents/innovate/Innovate58/farming-seaweed.aspx

Miller, S. (2007). Land-based polyculture for coastal Māori. *Water & Atmosphere 15(1)*: 22–23.

New Zealand Marine Farming Association Inc. Latest statistics – Aquaculture Industry 2006: www.nzmfa.co.nz/industryinfo.asp

Stenton-Dozey, J. (2007). Balancing ecosystems around mussel farms. *National Centre for Fisheries & Aquaculture Update No. 23*: 2.

Stenton-Dozey, J. (2007). Tagging sea cucumbers. *Water & Atmosphere 15(1)*: 6.

The New Zealand Aquaculture Strategy is available from Aquaculture New Zealand: www.aquaculture.org.nz

Dr Jeanie Stenton-Dozey studies marine ecosystems and aquaculture, based at NIWA in Christchurch. *Her co-culture research is supported by FRST's International Investment Opportunities Fund (IIOF).*

Marine Biodiversity

Putting Antarctic sea spiders in their place

By digging into the DNA of sea spiders brought back from BioRoss 2004, ***Johanna Nielsen, Anne-Nina Lörz,*** *and* ***Shane Lavery*** *have been able to shed new light on the creatures' evolutionary background.*

When RV *Tangaroa* headed south for BioRoss 2004, one of the main objectives of the voyage was to study the biodiversity of marine communities of the northern Victoria Land coast and the Balleny Islands. Among other discoveries, NIWA scientists found a great diversity of sea spiders. Three years on, our genetic analyses of the specimens from this voyage are influencing a revised view of the sea spider group's evolutionary development, or phylogenetics.

The scoop on sea spiders

- Pycnogonids, or sea spiders, are found throughout the world; the Antarctic is especially species-rich.
- 2220 specimens collected during the BioRoss 2004 voyage have been classified.
- DNA analysis is revealing new information about the evolutionary relationships of different sea spider families.

'Sea' spider?

Sea spiders, or pycnogonids, are a unique group of marine arthropods found in oceans around the globe. They vary in morphology (shape) and size, ranging from tiny species a few millimetres long to giant species, from the aptly named Colossendeidae family, that can have leg spans up to 70 cm.

They share a number of traits that clearly define them as a related group. These include a small abdomen and prominent proboscis (elongated head part) – which often leads to confusion between the anterior (front) and posterior (rear) ends of their body.

Most pycnogonid species have eight legs, hence their common name – sea spiders – but it is primarily their three pairs of 'cephalic appendages' that exclude them from being classified as true spiders. Cephalic appendages are limbs coming off the head end of the body; these appendages aren't made for walking, but instead serve for sensing and cleaning (palps), feeding and defence (chelifores), and reproducing (ovigers).

Biodiversity in the Antarctic

Antarctic pycnogonids make up approximately 40% of the 80 genera worldwide and 22% of the more than 1300 described species. This great diversity of species in the Antarctic supports suggestions that the region may be a centre of evolution of sea spider species.

Photo: Stefano Schiaparelli, University of Genoa

During the BioRoss 2004 survey, NIWA scientists collected approximately 2220 individual pycnogonids. We identified the specimens using published keys and the specimens in NIWA's invertebrate collection (NIC). The BioRoss sea spiders are now all cataloged in the NIWA Specify database and represent a significant taxonomic resource. In total, the BioRoss 2004 collection has 18 species representing 10 genera and five of the eight known pycnogonid families. These include three species with more than four pairs of legs and several taxa new to the national collection.

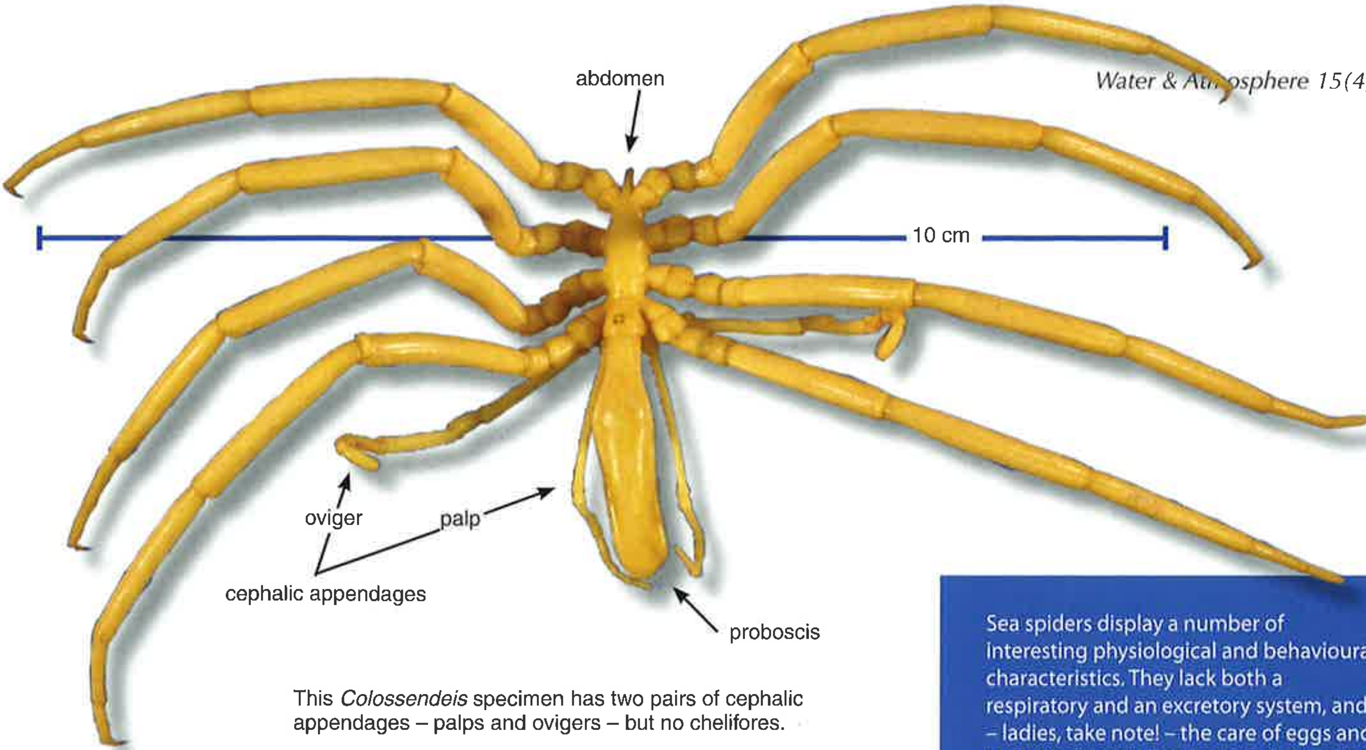
The majority of the BioRoss 2004 specimens were stored directly in ethanol. This preservation method let us extract high-quality DNA samples for detailed molecular studies of phylogenetic relationships.

Revising our view of the family tree

First we extracted DNA from 32 BioRoss 2004 specimens including 21 different species from each of the five different families. We compared the DNA with that from published reports about other pycnogonids and a range of different arthropod species. Then we examined the evolutionary relationships among these species by reconstructing phylogenetic trees.

Although the interfamilial relationship of the pycnogonids is uncertain, one of the most enduring evolutionary hypotheses is that there is a trend toward reduction in the number and complexity of cephalic appendages. Results from our study did not support the hypothesis among families and even suggested that the trend may be reversed.

One additional unexpected finding also resulted from this molecular study. Each of the phylogenetic trees showed strong support for the current family classifications – with one exception. *Austropallene cornigera* is an Antarctic species which has always been problematic to place within the phylogeny due to its complete lack of palps, uniquely shaped proboscis, and 'swollen' chelifores. It is currently considered a member of the Callipallenidae family. Each of the reconstructed trees in this study consistently placed *Austropallene cornigera* at the base of the Nymphonidae family. This provides further evidence



This *Colossendeis* specimen has two pairs of cephalic appendages – palps and ovigers – but no chelifores.

for refuting the cephalic appendage hypothesis as it would imply that palps developed separately in the Nymphonidae family.

Our phylogenetic study of sea spiders has generated new taxonomic and molecular data and has also addressed a long-standing hypothesis on the evolution of the entire group of these fascinating organisms. Though the scientific community is still undecided on some aspects of sea-spider classification, the BioRoss 2004 collection is a considerable contribution to the field of pycnogonid taxonomy.

Tangaroa will soon head south again, January–March 2008. During the International Polar Year (IPY) expedition, instigated by the Census of Marine Life, scientists will survey biodiversity patterns in previously unsampled areas of the Ross Sea. We will deploy different types of gear to collect biological samples from the shelf to the abyss (from about 400 to 3500 m depth). We can look forward to many more specimens to add to the NIC and to further our exploration of the evolution and biodiversity of Antarctic seaspiders. W&A

NIWA's Invertebrate Collection: a treasure chest of additional samples

Although archival organisms are a wonderful taxonomic resource, many older samples have been fixed initially in formalin, which eventually degrades DNA. Despite this, we've recently obtained data from NIC archival sea spiders using a modified DNA extraction method. This new data includes species from the remaining three pycnogonid families which will increase the taxonomic coverage of these datasets. This successful extraction of DNA from formalin-fixed samples is encouraging and further endorses the NIC as an important resource for taxonomic and molecular data.

Sea spiders display a number of interesting physiological and behavioural characteristics. They lack both a respiratory and an excretory system, and – ladies, take note! – the care of eggs and juveniles is exclusively paternal. Here the ventral (front) and dorsal (back) view of a male *Pycnogonum rhinoceros* specimen carrying eggs.

Photos this page: Iain MacDonald, University of Auckland

This specimen of *Austropallene cornigera* sports a pair of claw-like chelifores.

Johanna Nielsen recently completed her BSc (Hons) dissertation entitled 'The molecular phylogenetics of Antarctic sea spiders (Pycnogonida)' at Auckland University under the supervision of Dr Anne-Nina Lörz and Dr Shane Lavery. Anne-Nina is project leader of the NIWA Invertebrate Collection in Wellington and Shane is a senior lecturer at Auckland University.

Marine Biodiversity

Kingdom Chromista in New Zealand

***Dennis Gordon** reviews the diversity of New Zealand's third botanical kingdom.*

Kingdom Chromista? More than two decades ago, Tom Cavalier-Smith, currently a professor at Oxford University, argued that the minimum number of kingdoms required for classifying botanical life was three – Fungi, Plantae, and Chromista. Although textbooks have been slow to reflect this new understanding, today Chromista is near universally accepted by biologists, supported by molecular and cellular studies. It is one of six kingdoms in Cavalier-Smith's current schema for all of life, the others being Bacteria, Protozoa, Plantae, Fungi, and Animalia.

What are chromists?

Chromists are diverse in form, ranging from the very large to the very small and including both free-living and parasitic forms, and they are found in almost all environments. The smallest are ultra-tiny planktonic unicells; the largest include structurally complex giant seaweeds like *Macrocystis* kelp, longer than a blue whale.

The greatest number of chromist species are diatoms and some of these are known to kill fish or be harmful to marine life. Many chromists form a siliceous or calcareous skeleton; their remains are commonly found in hardened marine sediments like chalk and diatomite. The famous White Cliffs of Dover are made up almost entirely of the microscopic chalky scales (coccoliths) of chromists called coccolithophores.

Many unicellular chromists, and the sex cells of multicellular chromists like large brown seaweeds or water moulds, have two cilia – tiny hairs used for swimming or feeding. What distinguishes most chromists from other kingdoms of life is that one of the cilia is hairy. This hairy cilium is known as the tinsel type of cilium because it resembles Christmas tinsel. A second key characteristic of most chromists is an additional membrane around their plastids (structures inside their cells, like green chloroplasts, responsible for processes such as photosynthesis and food storage). This extra membrane was an important clue in the discovery that these plastids actually represent the evolutionary remains of a captured organism, probably a unicellular red alga, that persisted as a symbiont living within chromist cells.

Different groups of chromists

Chromists are divided into six phyla: Cryptista, Ochrophyta, Bigyra, Sagenista, Haptophyta, and Heliozoa. An all-biota inventory known as Species 2000 New Zealand has arrived at a national tally of 1868 chromist species, although not all of these have been fully identified yet. This number is conservative and many more chromists are likely to be discovered.

From diatoms to giant kelp

- Chromista was first named as the third botanical kingdom in 1981.
- All six phyla, 20 of the 27 classes, and 1868 chromist species have been reported in New Zealand, but this number is conservative and many more species are likely to be found.
- Many chromist species are ecologically or economically significant, especially diatoms, brown algae, downy mildews, and water moulds.

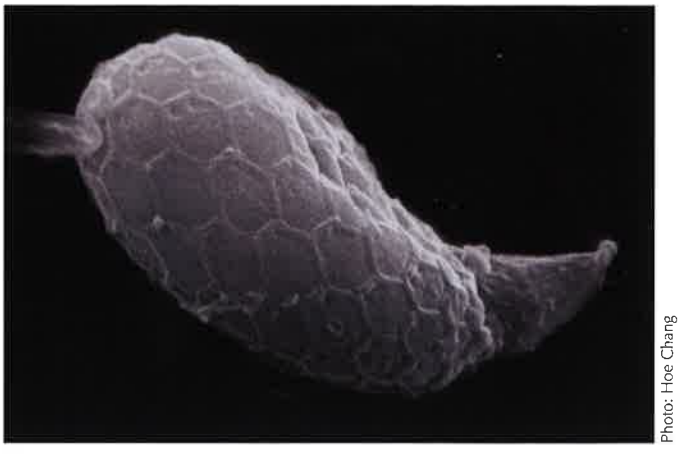


Photo: Hoe Chang

Phylum Cryptista: scanning electron micrograph of a cell of the microalga *Plagioselmis punctata*, a kind of marine phytoplankton.

Phylum Cryptista, also known as cryptophytes or cryptomonads, is found in both marine and fresh water. Some marine species, like *Hillea marina*, can dominate spring phytoplankton blooms, with densities of 1.8 million cells per litre of seawater and abundances twice that of all other phytoplankton combined. Cryptophytes can also mediate blooms in other organisms; for example, the bloom-forming protozoan *Myrionecta rubra* depends heavily on cryptophytes as a food source.

Phylum Ochrophyta is by far the most diverse chromist group in New Zealand, both in terms of numbers of species (1608) and in form. Its nine classes are spread across both marine and freshwater environments and include plankton, flagellates, yellow-green algae, and brown algae (including some seaweeds). Some of the more notable classes are Raphidophyceae (raphidophytes), Chrysophyceae (golden algae), Xanthophyceae (yellow-green algae), Phaeophyceae (brown algae), and Bacillariophyceae (diatoms).

Raphidophytes include the fish-killing species of *Heterosigma and Chattonella*. *Heterosigma akashiwo* has been implicated in the deaths of New Zealand farmed salmon.

Photo: Craig Stevens

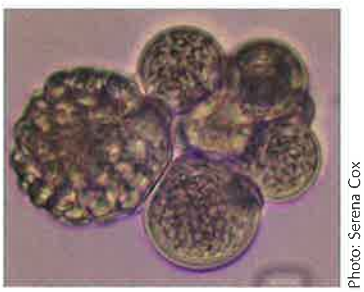
Phylum Ochrophyta: the bull-kelp *Durvillaea antarctica*. The piece cut open reveals a honeycomb structure that aids in buoyancy.

The most familiar brown algae are intertidal Venus's necklace, the southern bull kelps, and laminarian kelps. The Asian kelp *Undaria pinnatifida* is the most serious algal pest in New Zealand.

Phylum Bigyra in New Zealand includes the pseudofungi, which live as plant parasites or form moulds on decaying freshwater organisms, the gut symbionts known as opalinids, and the gut parasite *Blastocystis*. The best-known classes are Hyphochytrea and Oomycetes; the latter includes such economically important genera as *Phytophthora* and *Pythium*, which infect agricultural and horticultural plants. Water moulds include pathogens of algae, fish and their eggs, and invertebrates. Hyphochytrids are common in New Zealand soils. Class Blastocystea is represented by the wide-spread human parasite *Blastocystis hominis*, which causes abdominal pain and diarrhoea. Only two species of class Opalinea occur in New Zealand, both of which live in the guts of introduced Australian frogs; New Zealand native frogs lack opaline associates.

Phylum Bigyra: reproductive body of the blight organism *Phytophthora* sp., an unnamed species that kills kauri.

Phylum Sagenista is a small phylum of non-photosynthetic chromists. Two classes are found in New Zealand – Labyrinthulea, which includes the slime-net *Labyrinthula* that infects the seagrass *Zostera*, and Bisoecea, which comprises three species of protozoan-like organisms. These have a sort of casing around their cells and are freshwater bacteria-eaters.

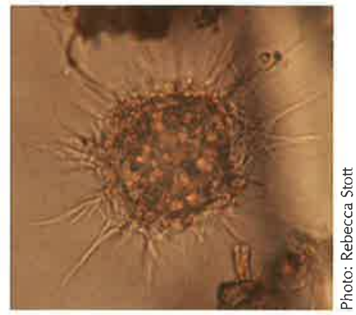


Phylum Sagenista: an unidentified thraustochytrid showing cells of various growth stages and a reproductive body containing zoospores.

Phylum Haptophyta comprises the golden-brown microalgae found in marine, estuarine, and freshwater environments. Marine species can be major components of coastal and oceanic phytoplankton, sometimes forming blooms of exceptional density and spread. Like diatoms, they contribute to atmospheric dimethyl sulphide, which seeds clouds and forms rain, including acid rain. In New Zealand, *Phaeocystis poucheti* can occasionally form foamy mucilaginous blooms that suffocate marine life. A native species of *Prymnesium* has also been implicated in fish kills. Other species can cause non-toxic blooms and the skeletal remains of some species in marine sediments are useful palaeoindicators of climate change.

Phylum Haptophyta: the colonial form of the marine phytoplankton *Phaeocystis pouchetii*.

Phylum Heliozoa (or sun protists) used to be classified among protozoans but molecular evidence suggests they are chromists, most closely related to haptophytes. Only three species (one marine) have been formally recorded in New Zealand, even though heliozoans are known to be common inhabitants of freshwater and marine environments.



Phylum Heliozoa: an unidentified centroheliozoon isolated from a freshwater stream.

NIWA's chromist research

Among the most notorious chromists is the invasive freshwater diatom *Didymosphenia geminata*. Better known as didymo, it was first found in New Zealand in October 2004. NIWA scientists are heavily involved with the biosecurity response, conducting research on didymo ecology, survivability, potential distribution, and control methods. We also study other diatoms, for example, as biological indicators in fresh waters.

On the marine front, we're monitoring and studying the full range of chromist phytoplankton, with a focus on invasive and harmful species collected from ports and harbours and the North Island northeast coast. These studies are important for aquaculture and biosecurity.

Our research on brown algae includes work on the life-histories and ecology of kelps, farming trials using brown algae in multi-species aquaculture, and taxonomic research to discover and document the diversity of species in New Zealand waters.

We're also investigating microscopic pseudofungi in the phylum Sagenista, in particular the genera *Thraustochytrium* and *Schizochytrium*. Their species produce high levels of omega-3 fatty acids, believed to be beneficial for both human and animal health. Some species also produce an interesting array of pigments, including antioxidants, and enzymes that degrade the woody components of organic matter. W&A

Dr Dennis Gordon's work at NIWA in Wellington focuses on marine biodiversity. He has spearheaded New Zealand's participation in Species 2000.

The Species 2000 New Zealand *inventory is a multi-scientist project. Information on New Zealand living Chromista has been contributed by Dr Hoe Chang, Dr Wendy Nelson (NIWA), Dr Lesley Rhodes (Cawthron Institute), Dr Vivienne Cassie Cooper, Dr Shaun Pennycook, Dr Barbara Paulus(Landcare Research), and Dr Paul Broady (Canterbury University).*

Marine Biodiversity

Lobster à la carte

'Squat lobsters' provide a significant food source for fish around New Zealand. ***Kareen Schnabel*** *and* ***Amelia Connell*** *take a peek at who lives where and who's eating whom.*

Munida gregaria, the sociable New Zealand shallow-water squat lobster.

Photo: Peter Batson, ExploreTheAbyss.Com

The crustaceans commonly referred to as squat lobsters are among the most abundant and diverse marine decapods worldwide. Their three families contain nearly 900 species and inhabit a range of environments including coral reefs, continental shelves and slopes, seamounts, cold seeps, and hydrothermal vents. However, knowledge on their diversity and importance to benthic communities is limited. Recent research at NIWA is showing that New Zealand squat lobsters are very species-rich and also an important component of fish diet.

Undersea delicacies

- Squat lobsters are abundant, diverse, and an important source of food for New Zealand marine fishes.
- Two of the three families are well represented in New Zealand waters.
- The squat lobsters of New Zealand have not been very widely studied, despite their major role in our marine ecosystems.

All in the (super) family

Marine squat lobsters belong to the families Kiwaidae, Galatheidae, and Chirostylidae, all members of the superfamily Galatheoidea. Often brightly coloured, with spines scattered over their bodies and appendages, they all vaguely resemble a small lobster or crayfish.

The abundance and diversity of squat lobsters has stimulated considerable taxonomic research in recent years; since 2005 more than 110 new species and four new genera (including the new family for *Kiwa*) have been described, the majority from the Pacific Ocean including Australia and the South Pacific islands from New Caledonia to French Polynesia. However, the New Zealand fauna remains vastly understudied: current taxonomic research by NIWA and overseas scientists is the first since 1974! Back then, only 19 species of galatheids and chirostylids were known from the entire New Zealand region, a number that is growing fast as museum collections around the country and globe are studied. Within the last two years, descriptions for 30 New Zealand species have been completed or reached their final stages, and approximately 35 further new species await description. Adding the many known species that have not been recorded from New Zealand before, the entire fauna now stands at 130 species, and counting.

Kiwaids (pronounced Ki-wa-ids) are represented by a single species, *Kiwa hirsuta*, the furry 'yeti crab'. In 2006, this unique creature received a lot of media attention when it was recovered from deep hydrothermal vents off the Easter Islands in the southeastern Pacific. The site remains the only known location of this family.

Galatheids are the most species-rich group with nearly 700 species worldwide, ranging from lentil-sized species common in tropical shallow-water reefs to large species of the genus *Munidopsis* that grow up to egg-size, live at abyssal depths (greater than about 3000 m), and can occur in huge numbers on hydrothermal vents and cold seeps. Other species congregate in such throngs during an early life stage that they form 'red tides' that become an important food source for baleen whales, sea birds, and fish. One such species, *Munida gregaria*, produces swarms around the coasts of New Zealand, Tasmania, Patagonia, the Falkland Islands, and some

Photo: Niel Bruce.

Langostino amarillo (*Cervimunida johni*) sold in the fish market in Coquimbo, Chile. The whole animal is approximately 7–8 cm long.

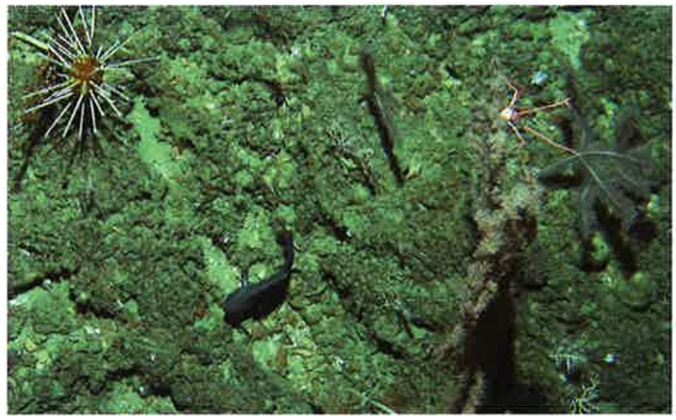


Photo: NOAA / NIWA TAN0616

The chirostylid *Gastroptychus rogeri* takes its usual stance, perched on a black coral (upper right).

sub-Antarctic islands. *Munida gregaria* in New Zealand and *Pleuroncodes planipes* in Chile occur in such vast numbers in their planktonic stage that commercial harvest has been suggested in the past but has never proven viable. Meanwhile, adult-stage *P. planipes* and *Cervimunida johni* provide a significant benthic-trawl fishery off the coast of Chile.

Chirostylids are some of the largest squat lobsters; they can measure more than 30 cm from the tip of the claws to the end of the tail and often have extremely slender and elongated appendages. Worldwide, more than 180 species are known and it appears that the majority are adapted to living among the branches of corals from the shallow-water tropics to the deep-water coral beds along steep continental margins and seamounts. The coral probably provides shelter, as well as an elevated position for reaching food items in the water above.

Catch of the day

Considering the sheer abundance of some squat lobsters, such as *Munida gregaria*, it comes as no surprise that they provide a significant food source for fish around New Zealand. A NIWA study of the diet of commercially important and by-catch fish commonly trawled at depths between 200 and 800 m on the Chatham Rise looked at the contents of 5925 fish stomachs. We found 11 fish species had fed on galatheids: red cod, ling, smooth skate, ghost shark, sea perch, stargazer, orange perch, lookdown dory, and three species of rattails. Of these, squat lobsters are particularly common in the diets of ling, oblique-banded rattail, and red cod. Galatheids turned out to be the most important part of the red cod's diet, and are a similarly popular menu item for ling: nearly a third of the ling we analysed had eaten a *Munida* species. Galatheids make up an especially large part of small ling's diet, but as the ling grows and starts to feed more on fish, squat lobsters become less important in the diet. Galatheids are also a food source for some rattails, whose body size is much smaller than red cod or ling. The stomach of the small-bodied rattail can be completely filled with a single specimen of *Munida* – perhaps a case of their eyes being too big for their stomach.

Photo: Ocean Survey 2020 voyage TAN0705

Spot the three *Munida gracilis* and the flatfish! The squat lobsters were observed seeking shelter under most objects available on the sea floor, 470 m deep on the Chatham Rise.

Camera surveys during the Oceans 2020 voyage on the Chatham Rise have revealed the prevalence of the main prey species *Munida gracilis* on the sea floor. They were photographed in large numbers, half hidden in small burrows and under any sheltering object. Together with other bottom-dwellers, they provide an enticing morsel for bottom-feeding fish, and are also a welcome appetiser for fish with different culinary tastes, like the sea perch or ghost shark, which usually prefer other crustaceans or invertebrates.

Photo: ROPOS RV *Sonne* Cruise SO192-2 Mango

Munidopsis species congregate around a cold seep in the Fiji Lau Basin. (A single individual is circled.)

Treasure trove of biodiversity

The ocean surrounding New Zealand is a treasure trove for studies on biodiversity and biological interactions. Our unique geographical and geological position and distinctive marine fauna provide many opportunities for discoveries and for testing research hypotheses. But any work on species assemblages and interactions relies heavily on taxonomic knowledge of each of the components of the communities, and we still have a lot to learn about the pieces of the puzzle! W&A

Kareen Schnabel is Collection Manager of the NIWA Invertebrate Collection in Wellington and a part-time PhD student at University of Otago, working on squat lobster taxonomy and distribution. Amelia Connell, formerly a fisheries technician at NIWA in Wellington, is an MSc student at Victoria University.

Fisheries Research

"We don't catch 'em like we used to ..."

Using traditional ecological knowledge in fisheries research

***Kimberley Maxwell** explains how the knowledge of local fishers and shellfish gatherers can be used to reconstruct our fisheries histories.*

Man with a catch of fish, circa 1910.

Photo: G-21592-1/2, Alexander Turnbull Library, Wellington, New Zealand

This research is part of a much larger multidisciplinary project investigating how humans and climate change may have impacted on the structure and functioning of the marine ecosystems of New Zealand's continental shelf. Scientists are collating data in an effort to describe the marine ecosystem for five different eras:

- before human settlement – circa 1000
- during the early Māori phase – circa 1450
- before European exploitation – circa 1790
- before industrial-scale fishing – circa 1945
- modern day – 2007

The data we're collecting include archaeological and historic information, stable isotope analysis of shellfish and otoliths (fish earbones) to determine climate conditions during their lives, climate data, commercial catch data, and traditional ecological knowledge (TEK) associated with fishing (hī ika) and shellfish gathering (kohikohi me te ruku kaimoana).

Traditional ecological knowledge

TEK is the knowledge of people with extensive experience and observations of an area or species, including knowledge passed down through oral tradition or shared among users of a resource. TEK has been recognised internationally as a way to improve scientific research and resource management by providing additional – and sometimes better – information. In this study, archaeological data will provide an idea of how humans impacted on the fish and shellfish resources up to about 1800, while historical data sources will be used to document marine resource use from the time of first European contact until the early 20th century. Modern fisheries records for many species were not well organised or established until the second half of the 20th century and have mainly focused on the commercial catch. Consequently, there's a large gap in terms of what effect humans, especially customary and recreational fishers, had on fish and shellfish stocks from 1900 to the 1960s. TEK may be able to improve our knowledge of human impacts on the fisheries during this period.

Combining TEK with Western science is a relatively new technique in New Zealand fisheries research. Elsewhere, this approach has been used to demonstrate the decline of the Gulf grouper (*Mycteroperca jordani*) in the Gulf of California, Mexico. Here we'll use similar social science research methods to collect and analyse the data so they can be incorporated into our marine ecosystem models. This includes conducting short interviews with local fishers and shellfish gatherers. We aim to interview an equal number of young (15–30 years old), middle-aged (31–54) and mature (55+) individuals. This will let us confidently compare our present-day data with that collected about the era before industrial fishing.

Those were the days

- A large study of New Zealand's marine ecosystems is characterising fish and shellfish stocks over the last millenium.
- Traditional ecological knowledge (TEK) draws on the observations and experiences of locals, and includes knowledge passed down through oral tradition or shared among users of a resource.
- TEK and Western science can be combined to fill gaps in the historical record of fish and shellfish stocks.

Our study sites and techniques

We've chosen two study areas for the project: the greater Hauraki Gulf (from Tutukākā to Waihī) in the North Island and the Otago/Catlins coast (from Ōamaru to Porpoise Bay) in the South Island. The study areas have many contrasting features that may reflect the effects of human impact and climate change on the marine ecosystems, including the surrounding human populations, land development, and ocean currents and temperatures. Also, both areas offer an extensive volume of earlier research, including oral histories, which we can incorporate into the bigger project. Many of the previous oral histories were collected for different research objectives and therefore are more likely to yield qualitative than quantitative information; this is why we must conduct further interviews.

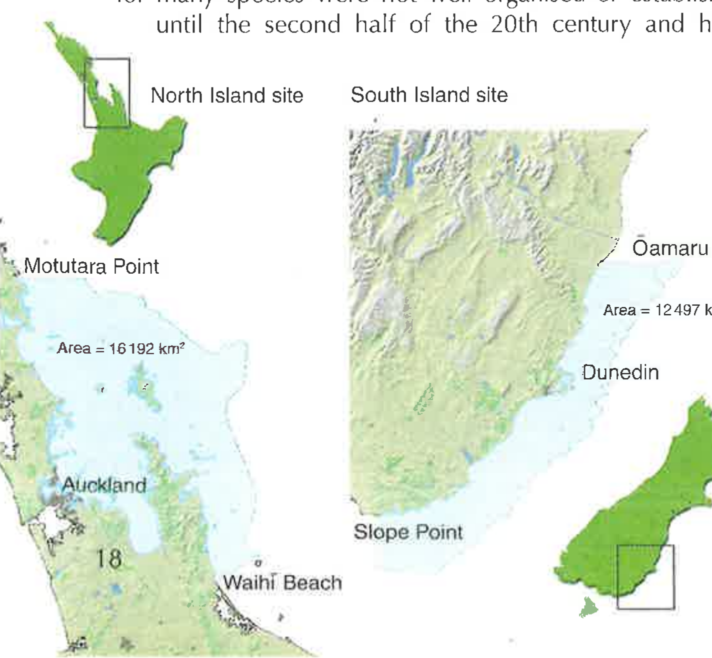


Photo: Courtesy of Basil McManaway

Photo: Pete Lamb Fishing

Then and now:
Hāpuku (groper) with shed hands at Barnao's Fish Wholesalers at Lorne Street, Wellington, in 1947.

Satisfied charter client with a 67-kg hāpuku caught off Mana Island in 2005.

Here's an example of the type of data we're gathering. I was fortunate enough to meet Pete Lamb, who has been fishing regularly in the Wellington region for 35 years. The largest hāpuku (*Polyprion americanus*) landed on his charter vessel was an estimated 67 kg and was caught in 200 m of water off Mana Island in 2005. In an article in *Seafood New Zealand*, I also found a picture of the hāpuku caught by Leslie and Wilfred McManaway who were regular fishers of the Wellington region 60 years ago. The caption said it weighed in at 120 kg and was caught in 360 m of water in the Cook Strait in 1947. The author of the article interviewed Wilfred's son Basil McManaway, who was also a regular fisher in Wellington. During his best day's catch, he remembers, they caught in excess of 250 hāpuku, and on an average day they would catch 70–80 large hāpuku on a set line. In contrast, on the day I went out in 2006 we caught a total of 24 hāpuku. Our catch was restricted by a catch limit of 2 hāpuku per fisher so, of course, it can't be compared with Mr McManaway's catch. However, taking into account advances in technology, we can plot this sort of information from an age-structured sample of fishers to determine the trend over time in maximum weight and total number of fish caught.

How can TEK help?

We can use TEK to improve the data with which we manage our fisheries. Every year we estimate the catch a stock can safely sustain. The catch histories upon which these limits are in part based were started sometime after the beginning of full-scale commercial fishing, and are based on the best information available. In the case of hāpuku, the earliest landings data are from 1936, although widespread European and customary fisheries for this species occurred much earlier.

If history and trajectories of change are ignored, then an ecosystem is more likely to be perceived as being stable or pristine. This problem is termed 'shifting baseline syndrome', where the current status of an ecosystem is assumed to be 'normal', creating a bias in resource management decisions. Incorporating pre-industrial-scale fishing data into our fisheries models may increase how accurately we set our catch limits.

The estimates of historical stocks may also be used in the development of iwi environmental management strategies. In 2004, the Hauraki Māori Trust Board published the Hauraki Iwi Environmental Plan. Many of their key objectives for managing the Tangaroa Rerenga Wai Tai, or marine environment, include restoring species, habitats, and ecosystems. The results of this research may be used to indicate what previous species abundances and distributions, habitats and ecosystems were like. Kai Tahu has also published the Kai Tahu ki Otago Natural Resource Management Plan (2005). Overfishing and depletion of the Mahika Kai (kaimoana) or seafood resources are key issues they have identified. This research may be used to demonstrate the extent of this fishing and resource use. W&A

Further reading

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Kimberley Maxwell is based at NIWA in Wellington, and works on customary fisheries and benthic ecology. She acknowledges Dr Erica Williams, Dr Alison MacDiarmid, Taoho Patuawa (all at NIWA), and Pete Lamb, Peter Stevens, and Basil McManaway for their assistance in preparing this article. This project is supported by the Capability Fund and the Biodiversity Fund.

Resource Management

Muddy waters at Te Māhia: cause and effect

The rapidly eroding cliffs around Te Māhia.

The coastal waters surrounding Te Māhia are subject to smothering plumes of sediment. ***Sheryl Miller, Murray Hicks, Mark Dickson,*** *and* ***Jarrod Walker*** *discuss where the plumes come from and how they affect the region's kaimoana.*

Clearing the waters
- Local geology, extreme events, and modern development all contribute to sediment plumes in coastal waters around Te Māhia.
- The clouds of fine sediment around the coast can hinder the customary gathering of kaimoana.
- Research to monitor sediment accumulation and its effect on particular species aims to help preserve kaimoana resources.

Tucked under East Cape, between Napier and Gisborne, Te Māhia (Mahia Peninsula) was once separate from New Zealand's North Island, but over the last 10 000 years beach sand and dunes have linked the two. Pasture predominates and the remaining native coastal bush clings to steep, erodible cliffs. The northern end of Te Māhia is rapidly succumbing to coastal development, with subdivisions potentially increasing the amount of sediment washing into the sea. Plumes of sediment often extend from the mouths of freshwater streams, drains, and eroded cliffs, particularly after heavy rainfall. These sediment plumes occur regularly around much of the peninsula, muddying the water. Moreover, drapes of sediment (up to 2 cm thick) sit atop the mudstone reefs much of the time, blanketing the rocky reef habitat, smothering the species living in the intertidal zone and seabed, and hindering the local community from gathering kaimoana – food from the sea.

Where does the mud come from?

The sediment comes from local sources and from farther afield. Large volumes of sediment are delivered to the coast from the catchments along the east coast of the North Island. The catchment erosion rates are influenced by geology, tectonics, climate, and deforestation. Geology is a key factor, due to the prevalence of unstable and highly erodible mudstone and sandstone. Coastal erosion also contributes sediment, with cliffs retreating about 25 cm per year on average. At Te Māhia, some of the sediment comes from local catchments, more comes from erosion of the mudstone cliffs and tidal platforms that fringe the peninsula, while yet more drifts in with coastal currents. Depending on the current direction, these may bring mud south from the Waipaoa River or north from the Mohaka and Wairoa rivers. Coastal erosion is so severe in places that substantial areas of culturally significant land are being lost. For example, the community at Kaiuku marae have had to move the fence marking their seaward boundary four times over the last 10 years, and a statue on the marae grounds has been moved three times in the last 26 years.

Landuse is another important factor affecting the sediment supply. Before human settlement, Te Māhia was predominantly covered by mature indigenous forest, but since the 1880s much of this forest has been cleared for pasture. Consequently, without stabilising vegetation, large areas of steep hillslope have suffered severe slips. Harvesting of exotic forests and development of residential coastal properties, particularly subdivisions on hilltops, slopes, and ridgelines, at times have fed increased soil runoff into the surrounding coastal ecosystem.

Thus, while some sedimentation may be expected naturally from erosion of the soft mudstone and sandstone coast and hillslopes, human (or anthropogenic) activities at Te Māhia, and also those spread over the wider East Cape area, have all contributed to the currently observed high sediment accumulation rates in the estuarine and rocky coastal habitats there. This is a phenomenon seen worldwide. The effects of increasing sedimentation in the nearshore marine environment are well documented (see article by Airoldi in Further reading).

Typical views around Te Māhia (left to right): Mudstone reef; muddy water in the nearshore marine environment following heavy rainfall; intertidal rocky platform covered with sediment and seaweeds.

Image: Seawifs, NASA

Detail from a Seawifs satellite image from 11 May 1999 shows sediment plumes around East Cape. During the preceding week, 63 mm of rain fell over Te Māhia.

Residential development contributes to soil runoff into Te Māhia's coastal waters.

Photos: Sheryl Miller

Te Māhia locals regularly enjoy customary gathering of kaimoana, including karengo seaweed.

How does the mud affect kaimoana?

Customary harvest of kaimoana resources occurs regularly at Te Māhia, well known for recreational and commercial harvesting of lobsters, pāua (abalone), and kina (sea urchins). The effects of excessive sediment in the nearshore are wide-ranging and complex, including reduced settlement and survival rates of marine larvae, smothering or burial of immobile organisms, and reduced water clarity limiting the light necessary for photosynthesis. These may result in further cascading effects along the food chain, changing what species are found and type of habitat. For example, if kina larvae are reduced by sediment smothering, it affects not only the kina population in the area but also cultural and recreational harvesting. And, as kina are an important component of their diet, lobster may move further offshore to forage.

What can be done about it?

The Wairoa District Council recognises the need for environmental protection and for mitigating the effects of coastal development, and has adopted a list of actions to be undertaken over the next 20 years. These measures will enhance the landscape through reforestation, restoration, and riparian planting.

An earlier article in *Water & Atmosphere* describes the voluntary rāhui already in place around the peninsula (see 'A gift from the sea' in Further reading). These bans on collecting kaimoana provide some protection against over-harvesting by closing the area to commercial fishing (except for lobster).

Events contributing to the muddy waters around Te Māhia

- The Hawkes Bay earthquake of 1931 (magnitude 7.8) caused numerous landslides, cracks, and fissures.
- An extreme storm in 1938 was the first large rainfall since land was converted to pasture. Aerial survey photos from the 1940s show sediment discharge plumes, indicating muddy waters are a long-term problem.
- Cyclone Bola in 1988 had a devastating impact on the area, with long-lasting consequences. Sediment concentrations in the catchments remained elevated for several years.

Members of the Māhia Coastal Marine Strategy (MCMS) monitor three species that live in the rocky reefs surrounding Te Māhia: pāua, kina, and lobster. In order to assess the impact the nuisance sediment is having on these kaimoana resources, and additional seaweed species such as karengo, NIWA and the MCMS group will set up permanent monitoring sites inside and outside the rāhui boundary. We will measure sediment cover as well as environmental variables, such as substrate type, water clarity, and depth, on a seasonal or bi-monthly basis to identify patterns in distribution and abundance of selected species. This research will enable robust conclusions regarding the progress and validity of using management techniques such as rāhui.

Ultimately, our research on the effects of sedimentation and the effectiveness of rāhui should complement customary knowledge and practices. Our goal is to determine the best methods of protecting an area while enhancing the ability of local communities to manage their kaimoana resources. W&A

Further reading and useful links

Airoldi, L. (2003). The effects of sedimentation on rocky coast assemblages. *Oceanography and Marine Biology: an Annual Review 41*: 161–236.

Miller, S.; Ormond, G. (2007). A gift from the sea: managing kaimoana resources. *Water & Atmosphere 15(2)*: 14–15.

Wairoa District Council website:

Māhia Isthmus Communities Structure Plan: www.wairoadc.govt.nz/consultation/mahiaisthmus

Wairoa Coastal Strategy: www.wairoadc.govt.nz/planspolicy/coastal

Māhia Beach Township Structure Plan: www.wairoadc.govt.nz/planspolicy/mbtsp

Dr Sheryl Miller (Ngāi Tahu, Kāti Mamoe, Waitaha) is a member of Te Kūwaha o Taihoro Nukurangi (NIWA's Māori Research & Development Group), based in Wellington. Dr Murray Hicks and Dr Mark Dickson are based at NIWA in Christchurch; their research interests include coastal process and sedimentation. Dr Jarrod Walker works in fisheries and marine ecology at NIWA in Auckland.

Marine Geology

Tracking the Waipaoa out to sea

The muddy Poverty Bay and the coastal waters around East Cape are a world-class site to examine sediment sources and sinks, tracking how mud eroded from the land makes its way to the deep ocean. ***Alan Orpin*** *and his colleagues in the international* ***Poverty Slope Group*** *are using a suite of techniques to unravel this story.*

At the coastal zone, vast quantities of sediment, carbon, and nutrients are transferred from land to the sea. Weathering and erosion, biological activity, and the shape of the land and seascape drive the nature of this transfer. Climate and ocean currents influence the frequency and magnitude of dispersal on time scales ranging from daily tides to glacial cycles spanning thousands of years. It's easier to conceptualise these different environments as separate components, but materials are transported from source to sink as a seamless cascade; as upland areas of the margin catchment erode, sediment accumulates offshore. Hence, marine mud deposits can preserve a continuous record of landscape, climate, and oceanographic change.

When muddy rivers go bad

Around the North Island's East Cape, a vigorous maritime climate, punctuated by storms and droughts, operates against a background of mountain-building tectonics and instability, driven by subduction of the Pacific plate beneath the Australian plate. There is widespread erosion of the mudstone- and sandstone-dominated hinterland, and the removal of native forests for cultivation and pasture by human settlers has led to an unprecedented acceleration in erosion. By the early 20th century, nearly all the forest cover was gone and landslides proliferated in steep headwaters.

The Waipaoa River today reflects these natural and human-induced influences, and is now New Zealand's second largest river in terms of suspended sediment discharge, delivering 15 million tonnes of mud per year to coastal Poverty Bay. That's the equivalent of about 4100 truckloads per day. The Waipaoa and the other major East Cape rivers – the Waiapu and the Hikuwai – collectively deliver 0.3% of the global mud budget to the ocean.

Global focus on the Waipaoa

The massive mud discharge and some compelling science developed from earlier studies won the Waipaoa River and the Poverty Bay margin – the continental shelf and slope – a coveted place as an international study site for sediment dispersal at mud-dominated coasts. Research offshore of Poverty Bay has received a significant boost since 2005, when the MARGINS Source-to-Sink project was funded by the USA, so that today it's the most cored section of New Zealand's coast. New findings about sedimentation on the Poverty Bay margin span time scales of weeks to millennia, but an ability to date the sediment, and thereby estimate the rate that mud is accumulating, is critical to unravelling the source-to-sink story.

Sediments from source to sink

- Geology, climate, and human influences contribute to high sediment discharge from the Waipaoa and other East Cape rivers into the sea.
- A major international research project is using extensive coring to study Poverty Bay sediments.
- Various ways of analysing the sediment cores are showing how much of the sediment discharge is due to man-made changes to the landscape.

Measuring the dynamics of mud dispersal

Among our key tools for assessing how fast and where sediments are accumulating offshore are radioactive chemical tracers. These include naturally occurring radioactive isotopes which show mud accumulation rates over different time scales. Isotopes of lead are useful for sedimentation rates over the last century, while beryllium's activity is short-lived and can show mud accumulation rates over recent months. Other radioisotope tracers were produced during thermonuclear bomb testing in the Pacific in the sixties and can provide a useful time marker that is incorporated in the accumulated seafloor sediments. Ongoing study suggests that these tracers have even pinpointed the occurrence of mud pulses from major floods, like Cyclone Bola. The challenge is now to assess if Bola-like events occurred regularly over millennial timescales and how they are preserved.

A seamless cascade of mud

New results show that mud is accumulating up to a few centimetres per year, even tens of kilometres from the mouth of the Waipaoa River, and is highest in the head of a submarine canyon. This result is supported by 3-m-long cores of soft homogeneous mud deposited over the last thousand years, and seismic profiles that show a mud drape tens of metres thick. Mud transport is controlled by the seascape and is focused into the steep gullies that feed into the Poverty Canyon system downslope. Beryllium tracer analysis shows seasonal differences: sediment was more widely dispersed and present in higher quantities in the winter of 2006 than after the summer months of 2005. This result could reflect an increase in rainfall – and subsequent riverine mud delivery – and increased ocean storm activity during winter months.

Photo: Dave Peacock, Gisborne District Council

The Waipaoa River in flood discharges a plume of muddy water into Poverty Bay.

Carbon dating and identification of discrete ashes erupted from the Taupo volcanic region have provided a remarkably accurate calendar for much of the core material. We've found changes in sedimentation over the last one thousand years since settlement: on the continental shelf, close to the coast, the sediments have increased by 2 to 3 times, but farther out on the slope we see a smaller increase of 1 to 2 times. If we look over the last few thousand years, we see slower but steady sedimentation.

Pollen shows Māori and European settlement

Pollen records from shelf and slope cores can fingerprint settlement of the land, first by Māori explorers around 700 years ago, followed by European settlers in the mid 1800s. A shift in landscape flora is recorded even in the deep-water sediments of the continental slope. Evidence from the cores shows a slow decline in native tall trees, such as rimu, matai, beech, and kaihikatea, matched by a proliferation of bracken scrub. We can see effects of the clearance of forests and the establishment of pastures in the dramatic and rapid shift in the material that eroded from the landscape.

Mud deposits, ancient and modern

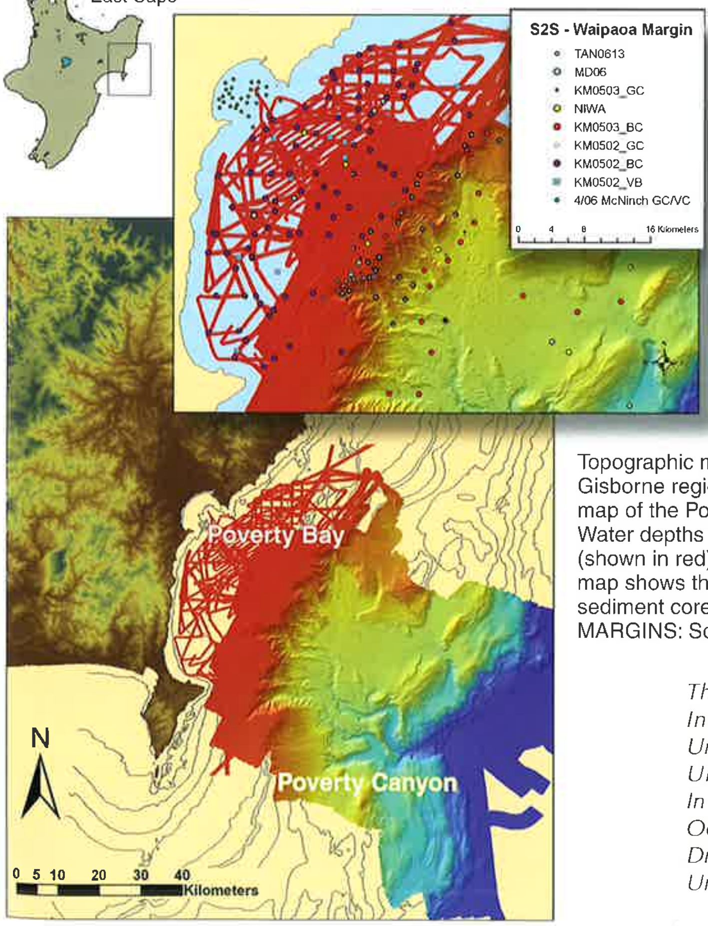
Our analysis of the sediment cores shows that mud dispersal from the Waipaoa drainage system spreads tens of kilometres from the coast, is affected by the seasons, and has persisted for several thousand years. There is also clear evidence of dramatic increases in terrestrial erosion in the last millennium, since humans arrived and began clearing the forests and cultivating the land. W&A





Drilling cores during MARGINS: Source-to-Sink (top to bottom): the twin-hulled research vessel *Kilo Moana*; selecting the next drill site; recovering a piston core; removing a short core; rigging the box corer.

Photos: Denise Walsh, East Carolina University



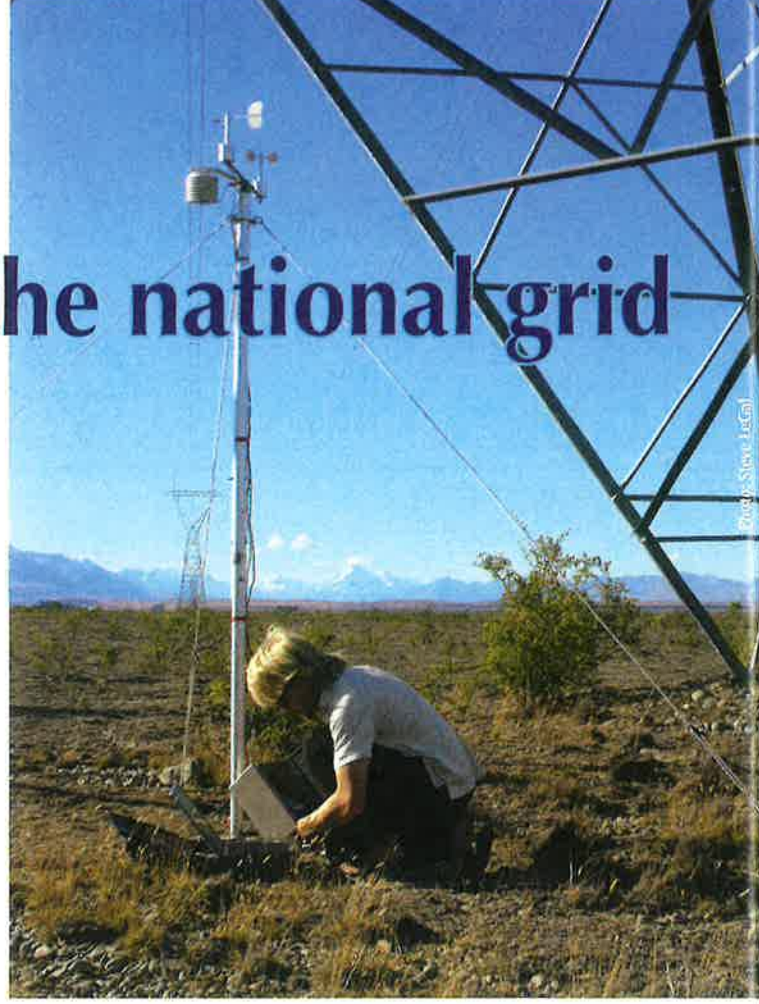
Topographic map of the Hawke's Bay and Gisborne region and coloured bathymetric map of the Poverty Bay margin and canyon. Water depths range from less than 100 m (shown in red) to 3000 m (in blue). Upper map shows the locations of the multitude of sediment cores collected for the international MARGINS: Source-to-Sink initiative.

The Poverty Slope Group comprises scientists from nine institutions. In New Zealand: Dr Alan Orpin (NIWA); Dr Alan Palmer (Massey University); Dr Gavin Dunbar, Dr Lionel Carter, Matthew Wood (Victoria University of Wellington); Dr Gary Wilson (University of Otago). In the USA: Dr Clark Alexander, Claudia Venherm (Skidaway Institute of Oceanography); Dr J.P. Walsh, Ben Sumner (East Carolina University); Dr Steven Kuehl (Virginia Institute of Marine Science); Tommy Gerber (Duke University); Dr Kathleen Marsaglia (California State University-Northridge).

Environmental Monitoring

Characterising the national grid

***Jeremy Bulleid, Tony Bromley, Tom Clarkson** and **Graham Elley** explain how we're using science and technology to better understand the capabilities of the high-voltage transmission lines in New Zealand's national grid.*



Technician Shane Rodwell downloads data at one of the temporary surface stations near Twizel.

Electricity flows from power station to consumer via power transmission lines, and thousands of kilometres of line are used to carry power throughout the country. As the demand for electricity increases through population and industrial growth, there is an obvious need to ensure that this network will operate within the limits for which it was originally designed, at all times and under all conditions.

Sound engineering practice dictates that transmission lines are operated within conservative limits and with minimal risk of lines overheating because of high loads. Increasing consumer demand for electricity underscores the need to understand and manage the conditions under which more power may be transmitted safely and reliably through the existing transmission networks.

Keeping transmission lines safe

The amount of power that can be safely transmitted through a line is limited by how hot the line gets. The temperature of a transmission line depends mainly on the amount of electric current flowing through it – which generates unwanted heat – and local weather conditions: air temperature, direct heating from the sun, and the cooling effect of wind. As the line temperature increases, the line expands and sags. Sagging reduces the clearance between the line and trees, buildings, or the ground, and excessive sag can cause electrical, physical, or operational hazards. If the line temperature gets high enough to soften the line material, then the line may suffer permanent damage.

As a part of grid maintenance, Transpower commissions airborne laser surveys (ALS) to accurately measure the location and characteristics of segments of the transmission network. In recent years, NIWA scientists and technical staff have provided meteorological support for some of the surveys conducted by Power Systems Consultants (PSC) as the primary contractor.

Getting power to the people

- As demands on electricity supply increase, the transmission lines in the national grid must be surveyed to ensure safe and optimal operation.
- NIWA's role in the surveys is to measure and model the meteorological conditions, as air temperature, wind, and sunlight affect line performance.
- The same modelling has further applications for tracking and eradicating biosecurity threats.

The mission and the instruments

For the aerial surveys, the contractors used a helicopter-mounted LiDAR (laser ranging instrument) to locate the position of each line relative to the helicopter, and a high-precision GPS (global positioning system) to determine the absolute position of the helicopter. They recorded the exact location of points along each conductor cable from a height of about 300 m above the transmission line. This technique accurately measures the line position to within a few centimetres.

During the over-flights, NIWA staff gathered high-resolution meteorological data in the vicinity of the lines, using permanent met stations within the National Climate Network supplemented by more than 20 temporary surface stations. Each temporary station logged wind speed, wind direction, and air temperature from sensors on a 2.5-m mast. Several of the stations included a solar radiation sensor. We also used an instrument package tethered to a Helikite to record the vertical profile of wind and temperature several times each survey day at intervals along the line being surveyed.

We then incorporated these data into a specialised model to determine the weather conditions close to the conductor cable at the time of the survey. Our objective was to get a realistic estimate of the meteorological conditions during the helicopter laser scan at the mid point of every surveyed span over a range of heights above and below the conductors.

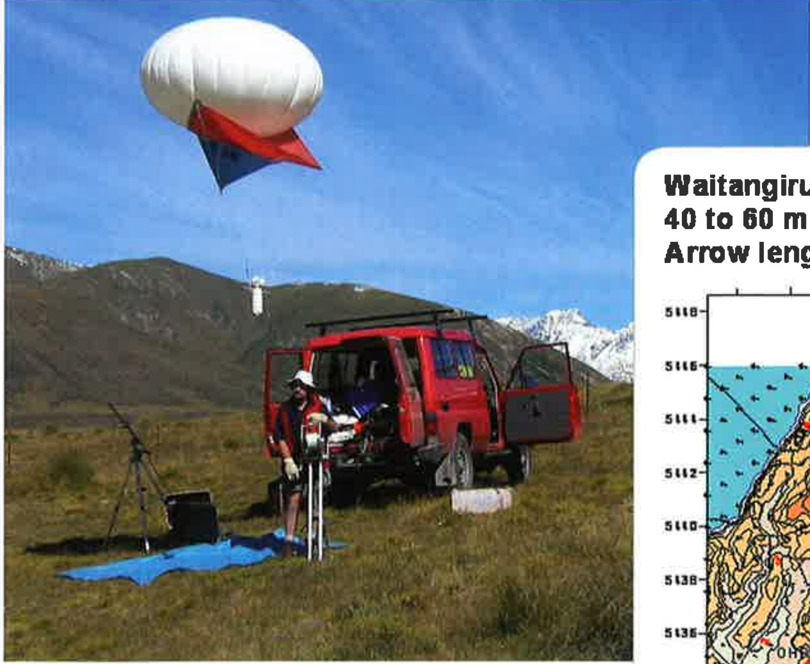
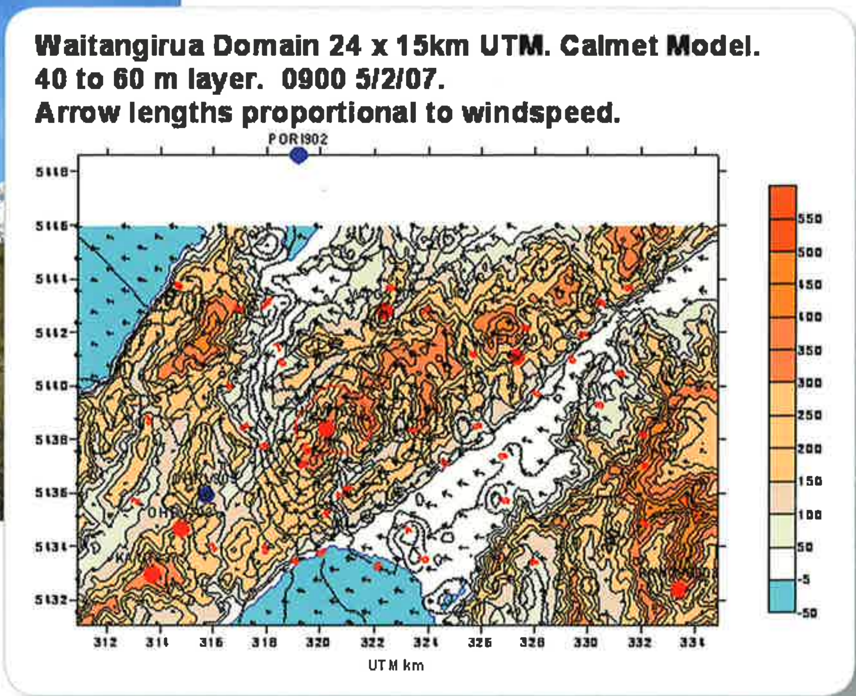


Photo: Ross Martin

Tony Bromley sends up the Helikite near Lake Tennyson to record a vertical profile of wind and temperature.



Sample output from the CALMET model shows wind conditions during a 10-minute interval within a 20-m-thick layer.

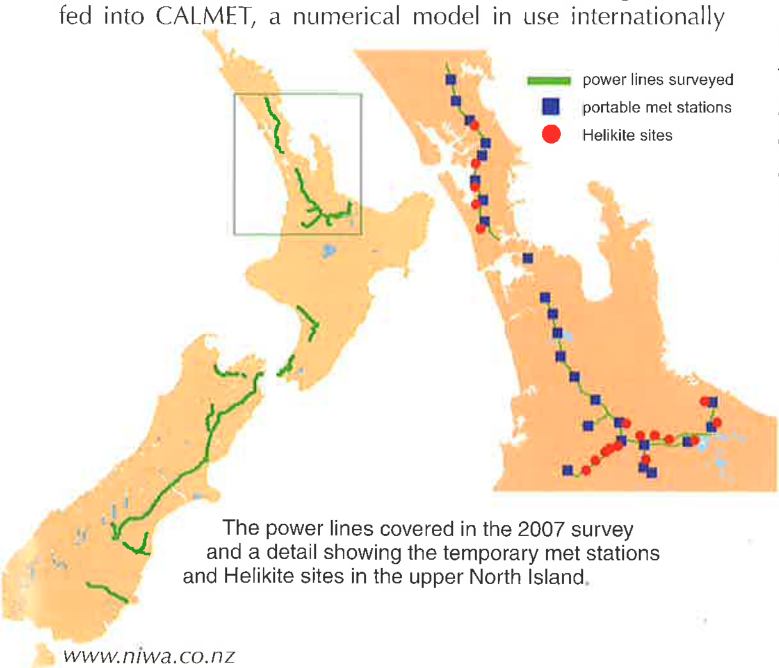
The field operation

For the 2007 campaign, specialist teams from NIWA collected the meteorological data. One team operated the Helikite for the vertical profiling, while the second team focused on the daily installation, data download, and decommissioning of the temporary met stations. The vertical profiles were measured as frequently as possible during the aerial survey. Data from the temporary stations were required from before dawn until at least an hour after the helicopter survey was finished for the day. The two teams 'leapfrogged' each other along the day's chosen survey line, usually covering several hundred kilometres each day. The temporary stations for each day's survey had to be installed the day before, and this necessitated careful logistical planning.

Modelling the survey results

Typically, we assessed 400 line spans in a day; on one exceptional day the NIWA team monitored and modelled over 700 spans. Each day's met data were collected from the portable weather stations, sent to NIWA in Wellington, and fed into CALMET, a numerical model in use internationally for air-pollution studies. The model created meteorological fields in three dimensions: at 10-minute intervals, over a 100-m horizontal grid, at heights of 10, 30, 50, and 70 m. We used CALMET to generate a vertical meteorological profile for each transmission line span. The model took into account the effects of terrain and land use (such as forest, pasture, or lake), which can affect the wind fields in different ways. The effects of larger-scale weather systems are also important, so we started CALMET running for the beginning of each day using real and modelled meteorological data, as is used in weather forecasting. CALMET outputs the data for every 10-minute interval over the full survey period.

Transmission lines are designed for reliable operation under worst-case weather conditions. By combining our meteorological modelling with the data from their laser survey, line operators are able to form a picture of how each surveyed line performed during known weather conditions and predict how it would behave at all times under all load and weather conditions.



The power lines covered in the 2007 survey and a detail showing the temporary met stations and Helikite sites in the upper North Island.

From power to pests

The same CALMET model is being used for biosecurity, such as in dispersion studies for predicting the spread of significant diseases. For example, in 2006 it was used to compile a risk atlas for foot and mouth disease in New Zealand. The model has also proved useful during campaigns to eradicate insect pests – from fire ants to painted apple moths – that threaten New Zealand's horticulture and forestry industries. W&A

Jeremy Bulleid and Graham Elley work with NIWA Instrument Systems in Christchurch and Tony Bromley works at NIWA in Wellington in the field of atmospheric emissions. Dr Tom Clarkson, formerly of NIWA in Wellington, is now a private contractor. For this project, NIWA was subcontracted by Power Systems Consultants (PSC), who are based in Wellington, and the LiDAR surveys were conducted by their project partner Opten Ltd (Russia).

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	Finding hidden treasure in aquaculture waste	Biology Level 2 US6309 Economics Level 1 AS90196	Integrated co-culture offers a way to increase aquaculture productivity without enlarging its environmental footprint.
12–13	Putting Antarctic sea spiders in their place	Biology Level 2 US6308, Level 3 AS90718	New phylogenetic studies of sea spider DNA are uncovering some surprises about the Pycnogonid family tree.
14–15	Kingdom Chromista in New Zealand	Biology Level 2 US6308	From diatoms to giant kelp, the six phyla of chromists fill many slots in New Zealand biodiversity.
16–17	Lobster à la carte	Biology Level 2 AS90460, Level 3 AS90461	Recent research shows that species-rich squat lobsters are an important component of fish diet in New Zealand.
18–19	"We don't catch 'em like we used to ..." Using traditional ecological knowledge in fisheries research	Biology Level 2 AS90769, US6309 Science Level 3 US21613	Through structured interviews, the knowledge of local fishers and shellfish gatherers can help reconstruct the history of our fisheries.
20–21	Muddy waters at Te Māhia: cause and effect	Biology Level 2 AS90769, AS90461 Geography Level 2 AS90331, US5089, Level 3 AS90701, US5095	Geology, climate, agriculture, and housing development all contribute to sediment runoff that is smothering local kaimoana.
22–23	Tracking the Waipaoa out to sea	Geography Level 2 AS90331, US5089, Level 3 AS90701, US5095 Science Level 3 AS9073	As part of an international research programme, scientists are studying the history of sediment dispersal from source to sink in Poverty Bay and beyond.
24–25	Characterising the national grid	Social Studies Level 2 AS90274 Electricity Supply US18273, US18275	NIWA instruments and modelling are helping to ensure the safe and full use of the high-tension power lines that span the country.

Colour key to Achievement and Unit Standards

Biology Chemistry Earth Science Economics Electricity Supply Geography Mathematics Physics Science Social Studies

Profile

David Wratt tackles climate change

The setting is short sleeves, but the topic is serious: David at a climate change meeting in Rarotonga.

When the Nobel Peace Prize was announced in October, David Wratt suddenly found himself in the spotlight, called upon by the New Zealand media to explain the workings of the IPCC, the Intergovernmental Panel on Climate Change. The prize was awarded jointly to the IPCC and to Al Gore, creator of the film 'An inconvenient truth'.

The IPCC was founded in 1988 and David has been involved in various capacities since about 1990; presently he serves on the panel's 30-strong Bureau (the steering committee), is vice-chair of Working Group 1 (which is concerned with the science of past, present, and future climate change), and is review editor for the IPCC Fourth Assessment Report.

When he's not involved with IPCC workshops and meetings, David works at NIWA's Wellington campus. Before returning to Europe for the meeting to finalise a Synthesis Report combining findings from recent IPCC reports, he paused long enough to answer a few questions about his life as a scientist.

Congratulations! Did you ever imagine that your research would have this sort of reward?

No, I'd never even thought about the prize. I'd call it a very pleasant surprise for myself and the other NIWA lead authors and review editors: Dave Lowe, Jim Renwick, and Jim Salinger. In all, 10 New Zealanders were lead authors for the latest assessment, which is presently being published.

Winning the prize is really good because it recognises the work of the thousands of scientists around the world who have contributed to the IPCC's findings. And it shows the value placed on a careful assessment of the science which can inform policy development and important international decisions.

How did you get into a career in science?

I grew up on a farm in Motueka and figured out early on that I didn't especially want to milk cows all my life. I was always good at science and maths at school, so I went to the University of Canterbury to take a degree in physics. Then I stayed on to do a PhD in atmospheric science, using radar to study atmospheric physics 90 km up. By the time I'd followed this theme through a post-doc at the University of Illinois in the States, I was ready for a change and came back to New Zealand to work for the Meteorological Service at Kelburn in Wellington.

I was meant to train as a weather forecaster, but this was around the time of Think Big and the Met Service was charged with providing information to help minimise air-quality problems from the big industrial plants that were planned. So I ended up doing a lot of field work at proposed power station and industrial sites, trying to determine what would happen to any emissions, modelling how they might spread in the particular terrain, and generally developing expertise in that field rather than weather forecasting.

Later, with restructure at the Met Service, I became the R&D manager and also started doing some work with climate change.

When did you find your way to NIWA?

When the CRIs were established in 1992, the research and climate people from the Met Service were transferred into NIWA. For me it was a chance to step away from management and get back into science.

One of the first big programmes I was involved in at NIWA was a collaboration called SALPEX, the Southern Alps Experiments. The aim was to understand and model how the Alps influence New Zealand's weather and climate, especially rainfall in the hydro catchment. We did some really interesting field work using the Australian CSIRO's instrumented plane – a Fokker Friendship – to measure droplet size, winds, and so forth during our big field campaign in 1996.

Since then, I've worked on some major studies that map present climate, climate variation, and soils within a region. We're able to identify the areas where climate and soils suit various crops, and this helps people figure out the best use of their land. When we factor in future climate scenarios, we can help a lot of sectors – such as councils, farmers, tourism, and emergency managers – to plan ahead and adapt.

You're NIWA's new General Manager for Climate Change. What's on the agenda?

Climate change and its potential impacts are becoming more and more of an issue in New Zealand. The position was created because climate change research draws on many disciplines – hazards, floods, aquaculture, water quality in rivers – and we need oversight of all these fields to understand what's driving change, what is vulnerable, and how to increase resilience.

We're working with other CRIs and universities to create a collaborative climate change centre that can help New Zealand Inc. by encouraging development of tools and science-based policies for reducing greenhouse gas emissions and adapting to climate change.

And your 'take-home' message about climate change?

Climate has always changed. What's different now is that humans are causing some of the changes through burning fossil fuels. If we continue down this track, we're going to see major problems around the world.

There's a strong scientific case for significantly reducing greenhouse gas emissions. We need a combination of reducing our emissions in New Zealand and being part of international negotiations to reduce emissions globally in order to forestall the worst effects.

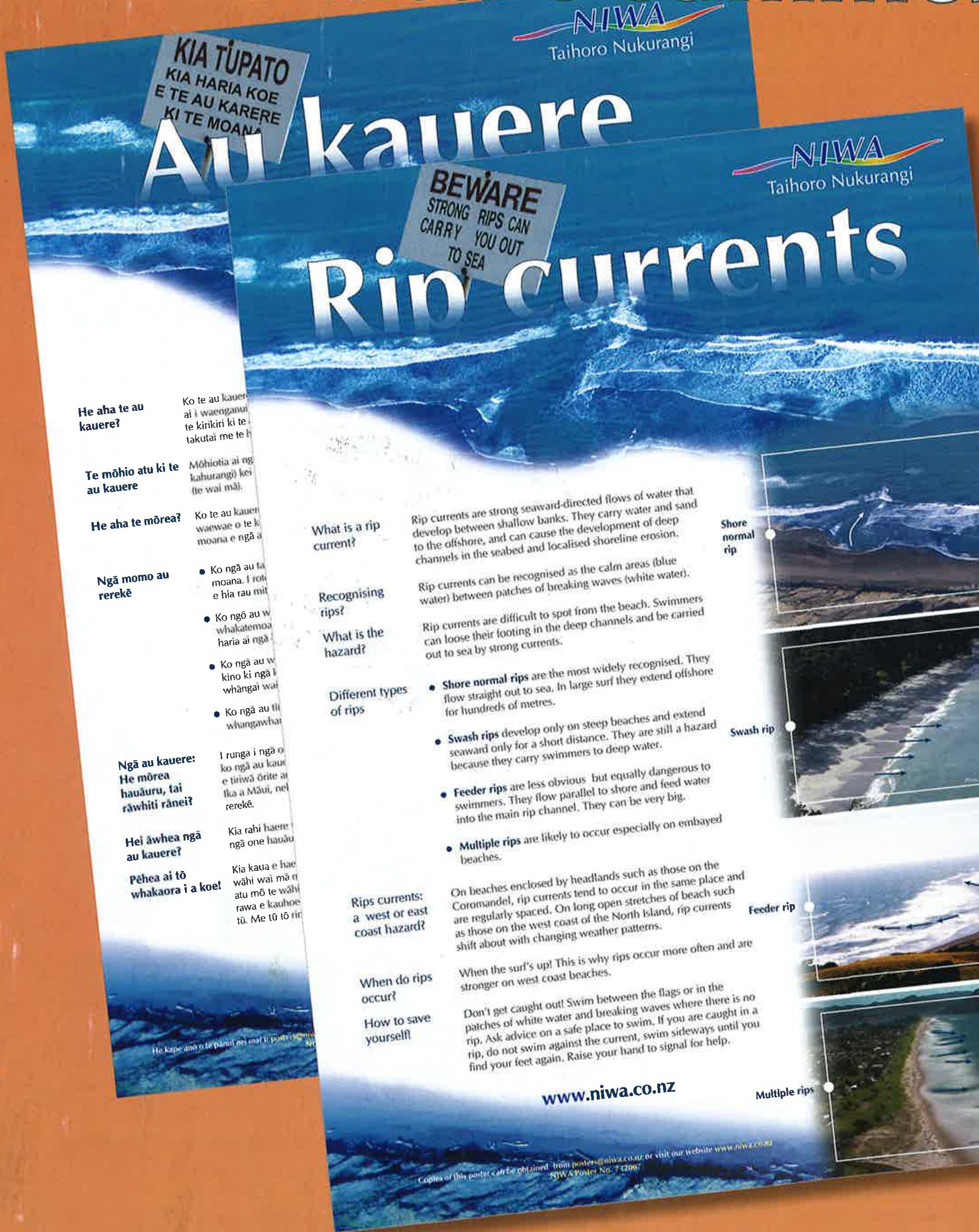
The 2007 Nobel Peace Prize was awarded to the IPCC and Al Gore "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".
To learn more about the Peace Prize, see: nobelprize.org

Photos: © The Nobel Foundation

Learn more about climate and climate change

NIWA's National Climate Centre: www.niwa.co.nz/ncc
Australian Bureau of Meteorology: www.bom.gov.au/climate/change
Intergovernmental Panel on Climate Change: www.ipcc.ch
UN Environment Program: www.unep.org/themes/climatechange
US EPA: www.epa.gov/climatechange

Have a safe summer!



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