

# WATER & ATMOSPHERE

June 2013

## The way ahead

Resources and revenues  
– the challenging science



### **Down on the farm**

Do fish farms deserve the flak?

### **A deeper understanding**

Biodiversity: our ace in the hole

### **Forewarned is forearmed**

Fighting fires before they start

# WATER & ATMOSPHERE

June 2013

## Cover

What are the great science challenges we need to address to ensure we can be proud of our childrens' legacy? *(Dave Allen)*

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## Editorial

# Working the percentages

It was 14 years ago that Tourism New Zealand (TNZ) launched its '100% Pure' marketing campaign in Queenstown. Images of majestic mountains, blue skies, green fields and sparkling waters were matched with imploring stanzas from Crowded House's "Don't Dream It's Over".

TNZ says '100% Pure' boosted visitor numbers by 50 per cent in a decade, and in 2005, the clean green brand was reckoned to be worth \$20.7 billion a year.

Over the same 14 years, New Zealand has begun to realise the fullness of its natural wealth; that it can generate more revenue from above and beneath the land, and more from the sea and fresh water.

New Zealanders have started dreaming about something else: doing far more with natural resources than modestly inviting people to pay to look at them.

It's no dream to consider that our resources, our wherewithal to use them, and our lifestyle in a clean and green country, mean we could be known as 'the luckiest country'.

The Government's Economic Growth Agenda calls for agricultural export revenues to earn 40 per cent of GDP by 2025 – which means that the value of production needs to treble. It is also encouraging exploration of our oil, gas and minerals.

The question is: how do we capitalise on that natural capital without destroying it?

The answer is something that science can help with.

Recognising the role of science in future development, the Government has just launched the National Science Challenges initiative. This has identified a shortlist of intractable issues which need priority attention. The \$133.5 million programme will "seek answers to questions of national significance by focusing scientific effort and providing additional focus on key areas".

NIWA is working on at least five of the issues which have since been listed as research priorities. These are New Zealand's biological heritage, our land and water, life in a changing ocean, the deep south, and resilience to nature's changes.

The Challenges project recognises that we are, above all, a ward of Nature: the country's economy stands or falls on the integrity of the environmental systems – water, energy, ecosystem services, nutrient and energy cycles – that sustain it.



Which comes down to accurate information, and innovative solutions. Environmental monitoring has always been crucial to good resource management, but if the rate of development threatens the capacity of natural systems to adapt, we must be critically sensitive to signals they are sending. These signals include challenges with air quality, fresh water – both quantity and quality – biodiversity loss, and high per capita greenhouse gas emissions.

High farm values and increasing competition for water mean our commercial advantage is eroding: by 2016, low-cost dairy producers – in China and South America for example – may well have undercut us. It's time, said a 2010 report by KPMG partner Ian Proudfoot, to start shifting to high-value niche commodities, backed by a demonstrable commitment to environmental responsibility.

The dilemma, then, is how our economic development ambitions might be realised without damaging the environment. Throughout industry and agriculture – and even in their markets – there are many who believe that we are smart enough to make money from resources, while we keep the environment healthy.

In these pages, some of NIWA's Chief Scientists talk about the big issues around their respective beats – fresh water, climate, oceans, fisheries, natural hazards – and the ways we might address them, while responsibly charting our path to economic recovery across the natural landscape.

With more than a collective century of experience in environmental research, these scientists grapple every day with the balancing act that is modern-day resource management.

Every day their science helps the nation make decisions about economic use of scarce resources that the nation also wants to keep '100% Pure'.

Becoming the luckiest country isn't something that can be left to chance.

A handwritten signature in black ink, which appears to read "John Morgan". The signature is fluid and cursive.

John Morgan  
Chief Executive

## RiskScape: a head start on hazard preparedness

When Christchurch City Council began work on the Avon Precinct Project – an ambitious and high-priority component of the city’s post-quake rebuild – they wanted to understand the likely consequences for the CBD during a once-in-a-hundred-year flood of the Avon River.

“We needed to know if it would make good economic sense to build flood protection measures into the precinct project at the outset,” says Graham Harrington, Senior Surface Water Planner, “and, if so, how they could be incorporated into the landscaping.”

And they needed to know fast.

Harrington turned to RiskScape, a software solution developed by NIWA and GNS Science that provides easy-to-interpret analysis of the risks, and physical, economic and social impacts, from a range of natural hazards.

RiskScape incorporates data and knowledge about a community – topography, roads, utilities, building designs, land uses and social characteristics – to create a detailed geographical inventory of the area. When hazards of different magnitudes and return periods – like a once-in-a-hundred-year flood – are superimposed, RiskScape estimates likely damage, replacement costs, casualties, economic losses, infrastructure and business disruption, as well as the total number of people affected.

“RiskScape was ideal for us because it already includes property valuations, and has been customised to New Zealand conditions,” says Harrington. “It gave us a rapid assessment and enabled us to make informed decisions about the project.”

RiskScape confirmed that incorporating flood defences into the project would be difficult to justify economically. “Instead,” says Harrington, “all new central city developments and re-developments will be located out of the predicted reach of the flooding. This will minimise potential damage costs, while avoiding initial capital and ongoing maintenance expenses and other impacts on the river landscape and precinct amenities.”

Cantabrians need no reminding of New Zealand’s vulnerability to natural hazards. But other areas of the country are just as susceptible: floods, windstorms,



RiskScape can analyse the probabilities and likely impacts of a range of natural hazards. (Alan Blacklock)

volcanic eruptions, earthquakes and tsunamis are a fact of life for Kiwis, and to build resilient communities, planners and managers must prepare for them.

That’s why NIWA and GNS Science, working within the Natural Hazards Platform, are extending RiskScape’s modelling capabilities. Says NIWA’s RiskScape Manager and Hydrodynamicist Dr Graeme Smart: “The software currently models earthquakes, river flooding, tsunamis, volcanic ash fall, windstorms and coastal storm-tide inundation. Now we’re looking to add landslides, volcanic lahars and pyroclastic flows, snowstorms and climate change effects.

RiskScape users are encouraged to supplement national datasets with as much local information as they can lay their hands on: a key to the tool’s effectiveness.

“The more – and more accurate – the local data, the better the result,” says Smart. “Detailed information about assets at risk is particularly important.”

Cost-benefit analyses of disaster mitigation measures, he adds, are complex, “because you need to know the damage costs your planned protection measures will avert. RiskScape evaluates the potential costs of future disasters, and delivers results at a fine scale.”

Potential damage to buildings, for example, can be calculated right down to individual structures.

RiskScape’s outputs can be tailored to a wide range of analytical and reporting requirements. Options include hazard and hazard-impact maps, shape files, PDF reports, summary tables and KML files that can be displayed in Google Earth.

The software is currently available to government and academic users, and NIWA aims for future wider release. A comprehensive user guide and dedicated website ([www.riskscape.org.nz](http://www.riskscape.org.nz)) provide support, important system information and updates.

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Scan this code  
with your smart  
phone to view  
RiskScape.



# In brief



NIWA's research station at Baring Head has been collecting atmospheric data for 40 years – the longest continuous time series in the Southern Hemisphere. (Dave Allen)

## Answers in the wind at Baring Head

What can 40 years' worth of CO<sub>2</sub> measurements tell us? An awful lot, says Dr Mike Harvey. "We want to know how the concentration of CO<sub>2</sub> in the atmosphere changes over time, in relation to what we're emitting into the atmosphere."

A little over half of CO<sub>2</sub> emissions are taken up by the land and ocean, says Harvey, NIWA's Baring Head Clean Air Observation Programme Leader. The rest persists in the atmosphere, "So by measuring that precisely, we have a better understanding of how much energy is trapped in the atmosphere as a result of greenhouse gases."

The Baring Head facility was conceived in 1969 by the then Department of Scientific and Industrial Research, and began measuring CO<sub>2</sub> on 14 December 1972. One of only a handful of monitoring stations in the Southern Hemisphere, it sits atop a sea cliff on the eastern side of the Wellington Harbour entrance. Its 40 years of data comprise the second-longest continuous measurement record in the world (the longest comes from a station atop Mauna Loa in Hawaii, begun in

1958), and the longest in the Southern Hemisphere. Research has since expanded into other greenhouse and trace gases.

The windy site is perfect, says Harvey. Baring Head stands squarely in the path of a 'clean' sample of mid-latitude southerlies, typically unsullied by contact with any land for the last five days.

So what are those southerlies showing us? "The 40-year trend," says Harvey, "shows atmospheric CO<sub>2</sub> increasing each year, currently at a rate of around two parts per million (ppm) or 0.5 per cent, every year. CO<sub>2</sub> concentrations recorded at Baring Head now – at 390 ppm – are 20 per cent greater than when measurements began, at 325 ppm.

The effects from any global efforts to cut CO<sub>2</sub> emissions should start showing up in the record in coming decades, he says. Nevertheless: "As the century progresses, we could move to quite a different climate to what we have today. If CO<sub>2</sub> emissions continue unabated, major global economic impacts are expected from the increasing severity of climate change extremes."

New Zealand, he says, is at the forefront of new measuring technologies. "We use lasers to make raw measurements of CO<sub>2</sub> and methane once every few seconds. Our research adds measurements from Baring Head to a meteorological modelling framework, to estimate the regional distribution of sources and sinks of CO<sub>2</sub>." The station also sends its data to an intercalibrated network called the Global Atmosphere Watch, coordinated by the World Meteorological Organization.

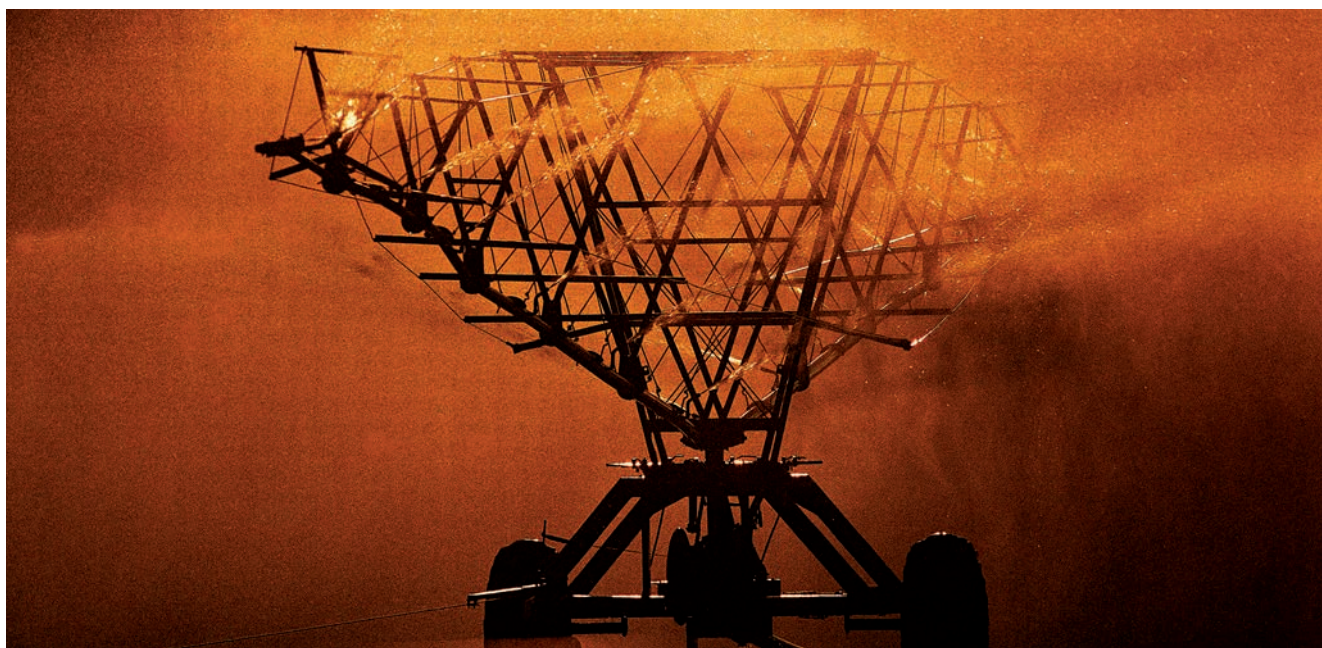
NIWA also makes atmospheric measurements at its Lauder station in Central Otago, Rainbow Mountain near Rotorua and Arrival Heights in Antarctica.

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Scan this code with your smart phone to view a video about Baring Head.





NIWA's new forecasting tool can help farmers irrigate much more efficiently, saving both water and money. (Dave Hansford)

## Smarter irrigation, more liquidity

A new collaboration between NIWA and Canterbury farmers could see huge gains in irrigation efficiency, with financial savings to match.

Dryland farming depends heavily on irrigation to maintain productivity, but to make best use of it, farmers need to know the moisture content of their soil, when it's going to rain and how much will fall. They also need to know how much water is available to them at any given time, but, most critically, during dry spells. To that end, NIWA researchers are working with five members of the Waimakariri Irrigation Scheme on a tool that generates customised, site-specific weather forecasts to help them better manage water use.

The new tool measures rainfall, irrigation and soil moisture at each farm, then combines those data with information from the existing Larundel climate station, to offer farmers 2-, 6- and 15-day forecasts. That information is emailed to farmers every day, helping them make a range of management decisions, both daily – such as irrigation scheduling and

stock movement – and more strategic, such as planning for water storage. “We’re sending out forecasts to show the farmers how conditions are varying on their farms,” says project leader and NIWA Hydrologist Dr MS Srinivasan, “and how parameters are expected to change over the forecast period of up to 15 days.”

Currently, many farmers don't have access to that crucial information, says Srinivasan, so will irrigate regardless, rather than risk losing pasture growth. “But if it's going to rain tomorrow,” he points out, “there may be no need to irrigate today, and that water can be stored or left in the river, so we're helping farmers optimise their water use and to stay within their allocation limits.”

The tool can also help farmers best schedule fertiliser and manure applications, to avoid having them washed into waterways by unanticipated rain. On the other hand, says Srinivasan, if only a drizzle is forecast, farmers might consider applying urea, as the drizzle can help reduce volatile losses from the fertiliser. “The challenge for us is to

find out what information is of most benefit to the farmers,” he says, “and the best methods and times to get that information to them so they can plan effectively.”

On a Ngāi Tahu dairy farm at Eyrewell, “managers are now using real-time information to produce better outcomes,” says Ngāi Tahu Farming General Manager Andrew Clayton. “We think it's great to be partnering with NIWA on a system that's designed to improve outcomes for the wider environment.”

The initiative is part of the Primary Innovation project, led by AgResearch and funded by the Ministry of Business, Innovation and Employment (MBIE). The project involves scientists from a range of primary sector research organisations, as well as growers, farmers and foresters.

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Scan this code with your smart phone to go to Waimakariri Irrigation Scheme tool.



# In brief



The 2012-13 drought has challenged both records and profits. (Alan Blacklock)

## Dry run

Over the three summer months, most of New Zealand sweltered under record or near-record sunshine, while much of the North Island, Canterbury and Westland got less than half their normal seasonal rainfall. NIWA Principal Scientist Brett Mullan told media that the long dry spell came courtesy of huge, “blocking” high pressure systems: “They sat over the country and steered the rain-bearing weather systems around them.”

Normally, he said, blocking highs tended to sit over eastern New Zealand, but high pressure systems this summer had been especially broad, stretching across the country and out over parts of the Tasman Sea.

So it was that on 15 March the Ministry for Primary Industries (MPI) declared the entire North Island as experiencing “a medium-scale adverse event due to drought”. Earlier that week, authorities declared a fire ban over practically the entire North Island – the first such sweeping measure in the country’s history. On 22 March, MPI extended the drought declaration to the Buller and Grey districts.

NIWA has confirmed that for parts of southern Northland, Auckland,

Waikato, Bay of Plenty, Hawke’s Bay and the west of the South Island, the 2012-13 drought was the worst in 40 years, more severe even than the 2007-08 Waikato drought. In Hawke’s Bay, it was second only to the devastating 1997-98 drought. In Marlborough and North Canterbury, it was less severe than 1997-98 and 2000-01. However, this drought was the most pervasive yet: only the dry of 1972-73 (Wairarapa, Tasman, Otago and Southland) comes close to matching its sweeping geographical extent.

In some locations, the Potential Evapotranspiration Deficit (PED) index – a measure of combined soil moisture loss to transpiration by plants and evaporation – confirms the driest conditions in 70 or so years. A little rain in mid-March did nothing to alleviate soil moisture deficits up to 50mm below the normal late-March average.

As autumn unfolded, those high pressure systems were not expected to monopolise the skies over, and to the south of, New Zealand as much, and indeed they did not. However, March remained dry, and the PED index climbed even higher, taking the 2012-13 drought well clear of 1972-73 drought.

New Zealand droughts typically break in autumn, although sometimes this is delayed until early winter. In 2013, the rains came in April – well above normal rainfall occurred in Waikato, Bay of Plenty, Manawatu and the upper South Island. By the end of April, soils had been recharged with water throughout much of New Zealand. By late May, some dry regions still remained, particularly Hawkes Bay and Wairarapa.

The 2013 drought cannot be categorically linked to climate change, but NIWA’s climate modelling indicates that droughts are likely to become more frequent, and more severe, in eastern and northern parts of New Zealand in coming decades. For example, a drought in eastern or northern New Zealand with a one-in-20 year return period based on data from 1971 to 2000 may occur twice, or even four times, as often by the end of this century.

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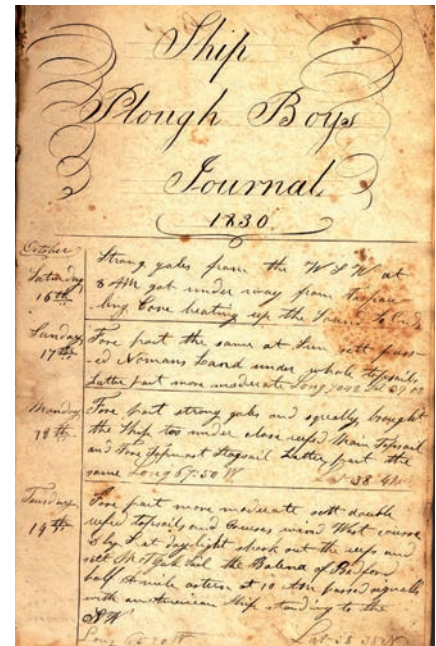
Scan this code with your smart phone to go to the NIWA Seasonal Climate Outlook.







After 65 years of protection, southern right whales are still at less than five per cent of their pre-whaling numbers. (Kim Westerskov/Hedgehog House)



Historical accounts of killing whales are now helping to save them. (The New Bedford Whaling Museum)

## Whaling's Domesday books now help protect

Nineteenth-century whaling logs – chronicles of systematic slaughter – are now helping to protect southern right whales. NIWA scientists pored over pages of grim reappings that nevertheless held valuable clues to the whales' present-day behaviour and distribution.

Funded by the Australian Marine Mammal Centre, the scientists spent three years analysing historic documents – compiled by the World Whaling History project – to deduce habitats where the nationally endangered species may still be at risk from shipping traffic and climate change.

"The data proved an absolute goldmine," says NIWA Marine Ecologist Dr Leigh Torres. "There is very little modern information on the offshore habitats of southern right whales. The historic documents are derived from vessel log books dating from between 1825 and 1888, in which whalers recorded their daily location and encounters and strikes of whales. They identify about 1800 locations where whale strikes or sightings occurred and – importantly – indicate about 23,000 places where whalers searched for, but failed to find, their target."

There were once some 27,000 southern right whales in New Zealand and Australian waters. But their slow speed and superior oil yield, plus their handy trait of floating once harpooned, made them the 'right' whales to pursue. At their nadir in 1913, as few as 14 survivors may have remained around New Zealand and, despite 65 years of official protection, species' recovery has been slow, hampered by a slow reproduction rate.

By combining historic data with present-day oceanographic information, sophisticated computer modelling helped the researchers predict the wanderings of the estimated 900 individuals alive today.

"We identified a number of consistent and influential predictors of whale distribution," Torres says. "For example, the data showed that the southern right is very sensitive to ocean temperature, and has a distinct upper limit."

That led the team to predict how climate change might alter the species' habitat and range. When ocean temperature projections for 2090–2100 were fed into the distribution model, says Torres, "substantial shifts in whale habitat suitability and availability in the Australasian area were indicated".

They also fed in shipping traffic data, which shed light on those parts of the whales' range and migration routes where they could be at greater risk from vessel strike. "We identified two areas – one on the Chatham Rise east of New Zealand and one in the waters south of Australia – where busy shipping lanes intersect key whale habitats," says Torres.

Published in the journal *Diversity and Distributions*, the results, she says, will "form an important basis for future management and conservation efforts," and validate unconventional datasets, such as historical exploitation data, as tools to predict present-day species distribution.

"We're confident in the predictive capacity of our models, and we're now familiar with the nuances of the historical information, so it's possible we could apply this technique to the entire Southern Hemisphere – and to other species of whale."

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## In brief



New arrivals and better records drove an update to Malcolm Francis' popular field guide to New Zealand fish. (Dave Allen)

### Plenty more fish in our seas

Dr Malcolm Francis has been diving for 40 years, but that doesn't mean he's seen it all. In fact, just last month he spotted two rare fish in the same dive, right off his local beach. "I saw a pygmy sleeper. They're only four centimetres long, and practically transparent, so they blend in beautifully with the background. Then I saw a banded weedfish, and got some good photographs of it. You think you know the Wellington south coast pretty well, but it still holds some surprises."

It's just that sort of revelation that prompted Francis to spend a year of his spare time writing the fourth edition of his popular guide, *Coastal Fishes of New Zealand*. As the oceans warm, more and more tropical species are venturing into New Zealand waters and, says Francis, there are many more divers out there nowadays to spot them. "And they're more savvy: they know what's new to the region. What's more, many now carry underwater cameras, where once may have been spearguns.

"In the old days, it was all about hunting and killing," he says. "Nowadays, more people hunt fish with a camera." Which means that, rather than gloomy studies of dead museum specimens,

we now have vibrant photos of living fish, and divers are always sending them to Francis. The upshot is that the fourth edition now boasts 275 colour photographs (though 70 per cent are still Francis') many of highly cryptic species formerly either poorly photographed or not at all. "Divers are much more observant these days," he says, "I might get as many as ten emails a year describing either new or interesting records."

It's been 12 years since the third edition and, in that time, 49 new species have been added to the pages. Better taxonomic understanding and techniques have seen some fish previously regarded as a single variable species re-classified as two. Francis says divers nowadays aren't content simply to know what they're looking at: they want to know more about how a fish lives its life: where it's found, its breeding biology, its behaviour.

And yes, there are still a couple in his own book that Francis hasn't seen, but, if he has a favourite, it might be the John Dory. Most of us have only seen it as fillets, but Francis says it's beautifully adapted as an open-water predator of smaller fish. "They have a very deep, very narrow body, which

makes them difficult to spot when they're approaching head-on. Then they shoot out that huge, extensible jaw and engulf their prey."

If more of us put on a mask and joined fish in their natural habitat, he says, we might regard them as something more than just dinner. "There are lots of characters in the sea. Spotties, for instance – they're so common everywhere, and most people know them, but they probably don't know that they all start life as females, then a few change into males at three or four years of age."

So is there a fifth edition in him? Most certainly, although he says it might be an electronic publication that people can consult on their phones or tablets.

*Coastal Fishes of New Zealand* introduces some 90 per cent of the species you might meet around our coast. It is available from the publishers, Craig Potton Publishing ([www.craigpotton.co.nz/store/coastal-fishes-of-new-zealand](http://www.craigpotton.co.nz/store/coastal-fishes-of-new-zealand)), and at bookstores everywhere.

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Marine biologists believe *Funicularina* – filmed by a NIWA remote operated vehicle in Fiordland’s Breaksea Sound – is a new species of sea pen.

## New sea pens write themselves into the records

The discovery in Fiordland of two more marine creatures new to science has researchers pondering just how many more unknown species await in its dark, undiveable depths.

In February, scientists from NIWA and the Department of Conservation (DOC) explored the seabed of Acheron Passage, near Dusky Sound, with a remote operated vehicle (ROV). At 80m depth, its cameras revealed two sea pens – so named because they resemble old writing quills – never before seen.

They turned out to be separate species, says ROV operator and NIWA Marine Biologist Dr Sean Handley: “We can identify one to genus level, but the other is completely new to us.

“This was our second exploration of Fiordland’s deep waters in the last few years, and on both occasions we’ve discovered previously unknown fauna. We can only guess at the treasure trove of life still waiting to be discovered down there.”

The dive was part of a wider biodiversity survey of Fiordland’s marine reserves, funded by DOC and supported by the Fiordland Marine Guardians, a

stakeholder and community group. So far, only Doubtful and Dusky Sounds have been explored, but nevertheless, says Handley: “We’ve found marked differences in fauna and habitats between the two, so it stands to reason that Fiordland’s marine environment as a whole could harbour an extraordinary diversity of life.

“It is an important area to study because it’s geologically unique and largely undisturbed by human activity.”

Sea pens are coral-like organisms that live in soft sediment. But, unlike corals, they lack a hard ‘skeleton’.

“They’re essentially row upon row of feeding polyps growing out of a soft stalk,” explains Handley, “hence their resemblance to feathers or quill pens.” He says sea pen colonies generally indicate an unpolluted, undisturbed environment.

At night, the creatures are luminous, attracting the tiny plant plankton they feed on. At 65 centimetres long, the Acheron Passage specimens are among the largest yet found in New Zealand, although sea pen species overseas can measure up to two metres.

The new discoveries will be logged in a biodiversity database. International experts will then help formally describe and name them.

“These discoveries, and the prospect of many more to come, reinforce the importance of the Fiordland Marine Area at both a national and international level,” says Fiordland Marine Guardians Chairman, Malcolm Lawson. “The Guardians are pleased to work alongside DOC and NIWA in identifying areas for future exploration.”

ROV footage of the discovery and sampling can be viewed at: [www.niwa.co.nz/news/fiordland's-depths-reveal-more-new-to-science-wonders](http://www.niwa.co.nz/news/fiordland's-depths-reveal-more-new-to-science-wonders).

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Scan this code with your smart phone to go to the sea pen media release.



# A deeper understanding

The sea might seem a distant, even hostile, place. But our coasts and oceans – and the creatures in them – not only grant us wealth, sustenance and pleasure, they keep our planet functioning, finds **Aimee Whitcroft**.



Blue maomao crowd an undersea arch at the Poor Knights Islands Marine Reserve. So far, more than 17,000 species have been described from the New Zealand EEZ. Another seven are added each week, on average. (Hedgehog House)

## A deeper understanding

Eighty per cent of New Zealand's biodiversity is in the sea. Our Exclusive Economic Zone (EEZ) – the world's fifth largest – is home to an estimated 17,134 known species, and, on average, another seven are added to the list every week. There are still 4315 more waiting undescribed, anonymous, in various collections. The Department of Conservation thinks there could be a total of 65,000 species off our shores, and it may be another 100 years before we get to know them all.

About 60 per cent of our marine creatures are found nowhere else on Earth. New Zealand is recognised as one of the top 25 global hotspots of biodiversity, and we've signed a raft of international treaties – and enacted tomes of legislation – that oblige us to look after it.

The EEZ also features, according to GNS Science, "a number of geological structures capable of holding giant oil and gas fields," and industry is eyeing iron sand and methane deposits. The challenge for policymakers and managers, then, is to strike the right balance between prosperity and perpetuity.

Decisions can only be as good as the science they rest on. We need to know what's at stake; what the risks – and the consequences – are. Which is where NIWA comes in.

### Plumbing the depths

First, you have to know what's down there; what part it plays in a healthy ecosystem, and how much disturbance – if any – it can tolerate.

NIWA Principal Scientist Dr Malcolm Clark and his colleagues have been looking at benthic communities across a range of deepwater habitats, such as seamounts and vents, and gauging their vulnerability to human impacts such as trawling or mining.

It's hard work – such communities can live hundreds of metres beneath an often tempestuous surface. Clark necessarily works remotely, towing video and photographic arrays above the sea floor, and sampling deepwater bottom sediment, where tiny creatures perform as much as 90 per cent of biological production.

"We look at species diversity, and various measures of it, then we try to relate it to environmental factors we're measuring at the same time – things like depth, substrate type, dissolved oxygen and salinity – so we're getting an idea of what's driving the species composition we're seeing. With repeat surveys, we can see over time what's happening naturally, and what's likely being caused by human impact."

By comparing, for instance, fished areas with unfished, Clark can measure impacts on species biodiversity or habitat integrity. This kind of deepwater expertise caught the attention of conservation NGO WWF-NZ in 2007, when they commissioned an ambitious catalogue of New Zealand's marine biodiversity – a project called *Treasures of the Sea, A Summary of Biodiversity in the New Zealand Marine Ecoregion*.

"We felt there was a real need for a comprehensive compendium," says WWF-NZ Marine Programme Manager Rebecca Bird. Information was scattered across dozens of sources, "but there wasn't a one-stop shop you could go to. *Treasures of the Sea* represented the latest information in one package."

Apart from informing WWF-NZ's own advocacy work, says Bird, *Treasures* was also produced for decision-makers, educators, researchers and students.

The work aimed to fill some of the holes in our

### The sky's the limit

If anyone can perceive order in Nature's apparent chaos of profusion, it's Dr Dennis Gordon. Last year, the NIWA Principal Scientist completed an edit of the monumental *New Zealand Inventory of Biodiversity*, a three-volume, 1758-page catalogue of nothing less than every known New Zealand animal, plant, fungus and micro organism, both living and extinct. That adds up to more than 56,200 living species and 14,700 fossil species.

But his labours aren't over. "New Zealand is still very much in the discovery phase," he says. "For macroinvertebrates – and I'm not even talking about protozoa or bacteria – our rate of discovery is about seven new species a fortnight. We can't keep up with the rate of discovery." By which he means taxonomists are struggling to identify, name and describe all those novel creatures that NIWA research vessel *Tangaroa* and others bring back.

"Add bacteria to that, and well ... we don't even have the faintest idea. The sky's the limit. There's over a century of work here waiting on the shelves to be done," says Gordon, "let alone the stuff at Te Papa."

Not only is much of it new to science, it's exclusive to New Zealand – probably, offers Gordon, down to New Zealand's long geographic isolation. That confers a duty: "We're one of the world's top 25 biodiversity hotspots, so we don't just owe it to ourselves: we have a global responsibility to conserve what's unique.

"If you look at the language concerning life these days," he muses, "it's that of the market: it's called a resource. It's almost a philosophical shift. But I feel that many people who simply love life and love Nature would say; 'we share this planet – we're organisms too.'"



A gorgonian, algae, sponges and anemones encrust an overhang at Northern Arch, in the Poor Knights Islands Marine Reserve. Sponges in particular use functional enzymes that could provide treatments for many human ailments. More than 5300 different products are already known from sponges and associated micro organisms, including the nucleosides spongothymidine and spongouridine. These compounds formed the basis of ara-C – the first marine-derived anticancer agent, used to treat leukemia and lymphoma – and the antiviral drug ara-A. (Dave Hansford)

understanding of New Zealand's marine biodiversity, and to mesh into a worldwide *WWF assessment, Global 2000*, which set out a network of 238 ecoregions based on a hierarchy of biogeographic assessments. The ultimate aim was to identify representative habitat types – terrestrial, freshwater and marine.

Criteria such as species richness, endemism, taxonomic uniqueness, unusual ecological or evolutionary phenomena and relative rarity were then used to estimate 'urgency of action' or conservation priority.

"It was an idea NIWA really supported," says Bird, "and we felt we could trust the integrity of the information, too, because it was coming through an independent, reputable organisation."

Not all NIWA's work happens at depth: in the coastal zone, the job is at least a little simpler. Researchers like Principal Scientist Dr Judi Hewitt use a combination of traditional methods, such as point sampling – installing cameras or taking core samples – and the more innovative. "Since 1994, we've been looking for methods to nest that sort of data within the more remotely-obtained types of assessments, and have been using sidescan and multibeam sonar, aerial and underwater photographs and long video transects." But, as yet, she says, there's no affordable technology that

can handle both the intertidal and subtidal areas, which studies often move between.

When Greater Wellington Regional Council (GW) wanted to get a better handle on the area's biodiversity last year, they got NIWA to take a look. Surveying found seven sites of special significance, from the shallow Porirua Harbour, down to methane seeps in 1100m of water on Opouawe Bank.

The project, a requirement of Wellington's Regional Policy Statement (RPS), demanded "the best available information," says GW Senior Policy Advisor Jo Beaglehole. "We thought that NIWA would be an obvious first port of call."

NIWA's report went into a mix of other information on estuaries, bird habitats and other sites identified by the RPS or the Department of Conservation.

Beaglehole will now add a schedule to the regional plan, listing sites of significant indigenous biodiversity in the coastal marine area. "I'm also drafting policies and rules that will apply to those sites, that will try to afford protection under the RMA over and above the management of biodiversity across the region."

She says that, while it's not always easy to articulate the need to protect ecosystems, "I think it's fairly accepted now that loss of biodiversity is a bad thing."

## A deeper understanding



Mangroves line the Matapouri Estuary, in Northland. One US study valued the ecosystem services provided by the world's mangroves – flood and erosion control, nutrient retention, carbon sequestration, and fisheries enhancement to name a few – at an average of \$US28,662 per hectare, per year. According to the United Nations Food and Agriculture Organization, global mangrove coverage is now less than 15 million hectares – down from nearly 20 million hectares in 1980. (*Hedgehog House*)

### A thousand billion support staff

Increasingly, in fact, marine management asks not what we can do for ecosystems, but what ecosystems can do for us. Marine organisms provide us with food, refresh our air (half the oxygen you breathe has been purified by marine plankton), recycle energy and nutrients, regulate our climate, sustain the marine leisure and tourism industries and offer our souls a touchstone – all for free.

Collectively, this economic aid is called ecosystem goods and services, or EGS. It can include leisure activities, tourism, food (such as fisheries), energy and nutrient cycling, temperature regulation, carbon dioxide absorption, cultural values and more.

**“All these things are under threat in a way, precisely because we’re taking them for granted.”**

Waikato Regional Council Programme Manager, Coasts and Marine, Peter Singleton

Much is made of the putative value of oil and gas reserves, but a 1999 study estimated that New Zealand's marine ecosystems annually perform \$184 billion worth of labour – more than twice our national GDP that year. Globally, the economic value of ecosystem services has been reckoned

at US\$33 trillion every year. The figure sparked a debate: one commentator considered it “a serious underestimate of infinity.”

Whatever the number, local government increasingly recognises that contribution. Says Waikato Regional Council's (WRC's) Peter Singleton, Programme Manager Coasts and Marine: “A healthy, functioning ecosystem – and the environment it produces – is an economic asset, because people are coming to the beaches, to the harbours, to benefit from that asset.”

But the very fact that their services come for free, he says, can put ecosystems at risk: “A lot of the aspects of the environment that we take for granted, like clean water, production of fish and shellfish – are under threat in a way, precisely because we're taking them for granted.

He says we need “to reverse our thinking from seeing biodiversity as a nice-to-have, to seeing it as essential in underpinning our economy and our lifestyle.”

For more than 20 years, WRC has relied on NIWA's marine expertise; more recently to help assess consent applications for mangrove management, building the first ever detailed map (in terms of its habitats and geography) of the Hauraki Gulf, and mapping habitats within estuaries. “To date, the coastal area for us has been very much an unknown frontier,” says Singleton. “NIWA has ... proved to be an incredibly valuable, if not indispensable, resource for us as a regional council. It's helped us go into that frontier and understand what resources we have there – how important they are, how scarce or common they are – and that helps us manage them,” he says.



## Taking a picture of health

Watching the creatures of a rocky shore defy pounding breakers, you'd assume ecosystems are tough and resilient. And they can be, but they're also complex, depending on intricate, often nebulous, relationships and flows. Ecosystems are a team effort, and some players, it turns out, can be game breakers. Harm them, and you can compromise the entire assemblage. Push them past some cryptic tipping point, and the whole system might collapse, promptly withdrawing all that volunteer labour that keeps our own systems going: for example, the Atlantic cod fishery collapsed in the early 1990s, some 19,000 jobs were promptly axed, and another 20,000 lost or scaled back in the subsequent fallout.

**“I feel that many people who simply love life and love Nature would say; ‘we share this planet – we’re organisms too’.”**

NIWA Principal Scientist Dr Dennis Gordon

In our own Hauraki Gulf, overzealous dredging since the 1920s destroyed the once-vast mussel beds of the Firth of Thames and inner Gulf. The grounds used to yield up to 500 tonnes of mussels a year – some 15 million mussels were landed in 1961 alone, but the very next year, the ecosystem collapsed. Apart from the squandered revenue, the Gulf lost an important water purifier and habitat for other organisms. The mussel beds have not recovered, even though dredging stopped nearly 50 years ago. A NIWA study suggests that, despite problems with juvenile recruitment and survival, restoration may yet be possible.

“Because the ocean is big,” says Dr Simon Thrush, “and ecosystems are complex, there’s a tendency to take notice only after major loss of biodiversity, and the ecosystem services that provides. But at that point, it’s very difficult to go back.”

But before you can spot a damaged ecosystem, you must first know what a healthy one looks – and functions – like.

Under contract to Auckland Council, Thrush, a NIWA Principal Scientist, and his team have devised a way to gauge an ecosystem’s integrity. They’ve been looking at functional groups – various species which perform a given task in similar ways. “The degree of overlap gives you an idea of the redundancy within that function. Redundancy means that if one species is particularly stressed by some environmental phenomenon or human activity, then there are other species that are able to step in and, to some degree or other, perform that function.”

As systems become more degraded, he says, they take on a more homogeneous nature. Small, rapidly-growing and reproducing species start to dominate. “A terrestrial example is a change from forest to grassland,” says Thrush. “The degree of habitat diversity in a forest is way bigger than in a grassland.”

We need to make smart decisions, then, on behalf of those communities – the countless billions of unpaid workers out there which sustain our very existence. The economic and environmental rationales are clear, but it’s not just a business case, says Thrush: “If we don’t have places that people can reference themselves to,” he says, “and remember that, when they were a kid, they could walk into the water and have fish around their feet, or find rock pools filled with life, then I think we lose a lot as a society, by not having that sense of place. I think that’s pretty deep in the Kiwi psyche.”

## Renaming nori

The abiding ambition of taxonomy might well be to abolish anonymity. It tells us where creatures fit on the vast family tree of life. It identifies organisms according to shared common characteristics, gives them a name, then asserts them in a hierarchy. As Dr Wendy Nelson, NIWA’s Taxonomy and Systematics Science Leader, explains, it also reveals the differences, similarities and evolutionary links between all life on Earth.

“The names are actually a whole lot of hypotheses and theories,” she says. “People sometimes get testy about why taxonomists change names, but we’re always trying to get a better understanding of these relationships, so if we discover new ones, or get fresh insights into how they relate to one another, the names change to reflect that.”

Take sushi, as many of us do each lunchtime. We know it comes wrapped in a handy roll of ‘seaweed’ sheet called nori, but what exactly is it? Nelson recently took part in award-winning international research that began with just that question. It’s a prime example of how research into marine taxonomy can pay huge dividends.

Nori is processed from particular types of red algae. Nelson and her team realised that the scientific names of the specific species in question didn’t accurately reflect their evolution, or the way they really related to each other. So the project completely reorganised the taxonomy for the whole group of organisms.

So what? Well, 600 square kilometres of Japanese coastal waters produce 350,000 tonnes of nori a year, worth more than a billion US dollars. Being able to identify those with the best characteristics, in terms of consistency and nutrition, is gold. Industry leaders have already picked up this new research, and use it to guide their work.

As Nelson points out: “People were trying to breed algae that were actually of such different types that they were doomed to failure. Taxonomic research may seem esoteric, but it has really profound implications.”





# The way ahead

The economy and the environment could both use some help, but both can flourish. NIWA scientists talk about managing the issues for the sake of our kids.

## The way ahead

### Australia's mineral wealth, underpinning a rigorous spirit, has earned it the moniker 'the lucky country'.

New Zealand now has reason to challenge that label. It's turning out that our natural resources are worth far more than we ever thought during the 150 years in which we had comfortably ridden on the sheep's back.

In its 2010 report, *The Changing Wealth of Nations*, the World Bank ranked New Zealand the eighth-wealthiest country in the world for natural capital per capita (above the 'lucky country', Australia), and the first for renewable natural capital. That endowment, say analysts, is our economic leverage, perhaps salvation.

We're learning ways to produce more foods from our green pastures. And now new, extensive mineral deposits are being discovered; from iron sand to oil and gas.

New Zealand's combination of agriculture, minerals, and innovative work ethic might well justify it being called 'the luckiest country'.

We're ambitious in our intentions. For example, the Government's Economic Growth Agenda calls for export revenues to constitute 40 per cent of GDP by 2025, including a near-trebling of the real value of agri-food exports to \$58 billion. Such ambition begs the question: How do we extract maximum benefit from our natural capital without destroying it?

This new found realisation of natural wealth has brought us to a fork in the national development road – and the route we take is a decision that science can help with.

The first step is to establish what we want to protect, and what we want to use. And that is a job for science. You can't determine what's important, rare, vulnerable, or worthwhile using, until you first know how much of it you have, the state of its health, the part it plays in a healthy ecosystem and its sensitivity to whatever you have in mind for it. That sort of knowledge requires intensive research, monitoring and sophisticated modelling. This is the sort of work NIWA is doing every day.

One government response to the fork in the development road is the National Science Challenges initiative. This has created a shortlist of intractable issues, some environmental, which need priority attention. The \$133.5 million programme will "seek answers to questions of national significance by focusing scientific effort and providing additional focus on key areas".

Commitment to science, and research and development, is likely to be the factor that makes New Zealand the 'luckiest country'. NIWA's research shows how science is helping New Zealand make its own luck out of these challenges.

### Public disquiet

There are signs that the public is unsure about granting "a social licence to operate" to those proposing new ways of using our natural capital.

In April 2012, the Christchurch City Council unanimously declared the city a fracking-free zone. Three other councils joined calls for a national moratorium, backed by community boards throughout the country.

Later that year, Brazilian oil giant Petrobras abandoned a seismic survey for oil and gas-bearing substrates off East Cape after being harried by a protest flotilla launched by Greenpeace and Te Whānau ā Apanui.

Similarly, plans to increase water take from rivers, or build dams and races for storage and irrigation schemes, have run into opposition.

The issue of declining quality of freshwater has been highlighted by multimillion-dollar clean-ups of Lakes Taupo and Rotorua, and the Waikato River.

Those planning to use resources in new ways want to work out how to do so without irreparable damage, and to monitor the effects. They also need this information to show the public that resource transformation can happen without putting the environment into overdraft.

Discussions on resource use and conservation will need to be conducted on a stage not rickety with emotion and baseless claims, but solid with scientific information.

Science can be an expert witness in the discussion; a critical part in gaining approval for new projects from the New Zealand public.

That's where NIWA comes in; working out the size and type of resources, working out the environment connected to them, and establishing how to use one without harming the other.

### Troubled waters

One of the most significant environmental items on the Challenges to-do list is water: enhancing primary sector production and productivity, while maintaining and improving land and water quality.

"If you're going to intensify land use, you must account for environmental impact," says Dr Clive Howard-Williams, NIWA's Chief Scientist, Freshwater and Estuaries.

Howard-Williams says there are two big challenges with water in this country. "One is quantity: whether we've got enough water to allow for both the economic growth agenda and the maintenance of the environment."

The other is quality. "The real need is to count and assess cumulative impacts. One discharge into water may look minor on its own, so someone gets a permit. However, others may have added discharges the year before, and the year before that, and the year before that."



Dr Barb Hayden, Chief Scientist, Coasts and Oceans: "One of the biggest challenges is to develop and utilise our resources in a sustainable way." (Dave Allen)

**“ [It's] a no-brainer. The cost of a degraded environment is a cost New Zealanders don't want to pay.”**

NIWA Chief Scientist, Freshwater and Estuaries,  
Dr Clive Howard-Williams

The only way to address it, says Howard-Williams is “to set limits”. Before you can draw any lines in the water, he says, you need to understand thresholds – tipping points past which freshwater ecosystems may not be able to function properly. Only then can you craft sound scientific advice into policy.

“The environment needs good water quality to maintain ecosystem values, but it also needs appropriate quantities of water. Minimum flows are a very crude way of setting limits.

“You can enable water allocation while keeping the environmental integrity of the river by taking account of natural fluctuations. For example, rivers need floods at certain times of the year to flush sediments and algae off river-beds, or to allow for fish migration. We’re looking at precisely that now with our research programme into better water allocation systems.”

Regulators have flinched from the unpopular business of capping allocations or discharges, “but the Government’s National Policy Statement last year was one of the best things that’s happened to freshwater management in many decades. It said: ‘The only way we’re going to stop this is to set limits beyond which you can’t go,’ and that was quite a brave step.”

Meanwhile, NIWA is developing various technologies to minimise the impact of agriculture on waterways – like riparian strip work, constructed wetlands, floating wetlands, or advanced pond systems to recover energy from wastewater.

Howard-Williams says NIWA’s forecasting (see ‘Forewarned is forearmed’, page 26) allows for “precision farming, where you apply fertilisers or irrigation or sprays only at the appropriate time – dictated by accurate forecasts – and not just before it starts to rain. All these technologies are helping farmers improve productivity while maintaining or improving water quality.”

Clean or otherwise, will there be enough water to go round? “Healthy dairy pastures need about 1200mm of rain a year,” says Howard-Williams, “but some of the most potentially productive landscapes are the flat lands along the east coast of the South Island and east coast of the North Island, where you’re down to something like 300mm a year.” Desalination’s out of the question, he says, so “the only other way to do it is to store water, so you can release it when you need it most”.

But storage usually requires altering flows or damming rivers. That’s where water modelling comes in. “NIWA has developed a tool to help regional councils work out the best place to site a dam. This means water can get to where it’s needed for production, while minimising impacts on downstream flows.”

Clever demand management is critical: “You can improve water use efficiency through precision farming. So it can take 800mm to irrigate a pasture rather than 1200mm.

## The way ahead



Dr David Wratt, Chief Scientist, Climate: Climate change is not all about impacts. "It's also important to think about opportunities." (Dave Allen)

We're helping farmers do that by more accurate weather forecasting, and improved measurement of soil moisture and evaporation to better understand the water balance."

Looking after our water resource, says Howard-Williams, "is a no-brainer. The cost of a degraded environment is a cost New Zealanders don't want to pay."

"We have very high environmental expectations relative to many other countries. But let's not get tied up with measuring ourselves against others. We need to decide for ourselves as a nation what constitutes good water quality, and just go for it."

### Warming to the task

The National Science Challenges has identified resilience to natural disasters as a key issue.

Dr David Wratt is NIWA's Chief Scientist, Climate. "It's pretty clear that the climate is going to change over the coming decades and century," he says. "The changes will include more extremes, shifts in rainfall patterns, increases in sea level."

That leaves a raft of sectors vulnerable, he says, unless they can use science to help with planning. Farmers will need help dealing with more – and more severe – droughts, uncertain water supply, shifts in pasture growth and animal welfare problems.

We're also facing more flood risk, says Wratt. "Quite a lot of our infrastructure is built on flood plains – houses and factories, roads and bridges, those sorts of things." Similarly, billions of dollars' worth of coastal development, he says, are threatened by rising sea levels.

As a scientist, Wratt's priority is to remain "aware of what's important to people when they're making climate-sensitive decisions and future investments. And making sure we've got the right research underway, so we can provide the right information to the right people. We don't make the decisions, we aim to give people good information, so they can better manage their lives and their businesses."

Nay-sayers and detractors, says Wratt, "tend to downplay the fact that scientists have been working hard on understanding the climate, understanding what's been happening, based on measurements, and projecting what may happen in the future. I really hope that good information will be made use of to inform decisions, rather than being disputed in the Environment Court and judicial reviews."

It's important to remember, he stresses, that climate change is not all about impacts. "It's also important to think about opportunities." Shifting trends in temperature, rainfall and frost could offer farmers and growers new crops and ventures. "That's partly a matter of keeping good track of what's going on with the climate, and being flexible."

Foresters might benefit from what's known as the CO<sub>2</sub> fertilisation effect, where greater CO<sub>2</sub> concentrations boost

plant growth. But warmer conditions might also encourage forest pests to spread and multiply.

On the other hand, more rain, rather than snow, in winter might see some hydro catchments get a boost.

Like Howard-Williams, Wratt thinks our future will depend on how we manage water "and providing the best information we can from climate studies – spatial and temporal variability in rainfall, evaporation and drought".

He stresses the value of sharing information across disciplines and organisations. "Climate information alone doesn't lead to developmental change: it demands an entire chain of people who can interpret and understand the social and economic issues that might arise from different ways of doing things."

He makes a research priority of getting "appropriate, systematic measurements, so we can determine what's happening (with the climate), and to help us understand local and regional variability. That requires a dense measurement network, which costs money. So I'd really like to see good collaboration across agencies and organisations, working together to collect, share and make use of climate data."

**“With good risk information we can make smart planning decisions, rather than reaching them after hazardous events.”**

NIWA Chief Scientist, Natural Hazards and Atmosphere, Dr Murray Poulter

Addressing climate change requires a good understanding of the climate system, right across the atmosphere, oceans, water, ice, biosphere and society.

## Hazards ahead

On Tuesday, 22 February 2011, at 12:51 pm, Nature sent us a jarring reminder that there's a limit to our luck; we've chosen to live in one of the most geologically jittery regions on Earth.

Murray Poulter is NIWA's Chief Scientist, Atmosphere and Natural Hazards. He says that, if we're to mitigate the impacts – not just from earthquakes, but flooding, wind, storm surge, slips and heavy snowfall – we need to understand why such shocks happen where they do, how large they might be and how often they occur. We need to better understand their social and economic impact. "With that fundamental understanding of individual hazard processes," he says, "we can estimate the risk and impact across the range of hazards we face in New Zealand."

The other side of the coin is how we respond to risks. "With good risk information, we can make smart planning decisions, rather than reacting after hazardous events. That means getting resources and mitigation in place – measures like stopbanks or earthquake-strengthened buildings."

"If you base mitigation on a given level of risk", he says, "there will still be large events that exceed your chosen mitigation standard. So what's your option then? Forecast those events, and then get out of harm's way." This applies particularly, he says, to weather, flood and coastal storm



NIWA Chief Scientist, Atmosphere and Natural Hazards, Dr Murray Poulter: "Once you have children, you appreciate that the world will actually carry on beyond your lifetime." (Dave Allen)

## The way ahead

surge hazards, where more accurate forecasts can provide advance warning, model the impacts in real time and guide our emergency response.

“The key thing is understanding risk – being able to estimate it – and then communicating that risk. New Zealanders will tell you that earthquakes are their biggest worry, but, in fact, earthquakes are infrequent – albeit very high impact – events, whereas flooding is very frequent. If you examine the costs over the longer term, both hazards cost us about the same.”

The Christchurch rebuild offers a valuable opportunity to think about our future, and how we want it to look and work. “If you were going to design New Zealand again, would you end up with what we’ve got? From a hazard point of view, our biggest city sits on an active volcanic field, our capital is on a major fault line, half our second-biggest city is built on a swamp. And look at our secondary cities: a lot of them lie at river mouths or on flood plains.”

### Sunken treasure

By some estimates, the New Zealand Exclusive Economic Zone (EEZ) holds gas, oil and mineral reserves worth billions, though exploration to date has been piecemeal.

The Government has encouraged oil and gas companies to step up that exploration. But there is still some public scepticism in the wake of the *Rena* grounding off Tauranga, and the Deepwater Horizon blowout in the Gulf of Mexico. Some believe that environmental controls are insufficient to protect the waters and wildlife regarded as a national touchstone.

We need more information, says NIWA’s Dr Rob Murdoch, General Manager, Research, about the mineral and biodiversity wealth of our EEZ, so we can realise the revenues from one, without harming the assets of the other.

The Government agrees. The National Science Challenges list says it is crucial to understand “how we can exploit our marine resources within environmental and biological constraints”.

Murdoch says the New Zealand public is unlikely to grant a “licence to operate” if we can’t demonstrate more rigour in our understanding of the environment.

“There’s a lot we don’t know about the extensive sedimentary basins in our EEZ,” says Murdoch. “We need to provide critical resource data to attract prospective explorers, and to provide information that allows Government to make sound licensing decisions and enact effective regulatory policy.”

The other consideration, Murdoch says, is that we need to develop measurement tools and predictive models to assess how mining and other activities will affect oceanic ecosystems and other resource users, and to assess the risks of deepsea drilling and hydraulic fracturing. “That’s a necessary precursor to gaining public approval and awarding mining licences.”

“The Government has been clear that it wants ocean resources developed,” says Dr Barb Hayden, NIWA’s Chief Scientist, Coasts and Oceans. “The challenge is to come up with processes that make sure any development is environmentally sound.”

Oil and gas and minerals aren’t the only treasures found in our marine estate: commercial, customary and recreational fisheries sustain thousands of New Zealanders, and a fantastically rich biodiversity delivers all manner of ecosystem services (see ‘A deeper understanding’, page 12).

As our uses of the ocean have proliferated, so have the conflicts, leaving policymakers and resource managers struggling to reconcile them: where lies the balance between exploitation and protection, between a healthy ocean and a healthy economy?

Hayden says the regulatory landscape of the EEZ is almost as tortuous as its topography. So far, we’ve managed the uses of our ocean, sector by sector: “We manage aquaculture over here, fisheries over there, and mining over there, each under separate legislation.” And, while we are working on an oceans research strategy, we don’t yet have a national oceans policy.

“We haven’t managed multiple activities in one space. But it’s essential that we start to do that, because the values of the commercial fishery could be quite different from those of you and me, for instance. But they’re all important to the collective values we share as New Zealanders. It’s a difficult area, but we’re happy to be working in it.”

Something else we need to get to grips with, she says, is the concert of consequences environmental managers call cumulative effects. We might understand the effects, for instance, of a fish farm on the benthos of a sheltered bay. We can place conditions on a consent that will mitigate them, but what if that bay also receives runoff from a forest, a motorway or a dairy farm? Or what if it’s being colonised by an invasive pest? Over time, such cumulative effects, she says, can deal a heftier blow than a single event like the *Rena* grounding.

Hayden says that people are overly focused on catastrophes. “In the grand scheme of things, oil spills can be relatively short-lived, whereas cumulative impacts can go on for decades or longer.”

All of which highlights, she says, a need for collaboration, and “stronger partnerships between managers, policymakers, scientists and users of the marine environment. We need to be doing this in tandem”.

To that end, NIWA has launched a programme to develop “a consultative process that brings in the values and aspirations of Māori, the general public, fishers – any users of the marine estate”, says Hayden, “in a way that allows for the concurrent management of all uses, because we must be good stewards of our environment”.





Dr Rosie Hurst, NIWA Chief Scientist, Fisheries: "Society needs to determine how things are managed. It's the job of science to inform that determination." (Dave Allen)

## A growing appetite

Dr Rosie Hurst, NIWA's Chief Scientist, Fisheries, is concerned that "feeding a growing population is going to become an increasingly serious challenge." Success will depend on two things: "the sustainability of the food production we have now, and whether or not we can increase that production. New Zealand's done a lot to manage its fisheries sustainably, and we have an excellent international reputation for our Quota Management System."

"While we monitor some fisheries very well", she says, "we don't have a good understanding of how key species fit into their ecosystems, or the impact of fisheries and other users of the marine environment on ecosystems and their productivity".

In particular, it is important to be able to determine when fisheries are likely to have adverse effects on other species (such as seabirds and marine mammals) and seabed communities. Add other uses of our marine estate, like seabed mining, she says, "and it becomes very hard to assess what the cumulative effects might be".

The way ahead, says Hurst, lies in "ecosystem-based approaches to management". But deepsea fisheries research is both expensive and difficult. "So we need to rely on computer-generated ecosystem models. The quality of these models depends on the quality and quantity of the

information we have, and the assumptions we need to make. It's difficult enough to build a single-species fisheries stock assessment model, let alone model an entire ecosystem, so it's a big challenge."

Like Howard-Williams, Hurst believes the important decisions lie with ordinary New Zealanders. "Society needs to determine how things are managed. It's the job of science to inform that determination."

The impacts of climate change on marine ecosystems also have her attention. "Localised warming in some parts of the world has already caused changes in fish distributions and productivity. There are likely to be winners and losers, but making predictions is extremely challenging."

Even as it warms, the sea is also absorbing more and more carbon dioxide, shifting its pH balance. "Ocean acidification is expected to be pronounced in the Southern Ocean. How this might affect primary productivity – and therefore fisheries production – we don't yet know."

Again, it's not surprising to find the 'Life in a changing ocean' as a priority research topic on the Government's list of Science Challenges.

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# Forewarned is forearmed

Whatever their domain – land, asset, production or risk – managers are hungry for good intel about the future. That’s where NIWA’s customised forecasting comes in, writes **Colin Barkus**.

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Hawke’s Bay’s rural firefighters won’t forget the summer of 2009 in a hurry. Throughout January, desiccating northwesterly winds pushed the fire risk a little higher each day. Then, on the morning of 1 February, relative humidity plunged below 30 per cent and the temperature soared towards 30°C, arming an incendiary time bomb in the space of a few hours.

Sure enough, by late afternoon, quiet coastal settlements near Mahia Peninsula were surrounded by blazing scrub. No-one is certain of the cause, but crews soon realised they’d turned out to no ordinary wildfire. By the time the last hot spots were hosed into submission a week later, 110 residents had been displaced, 240ha of land had been charred and eight buildings – mercifully, only one of them residential – had been razed. The inferno cost around half a million dollars to quell.

**“That fire was out of control during the first six hours. A community faced significant threat.”**

Gary Lockyer, Manager of Rural Fire Operations,  
National Rural Fire Authority

“Without a doubt, we were stretched during that first day at Mahia,” says Gary Lockyer, Manager of Rural Fire Operations for the National Rural Fire Authority (NRFA). “That fire was out of control during the first six hours. A community faced significant threat.”

Part of Lockyer’s job is to calculate risk using the New Zealand Fire Danger Rating System, a model that generates fire-risk and behaviour indices. The country’s 73 regional rural fire authorities rely on that information to marshal firefighting resources, inform the public, manage restrictions and bans and issue fire permits.

It’s an awkward juggling act, but it’ll get considerably easier this July, when EcoConnect-Fire goes live. NIWA’s new online tool will give fire managers earlier warning when

environmental conditions point to another Mahia, keeping Lockyer and his regional managers posted with daily (later to become hourly) local fire-weather index forecasts up to six days ahead. They’ll be backed by 2-, 6- and 15-day weather forecasts, and a range of longer-term climate analyses of the fire season ahead.

Back in 2009, NRFA’s risk management relied on software adapted from a Canadian rating system developed in the 1960s. Combining data from around 100 NRFA-operated weather stations, the software generated a daily fire-weather status report, then despatched it to regional managers each morning. That report – combined with their assessment of local conditions – underpinned each manager’s operational decisions.

## NIWA forecasts

NIWA’s forecasting system EcoConnect is powered by sophisticated numerical forecasting models. Data from NIWA’s environmental monitoring network, and from other sources including satellites, weather balloons, ships and aircraft, feed a series of complex computer programmes processed by NIWA’s IBM p575 Power6 supercomputer in Wellington.

The programmes use elaborate mathematical formulae to mimic natural systems and processes, generating discrete forecasts for locations as close as a few kilometres apart. The resolution is improving all the time.

Individual models predict atmospheric variables; land surface attributes such as soil moisture; ocean wave height, direction and period; tides; storm-surge and river flow. Outputs from different models can be combined to produce tailored multi-hazard forecasts.

All data fed in from the monitoring network are quality controlled, and the model forecasts are continuously validated against actual data. Where real-time data are available from weather stations, EcoConnect users can compare actual values within a range of parameters, versus those forecast, just by looking at their computer screen.



In February 2009, climate forecasting systems were found wanting when scrub fires, energised by 30°C heat, and bone-dry humidity, raged across the Mahia Peninsula in Hawke Bay, catching firefighters unawares. As of July this year, EcoConnect-Fire will offer fire-weather index forecasts up to six days ahead. (PhotoNewZealand)

“While it was pretty clear the Bay was getting dry,” recalls Lockyer, “the system wasn’t capable of warning us, ahead of time, that widespread extreme conditions would develop so rapidly that day.” With more warning, fire chiefs would have seen the need for backup.

Instead, he says, “we were playing catch-up from the outset”.

## Data to the rescue

Lockyer and his regional teams tread a fine line: “The public want to be able to go about their business; to visit recreational areas ... use machinery and chainsaws in rural areas and forests. We can’t just slap prohibitions on, (because) they affect the community. But when conditions pass a trigger point, we need to apply restrictions and deploy resources proactively and confidently.

“So we need solid science to support whatever decisions we make. That’s where EcoConnect-Fire will come into its own.”

NIWA atmospheric scientist Dr Michael Uddstrom has led the development of EcoConnect services since its launch in 2007. He says EcoConnect “bridges the gap between NIWA’s

science and businesses – like NRFA – that may be affected by certain environmental conditions.

“Once we understood the NRFA’s requirements, we sat down with our research partner, Scion, to design a system that would overcome the existing limitations.”

Uddstrom and Lockyer knew the NRFA’s weather-monitoring network needed work, so they incorporated some 80 key NIWA climate stations and upgraded a number of NRFA sites as well. “That significantly increased the density of high-quality data available to produce more accurate forecasts in areas of greatest concern,” Uddstrom says (see sidebar: ‘An electronic vigil’).

NIWA’s advanced numerical modelling capability does the rest (see sidebar: NIWA forecasts). EcoConnect-Fire feeds data from the monitoring network into a sophisticated weather prediction model that generates forecasts for temperature, relative humidity, precipitation, wind speed and wind direction across a high-resolution grid of the entire country. These will inform the NRFA’s new Fire Weather System, which will issue fire-weather indices and weather forecasts – along with climate analyses – to regional fire managers.



Charlotte Hardy, Technical Research Coordinator at Kiwifruit Vine Health (KVH) Inc. When PSA arrived in 2010: "the industry went into panic. Many growers felt angry and let down". (Dave Allen)

Each forecast, and all observational data, will be stored, allowing past emergencies – and resulting operational decisions – to be reviewed. The tool will also display real-time weather data where available, giving managers an instant snapshot of current conditions in their area. Automatic SMS or email alerts will signal when conditions are forecast to pass user-defined thresholds.

"Every decision we make and resource we deploy during the fire season involves time and money," says Lockyer. "EcoConnect-Fire will allow us to act with justifiable confidence – both in advance, and when we're in the midst of a fire.

"Even if an extreme situation doesn't eventuate as forecast, we'll know we've acted with the backing of the best science available."



Scan this code with your smart phone for a video about NIWA forecasts.

### Bacterial warfare

It's weather of a very different kind that concerns Charlotte Hardy.

When a prolonged spell of damp and windy conditions sets in, an insidious little bacterium called *Pseudomonas syringae pv.actinidiae* (better known as Psa) gets moving. The virulent form of Psa – Psa-V – causes canker in kiwifruit, manifesting as leaf spot and a viscid, orangey-red discharge from the trunk or leaders of the vine. At worst, the canker can kill the vine or render it susceptible to attack from pests and other diseases.

Hardy works for Kiwifruit Vine Health (KVH) Inc., the agency charged with minimising the impact of Psa-V on the New Zealand kiwifruit industry, and helping affected growers rebuild their orchards. As Technical Research Coordinator, her focus is on the science that will help halt Psa-V's destructive advance.

Psa-V was the first major disease “that’s really threatened the industry,” says Hardy. When it was positively identified in Te Puke in 2010, “the industry went into panic. Many growers felt angry and let down”.

With estimates of potential losses reckoned at some half a billion dollars, the industry galvanised: KVH, the New Zealand Institute for Plant & Food Research Ltd and Zespri teamed up to try to curb the blight. Plant & Food scientists, who’d been running a kiwifruit breeding programme for many years, set to work modelling risk and identifying Psa-V’s favoured environmental conditions.

“A shower here or there is not the real concern,” Hardy explains. “It’s when you get leaf dampness lasting 48 hours or more that the bacteria become highly mobile. They have two flagella – little wiggly tails – so they can swim on the surface of wet plants, and enter the vascular system through small openings, like stomata on the leaves and lenticels in the stems.

“Wind is also a factor. The bacteria can get airborne, and blow from vine to vine with rain splash. So wind and prolonged dampness – they’re the conditions we’re looking out for.”

**“We call EcoConnect a ‘bridge’, because a two-way flow of information is essential.”**

NIWA atmospheric scientist Dr Michael Uddstrom

Uddstrom knew EcoConnect could help.

“We’d worked with Zespri to produce a wind plume model that estimated how Psa-V may have spread since the first positive identification in Te Puke,” he says. “Once Plant & Food had developed the risk model, we knew we could forecast that risk through EcoConnect.”

But first, weather-monitoring capability had to be stepped up: four new stations were installed for KVH, then NIWA added five more in kiwifruit country and upgraded another four.

They now feed data to EcoConnect, to generate weather forecasts out to two days ahead at high resolution, and six days at less-accurate lower resolution. Critical locations get 15-day weather outlooks. The Psa-V risk model issues a simple six-level risk index, with 1 indicating minimal risk of an infection spreading, and 6 indicating extreme risk. Growers can access their local risk index and weather forecasts at any time on KVH’s website.

“We encourage growers to undertake orchard management activities during the low risk periods,” explains Hardy. “We don’t want them working in the rain, when water on tools can spread bacteria between vines.

## An electronic vigil

NIWA runs a network of about 330 solar-powered environmental monitoring stations around the country, silently taking the environmental pulse every few seconds – day and night. Those measurements are sent by satellite or cellular phone network to the New Zealand Climate Database held in Wellington, or direct to end users via the Internet.

Electronic sensors typically monitor temperature, rainfall, relative humidity, wind speed, wind direction and barometric pressure, but selected stations also log sunshine hours, solar radiation, grass temperature, soil temperature, soil moisture, leaf wetness and snow density.

As well as receiving real-time data, the New Zealand Climate Database holds historical information dating back to the very first climate observations made in the 1850s – a trove of information used by NIWA and many other national and international organisations. It also feeds into NIWA’s numerical forecasting models.

“And when bad weather is in the forecast, we encourage them to spray in advance for protection.”

She says the service is proving increasingly popular, but there’s more to learn: “Recent indications are that heavy frost may play a role in spreading Psa-V, by breaking plant tissue. That’s not a variable in the model at the moment, but as EcoConnect can already forecast frost, the risk model could be improved as we understand more about the disease and its epidemiology.”

That sort of feedback is easily incorporated, says Uddstrom: “We call EcoConnect a ‘bridge’ because a two-way flow of information is essential. EcoConnect products will evolve as NIWA’s science advances, but also as users present us with new challenges and new information.”

EcoConnect’s forecasting capabilities go beyond weather and climate. Models predicting river flow, sea state, tides and storm-surge are incorporated, offering customised multi-hazard forecasts to anyone who might have to base management decisions on environmental conditions.

It was even used to forecast lake conditions during the World Rowing Championships held at Lake Karapiro in 2010 – and organisers praised it as the most accurate forecasting they had available anywhere in the world.

For Gary Lockyer and Charlotte Hardy, the stakes are high. They might have different ideas of what a bad forecast looks like, but they agree that environmental forecasting is critical to managing risks and seizing opportunities.

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# Down on the farm

Clean and green? Or a noxious blight on our coasts? A sustainable way to feed the world? Or just another example of fishing down the food chain? Opprobrium towards fish farms, finds **Marieke Hilhorst**, is sometimes based on perceptions either outdated or just plain wrong.

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Fish farming excites conflict whenever – wherever – it's mooted. Last year, a bid by King Salmon to add nine more salmon farms to the five it already runs in the Marlborough Sounds saw protest flotillas put to sea (in early March this year, the Environmental Protection Agency approved five of the nine applied for. The Environmental Defence Society has mounted a High Court appeal.), and science wielded like a club in trenchant submissions, both community and corporate.

Expect to see more such arguments: aquaculture is one of New Zealand's fastest-growing primary industries, and means to be a billion-dollar business by 2025. That ambition is backed by the Government's 2012 aquaculture strategy and a five-year action plan, along with revamped resource management planning to expedite new applications.

## You are what your fish eats

Some 90 per cent of fish meal protein nowadays comes from terrestrial byproducts or fish offal. Farm salmon dine on such incongruities as soya beans, canola and lupin, even feather meal. "Feathers are quite high in protein," says Andrew Forsythe, "so, instead of just chucking them away, you can turn them into quite a nice protein source." So too, chicken skin; the waste from the skinless fillets on supermarket shelves. "Nobody wants to buy a kilo of chicken skin, but it's all food grade, so that valuable protein gets used in fish pellets."

And energy efficiencies have improved, he says. "Thirty years ago, it wouldn't have been unreasonable to get three kilograms of feed making one kilogram of fish – the other two kilos went into the environment. But today, if you're an Atlantic salmon farmer and you couldn't get 1.2 kilograms of feed making one kilogram of fish flesh, you'd lose your job."

New Zealand's Chinook salmon is a different beast, but there are still opportunities to improve conversion rates. NIWA estimates a kilogram of Chinook flesh might conservatively take 1.7 kilos of feed to produce.

Presently, more than 70 per cent of marine farms are raising green-lipped mussels, but molluscs won't be delivering those billion-dollar earnings alone, says Andrew Forsythe, NIWA's Chief Scientist, Aquaculture. He points out that a hectare of mussels returns about \$50,000 – a typical one-hectare fish farm, however, could gross \$25 million.

"Growing aquaculture through mussels would need thousands of hectares of space, which would be politically and socially difficult," says Forsythe. "Far less is needed for finfish farming – the scale and the value are worlds apart."

But with the returns comes the strife. Unlike mussels, which simply eat whatever the sea wafts past them, fish need feeding. Opponents say that leaves the environment vulnerable to excess nitrogen loads, algal blooms, pollution and smothering by uneaten feed or faeces. They also question the ecological wisdom of catching wild fish simply to feed farmed fish.

That criticism, says Forsythe, is 20 years out of date: "People think it's all fish meal and oil from reduction fisheries – Peruvian anchovies dried, ground up and turned into fish pellets. That hasn't happened since the early 1990s."

Today's standard commercial salmon diet is probably 10 per cent marine protein at most, he says, and that would be sourced from certified sustainable reduction fisheries and fish waste (see sidebar: 'You are what your fish eats').

NIWA's General Manager, Strategy, Dr Bryce Cooper, says public antipathy stands in the way of the industry's aspirations. Aquaculture, he says, will always be a challenging environment: "It's a complex, dynamic, changing environment, with many influences. Aquaculture uses public space for private gain, and that coastal space is highly treasured by New Zealanders."

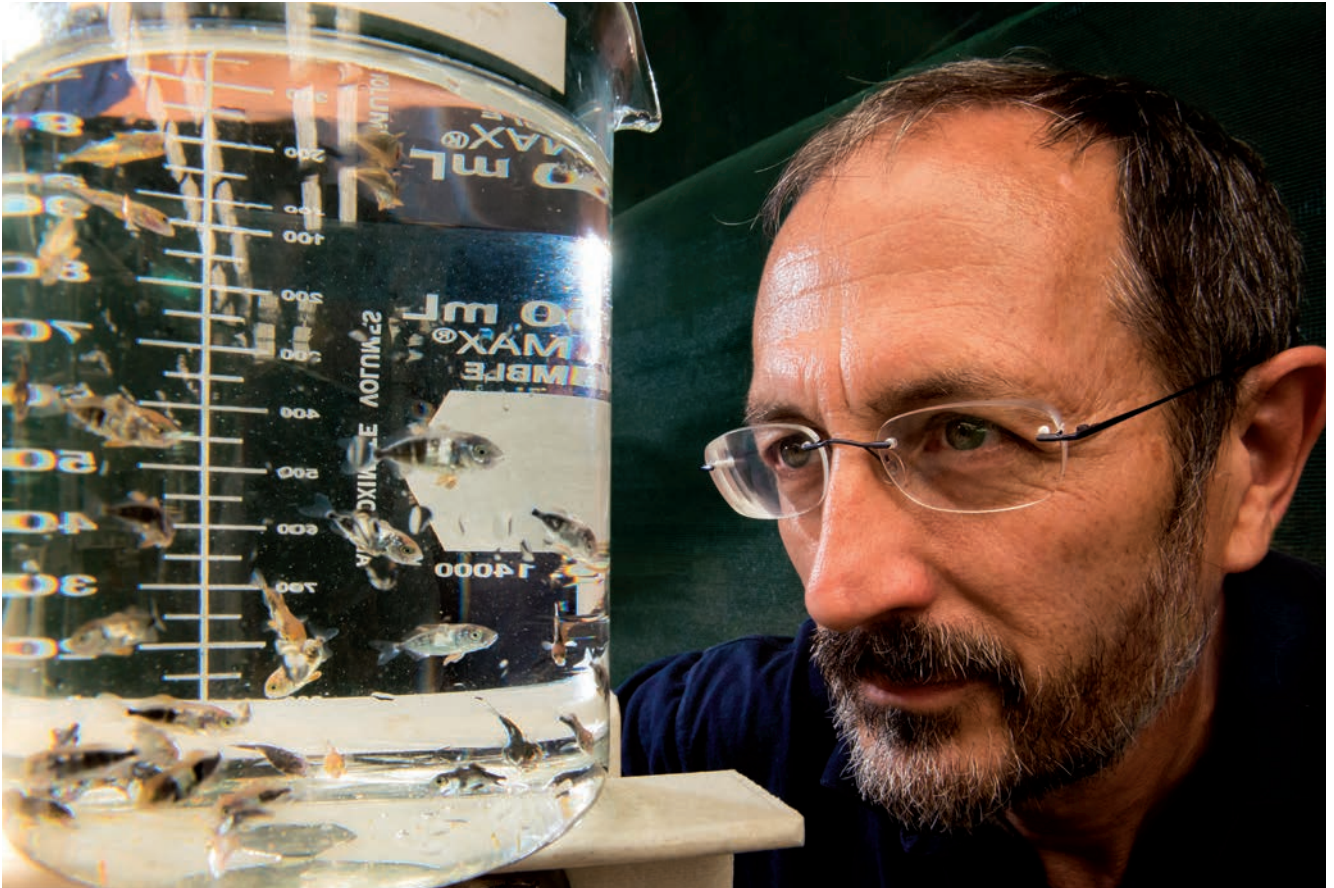
**“We need to get some balance and trust back into the debate.”**

NIWA General Manager, Strategy, Dr Bryce Cooper



Hatchery Technician Dave McQueen (L) and Chief Scientist, Aquaculture, Andrew Forsythe with farmed hāpuku at NIWA's facility at Bream Bay in Northland. Opportunities are opening up – last year, Ngāi Tahu Seafoods Ltd was granted consents for New Zealand's first commercial hāpuku farm at Beatrix Bay, in Pelorus Sound. *(Irene Van de Ven)*

## Down on the farm



Andrew Forsythe with juvenile kingfish. NIWA has identified kingfish as an ideal aquaculture species: it grows quickly – reaching a marketable size of three kilograms in 12 to 15 months. Its excellent flesh quality lends it to whole fillets, sushi and highly-valued sashimi. *[Dave Allen]*

But, he insists, many negative perceptions are based on less-than-enlightened aquaculture practices elsewhere. “There have been past examples from overseas,” says Cooper, “where extreme stocking densities, poor feed and disease management and inappropriate siting of farms have led to fish kills and significant damage to the environment. But New Zealand has learnt from those. Our record is far better than that. “We need to remove the misinformation that’s out there,” says Cooper, “and get some balance and trust back into the debate. At one extreme you have people saying any fish farming will be an environmental disaster, and on the other you have some in the industry saying there are no real problems and they should be allowed to get on with it unimpeded. Somewhere in between is the truth.”

NIWA’s job is to find it. New Zealand’s largest team of aquaculture specialists is delving into how fish farms affect the vitality of the environment, and vice versa. Two main research threads are environmental performance – how to monitor and manage the environment to minimise any adverse effects – and fish husbandry – how to grow good animals well.

To that end, NIWA’s been looking beyond the fish-farming staple of salmon, towards new species – kingfish and groper, or hāpuku. From those species, it’s selected and

bred the healthiest, fastest-growing stock. The programme also develops and tests fish diets based on nutritious, environmentally-responsible ingredients – often from unlikely sources such as leaf and twig meal from the wine industry and oil from mussel industry waste.

Forsythe says the lab work on kingfish is “done and dusted,” while hāpuku is “nearly there”. The next step is to test the species’ commercial viability in sea pens, and to ensure the broodstock can reliably produce the young for on-growing.

### Monitoring the environment

The environmental component of NIWA’s research programme is looking at what happens to fish farm waste: where it goes, what effects it has and whether those consequences are socially and ecologically acceptable. That means measuring any effects on the seabed directly under a fish farm, as well as the water column.

“We all recognise that immediately under a fish farm there will be environmental damage – changes to the flora and fauna on the bottom,” says Forsythe. “So the questions are: do they affect wild fish or the farmed stock? How far do those effects spread? Are they reversible? Are there rare species that could be lost?”



**“Our job isn't just to ... produce fish, but to produce it in a manner that will be acceptable to the consumer.”**

NIWA Chief Scientist, Aquaculture, Andrew Forsythe

When fish farms are consented, reasons Forsythe, regulators have effectively accepted measurable impacts on the benthic communities beneath them. And because fish are very sensitive to water quality, he says, it's in fish farmers' own interests to minimise those impacts because consequences like depleted oxygen and hydrogen sulphide loadings can affect the fish in the pens above.

That leaves the pelagic effect: nutrients that end up in the water column – particularly nitrogen. Cooper says the best mitigation is to limit them in the first place. If feed is well formulated, and applied in quantities just sufficient for fishes' needs, he says, only a small fraction of nitrogen enters the environment. “High conversion of feed to fish flesh is in the best interests of the farmer and the environment. It's a win-win. No-one farming fish should want to waste feed – its expensive.”

That's cold comfort to those who cite damage caused by fish farm nutrients overseas (see sidebar: 'The nuances of nitrogen'). Forsythe says there's a recognised lack of scientifically robust, publicly available information about feed conversion rates in fish farms here and overseas, as aquaculture companies keep commercially sensitive feed conversion rates close to their chests.

## Tracking the fate of nutrients

Forsythe says NIWA's research has already shown us how much a fish eats, how much it excretes, and the difference between them – in other words, how much feed gets converted into fish. NIWA's hydrodynamic models predict where the waste feed, fish faeces and nitrogen excreted through the gills will end up. “Feed has a certain settling velocity in the water, so if we say up to one per cent might not be consumed by the fish, we can plot where those uneaten chunks of food might land on the seafloor.” Faeces behave differently, but with appropriate analysis, says Forsythe, “we can plot where that falls on the bottom, and where the nitrogen discharged through the fish's gills goes. Then we can add that nitrogen into a model and say how likely it is to be converted into algae.”

Today's consumers are informed, says Forsythe. “Their interests go beyond the things that are physically embodied in the product; beyond wholesomeness and taste and appearance – those are all taken as read. They also have an expectation that the product is produced in an environmentally and socially appropriate manner. And that's where I think it actually becomes quite intriguing – our job

## The nuances of nitrogen

A major criticism of fish farming stems from the fact that captive fish must be fed. Says Ministry of Primary Industry (MPI) scientist Rich Ford: “As opposed to mussel farming, you're putting food into the system, and that food – and the faeces from that food – releases nitrogen. One of the harmful spinoffs of excess nitrogen is excess algal growth.”

At best that's merely a nuisance, but when an algal bloom turns toxic, ecosystems suffer. In extreme cases, the water is robbed of dissolved oxygen, killing fish both inside the cages and out, as has happened in shallow Scandinavian bays.

However, proving any link between nitrogen from fish farms and harmful algal blooms, says Ford, is complicated: “It's not just about the nitrogen. It's also about stratification, and wind and temperature.”

That means it's difficult to set limits on fish farms on the basis of nitrogen output alone. “We're not really sure about ... how many farms we can stick in the Hauraki Gulf, or Tasman and Golden Bay, or the Marlborough Sounds, before we get to a level where we're likely to see harmful impacts from the build-up of nitrogen.”

An MPI review of overseas literature might offer some answers. The temperate environments of Norway, Scotland, Canada or Chile may be similar enough to our own to allow for analogies between stocking densities, nitrogen outputs and harmful effects. If we're not seeing harmful effects at New Zealand's lower stocking densities, says Ford, “that may suggest what we should be thinking about it in terms of limiting growth”.

## Informing the debate

Stephanie Hopkins, an MPI Senior Aquaculture Advisor, hopes the Ministry's work will go some way to clearing the air around aquaculture, and that people on all sides will see it as neutral, up-to-date and independent. “That's why, with the literature review, we got the leading New Zealand experts from NIWA and Cawthron to work collaboratively on it.” Exhaustive peer review meant “it's been a very thorough process, and I'm hoping that this will become the 'bible' of ecological effects ... that people can really trust.”

New Zealanders value their environment, she says, but it's difficult convincing them of scientific rigour. “We have a very high bar that industry has to pass, so they do have to keep constantly proving their environmental performance. It's a tough dance.”

isn't just to figure out how to produce fish in a conventional sense, but how to produce it in a manner that will be acceptable to the consumer.”

## Down on the farm



Dr Michael Bruce, Assistant Regional Manager, Bream Bay, with juvenile hāpuku. With lab work on hāpuku almost complete, NIWA will next test the fish's commercial viability in sea pens. *(Dave Allen)*

Negative perceptions can sometimes resist all manner of evidence to the contrary. What's more, the protagonists view each other's information with deep distrust. Says NIWA Assistant Regional Manager, Michael Bruce, some people are blind to the many other sources of nutrients – farms, forests, towns, sewage treatment plants, industry – yet are fixated on fish farming. Ideally, the ecological effects of aquaculture would be considered alongside all those other activities, but too often that holistic view is lacking. "Above all, our position at NIWA is to provide good scientific information," says Bruce, "upon which sensible and realistic decisions can be made."

### Learning by doing

Given the controversy around finfish farms, Dr Bryce Cooper says 'learning by doing' is entirely appropriate. Waikato Regional Council applied adaptive management to a staged expansion of mussel farming in the Firth of Thames, and may follow the same approach in a designated finfish zone west of Coromandel. While the designation allows for 8000 tonnes of fish a year, the first stage, if consented, would likely provide for around half that, with a requirement for environmental monitoring.

"So, you introduce some nets at lower production, then see how it works, and whether everything goes according to our modelling and best estimates. If it does, everyone is more comfortable with expansion." One key assumption, Cooper says, is the feed conversion ratio. If Firth finfish farms get the green light, monitoring would deliver actual feed conversion ratios, rather than NIWA's estimates, improving the accuracy of modelled effects. "That would show us whether it's financially viable. Even if it is, the environmental consequences may mean you could possibly only go up to 5000 tonnes per annum, instead of 8000. Or maybe 8000 tonnes is easily absorbed."

### Minding the gaps

So when the Ministry for Primary Industries (MPI) set out to gather the best available information about the ecology of aquaculture in New Zealand, NIWA was on their call list.

Stephanie Hopkins, an MPI Senior Aquaculture Advisor, is overseeing the project. It's intended to help local government and industry, but she hopes it will be used by anyone with an interest in fish farming. The Internet is brimming with overseas content, but, says Hopkins, much of it is either dubious or has no relevance here. "We identified a lack of quality information, and quite a bit of misinformation, around the ecological effects of different forms of aquaculture in New Zealand."

After gleaning everything we know about the ecology of marine farming in New Zealand, Hopkins' project will sift that information, looking for the biggest risks to be managed. Then the findings will be presented in a user-friendly summary that presents an accurate, simple picture of likely issues and effects at future New Zealand aquaculture sites.

**"We identified a lack of quality information ... around the ecological effects of aquaculture."**

MPI Senior Aquaculture Advisor Stephanie Hopkins

It's hoped the information package, due out in mid-2013, will foster a more informed and balanced debate thanks to input, not just from NIWA, but from other scientists, councils and environmental NGOs. It will address the raft of concerns that surface whenever aquaculture is on the table: pelagic effects; benthic effects; impacts on marine mammals, wild fish and seabirds; biosecurity threats; escapees; genetic modification; additives and impacts on water flows.



Workers pack salmon at New Zealand King Salmon Company Ltd's Nelson processing plant. Backed by Government measures, the aquaculture industry seeks billion-dollar-a-year revenues by 2025. (Getty Images)

Hopkins says the review covered not only existing species – salmon, mussels and oysters – but those likely to be commercialised in the next five years or so, such as kingfish, hāpuku, undaria and sea cucumbers.

"This latest effort builds on earlier work, and identifies some management options and knowledge gaps within each topic," Hopkins says. "It points us to what we need to look at now with our research."

MPI scientist Rich Ford says the project's risk analysis will prove vital to informed debate. Technical information alone would easily mislead discussion, he says, because not all issues and risks are equal – hydrodynamic effects, for example, get less attention than biosecurity, which is a top concern. "So we've done a lot of work on getting better context and risk analysis, and it's very useful in identifying where we believe most of our effort should be," says Ford.

The literature review made it clear that nitrogen loading is a critical consideration in fish farm applications, determining just where they might be placed and how many should be permitted.

Ford says another useful exercise would be to create good biosecurity management plans and guidance on best practice for adaptive management (see sidebar: 'Learning by doing').

He also wants coasts surveyed for any ecologically sensitive areas that should be considered no-go zones for aquaculture. "We know there are benthic impacts from aquaculture, particularly fish farming, so if there are areas we think shouldn't be impacted at all ... we don't want to put (farms) on top of them."

Biosecurity is trickier: "The best we can do is manage the risks – we'll never eliminate them because there are things like larvae which can be released. And aquaculture is only one small part of that picture; it's (also) about port activities and recreational boaters."


We know plenty about farm-level impacts, says Hopkins, but we don't know enough about the cumulative impacts of aquaculture at a broader, ecosystem level. "That's hard to nail down, because it requires a more collaborative approach – it's not just about aquaculture. You're looking at the assimilation capacity, the carrying capacity, of the environment on a bay-wide level."

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Scan this code with your smart phone for a video on aquaculture at Bream Bay.



# Clouds



**Convective cauldron:**

Circulations in this developing cumuliform ('heaped') cloud twist and boil in a complex convective dance. If menacing clouds like this develop, it's likely that heavy – and possibly thundery – downpours are on the way. (*Alan Blacklock*)



Altostratus glows in the dying rays of the day, against a backdrop of cirrus. Altostratus forms waves or rounded patches between 2000m and 6000m altitude. Cirrus, made of ice crystals, usually forms at around 5000m or higher in New Zealand. (Alan Blacklock)



**Refracted glory:** When sunlight passes through the ice crystals forming these cirrus clouds in the high, cold atmosphere, it can refract into a range of colourful optical phenomena, including haloes (pictured), 'sun dogs' and arcs. The cirrus family of clouds typically forms at about nine or ten kilometres above New Zealand. (Alan Blacklock)

## Clouds

**Catching an atmospheric wave:** *Altostratus lenticularis* ('lens-shaped') clouds form when moist winds are disrupted by a mountain range. The airflow forms a series of standing waves just downwind of the mountains. Cloud develops in the rising air on the upwind side of the wave before evaporating in the descending downwind air. Canterbury's 'Nor'west Arch' is a classic example. *(Alan Blacklock)*





**Harbingers of change:** High-altitude cirrus streaks, or 'mares' tails', steadily invading the sky often signal an end to settled weather. They indicate an increase in moisture at the highest levels of the troposphere (about nine or ten kilometres up) – a sign that a front is approaching. *(Alan Blacklock)*



**Sunset rainmaker:** When a cold or warm front nears, moisture in the middle levels of the troposphere steadily increases, and the sky begins to choke with layers of altostratus and altocumulus cloud. If the clouds continue to thicken and lower, rain or snow will eventually set in. *(Alan Blacklock)*

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# A life aquatic

For river specialist John Quinn, science, society and songs are an easy confluence, he tells **Dave Hansford**.

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John Quinn swam his first five strokes in the Tukituki when he was five years old. Today, 50 years later, he's back, but this time he's here as a NIWA Principal Scientist, striving to fathom its watery workings. "Rivers take you along with them," he says. "Learning to understand their processes better is a lot of fun, especially in places you're attached to."

His return to the Tukituki, he says, "is a really special circle of life". He was born not far from here: in Waipukurau, the son of a rural GP, and went to Central Hawkes Bay College. "For a while, it looked like I was going to be a country doctor myself," but Jacques Cousteau intervened. "I was one of that generation of kids captured by what he showed us about the undersea world."



NIWA Principal Scientist John Quinn tests stream water near Pirongia. "I love rivers. I get a huge kick out of being on the water, and from understanding how they work." (Geoff Osborne)

Quinn took up diving and, during his time at Otago University, he thought about a career in the sea – but somehow, he always ended up back on a riverbank somewhere: they became a spiritual and cerebral touchstone, and his place of work. "It seemed to me that fresh water offered more opportunities to interact with people, and I'm fascinated by the land/water interaction – I've always been interested in trying to resolve the problems of land use and fresh water." During the bullish days of Think Big, Quinn thought small – sometimes microbial. "Unlike others, my interest was in not damming rivers, but in those days a career as an aquatic ecologist was unheard of."

In the early 1980s, he did a PhD at Massey University, studying the waterway that was to become stigmatised as one of the most polluted: the Manawatu River. In those days, he recalls, towns simply piped primary treated sewage (at best), dairy factory and meat works effluent into the river, which laboured brown and sluggish through vast tracts of "sewage fungus" – a slimy medley of bacteria, fungi and protozoa. Fish routinely died from oxygen depletion.

For the last 28 years, Quinn has been based at NIWA's Hamilton office and, over that time, he's seen "a material change" in our attitudes to water: "Farmers, especially, are much more aware of the impact of their practices. There's lots more riparian management, and many fewer dairy shed effluent discharges to streams. NIWA's played a role in that: our information gives people confidence to change the way they do things, which is an important part of what scientists do."

Also, he says, Māori have brought a vital new dimension to the national conversation. "Māori can talk about their feelings around water in ways we Pakeha struggle with: 'If the river is healthy, the people are healthy', 'I am the river: the river is me' – that sort of thing." That cultural imperative isn't new, he points out, "it's just that Māori have more opportunities to express it these days, and it's a very powerful way to do things positively. If you stop to think about it, most of the major (freshwater) restoration projects have been driven by the treaty settlement process".





To solve our freshwater problems, says Quinn, "you have to apply as much knowledge as you can, and take people along on a journey." (Geoff Osborne)

A feeling of being at the epicentre of perhaps our most momentous resource issue keeps Quinn energised. "Water is fundamental to life, so you feel like you're working on one of the most important solutions of all. It seems like it's our time at the moment, and that's exciting – it's a sweet spot to be."

Like all social dilemmas, freshwater issues come in myriad shades of grey: "The issues are very complex, so the answers aren't simple." But there is, says Quinn, a bottom line that shouldn't be negotiable: "People need to be able to make a living, but, in the end, it's a sustainability argument. Future generations are entitled to that very same right, and we can't stuff that up for them."

Reconciling farming and fresh water, he says, will be crucial. His contribution, he hopes, will be "to better predict how habitat restoration and nutrient management protect or restore the values people have for rivers," which will help us better understand the many ways our actions dictate the fate of fresh waters. He also wants to help develop "water-sensitive" farm practice guidelines "appropriate for different settings around New Zealand, that will match sustainable farming with healthy rivers, lakes and estuaries".

He's unfazed by the size of the challenge: "Yes, there's a juggernaut of development, and getting behavioural change is tricky. But there's also a real willingness to get this sorted, and a community coherence in New Zealand that means we can do it. The scientific community is small and close-knit, which fosters collaboration. There's a big crossover in understanding, so people can blend their skills and take these things on together."

Every river is different, says Quinn – some even transform reach by reach. "They each have their own distinctive character, their own combination of scent, sound, species and form that combine with the surroundings – and cultural history – to give a unique feeling. The more you get to know a river, the more that individuality emerges."

For a small place, he says, New Zealand has an amazing diversity of river types. "Within 100 kilometres of Hamilton, we have the very stable-flow, spring-fed rivers with U-shaped channels like the upper Waihou, and on the Coromandel, rivers like the Oponoi with a highly flashy flow with wide channels and strong riffle-pool sequences. Elsewhere, we have everything in between – it's a researcher's paradise. I think that's a big part of why I never left New Zealand."

When he's not wading about in rivers, Quinn likes to play guitar. "I've always liked having some artistic stuff in my life, and I think it helps my scientific creativity too. I did painting classes for ten years, but I was always more interested in music. I'm in a folksy-poppy band with some other scientists. I've dabbled in songwriting, so we do a mix of covers and originals."

He sometimes kicks off a science presentation with ballads like 'I'm a river for you' and 'Migrating salmon blues'. "Logic and Powerpoint can go so far, but I've found a bit of melody and quirky humour can help win over a tough audience."

## Q&A

# Is New Zealand really clean and green?

It's true that, by some indicators, New Zealand enjoys better environmental health than many other developed nations. Some of that performance is down to pioneering regulation, such as the fisheries Quota Management System and the Resource Management Act. However, much of it might also be described as a happy accident: New Zealand is, by global standards, sparsely populated, with an average of just 16.59 people per square kilometre in 2010 – less than half the OECD average and higher than only Australia, Iceland, Canada and Norway.

That means the human footprint is comparatively small here. That said, it's sobering just how much impact humans have had on New Zealand's environment, given that they've only been here since the 13th century.

### What do you think?

Every two years, Lincoln University researchers ask New Zealanders how they feel about the state of their country's environment. In 2010, respondents reinforced findings from earlier surveys, considering it to be in good health and well managed. They felt that air quality, along with coastal waters and beaches, were the best managed environmental assets.

They considered rivers and lakes, marine fisheries and wetlands the worst managed, but still rated them highly compared with other countries. They felt that most assets were being managed well – a significant jump from previous surveys – but still felt that groundwater, rivers and lakes, and marine fisheries were not managed well enough. Farm effluent and runoff continued to be perceived as the least well managed.

Water pollution and associated water issues were considered the most important environmental issue we face. A third of respondents felt that, globally, climate change is the most important environmental issue.

### How do we rate globally?

Yale University's annual Environmental Performance Index ranks countries according to indicators such as air and water quality, land use and resource management. In 2012, New Zealand came in 14th out of 132 countries, sandwiched between Iceland and Albania. In 2006, we were number one. The index also measures environmental trends by tracking progress over the past decade. Here, New Zealand managed just 50th, between Armenia and Slovenia.



Plastic fishing debris lines a Southland beach. Critics accuse New Zealand of running an environmental double-standard. (Hedgehog House)

A 2010 study by Australian, US and Singaporean researchers – *Evaluating the Relative Environmental Impact of Countries* – compiled such indicators as habitat conversion, marine capture, carbon emissions and fertiliser use, and placed New Zealand in the 20 worst proportional environmental performers, shoulder to shoulder with China, Indonesia and Bangladesh. Overall, we scored 47th worst in the world. The study's methodology, however, came under critical review from some quarters.

### Where do we need to improve?

#### Biodiversity

New Zealand's record on biodiversity is one of the worst anywhere. We have one of the highest extinction rates, and we currently have more threatened species than any other nation on Earth. A 2007 biodiversity assessment found 2788 native species at risk. The International Union for the Conservation of Nature rates 37 per cent of our 215 native birds as threatened. Thirty-four per cent (797) of our plants are considered to be under some level of threat. Sixty-eight per cent of our freshwater fish are threatened (four of the five species in your whitebait fritter are on the endangered list), and the freshwater crayfish and mussel are also in danger.

#### Water quality

Last October, the Ministry for the Environment (MfE) reported that New Zealand freshwater quality was either 'poor' or 'very poor' at just over half of 210 monitored river swimming sites around the country.

A 2010 report from MfE assessed water quality trends in 112 New Zealand lakes between 2005 and 2009. Over the study period, 12 per cent of lakes assessed had improved, while 28 per cent had worsened. It then extrapolated those findings across 4000 lakes smaller than a hectare, and found that 43 per cent were likely to have very good or excellent water quality – meaning very low nutrient levels – while 32 per cent were likely to have poor or very poor (nutrient-enriched) water quality.

Those assessed lakes surrounded by farmland fared worst: 44 per cent were eutrophic (meaning they carried excessive nutrient loads) or worse. When extrapolated, the study concluded that out of 3820 New Zealand lakes, more than a third would be eutrophic or worse. In 2010, NIWA reported that water quality in our major rivers had declined between 1989 and 2007. Over that period, nitrogen and phosphorus loadings had increased greatly at many sites. Nitrogen had increased by about 1.4 percent per annum over most of the country, and no sites recorded a drop. Upward trends for temperature, nitrogen and phosphorus had accelerated, commensurate with a surge in nitrogen fertiliser use – which has doubled since the mid-1990s – and dairy cow numbers. In the early 1990s, there were around 2.7 million dairy cows in New Zealand; by 2012 there were 4.6 million.

In 2007, New Zealanders were the second-most prolific users of water in the OECD. The Manapouri hydro station uses 41 per cent of the national weekly take.

### Air quality

Last year's *Health and Air Pollution in New Zealand* study found that 16 monitored airsheds met the National Environmental Standard for PM<sup>10</sup> – tiny airborne particles. Of the remaining 27 airsheds monitored in 2011 – all required to meet the same PM<sup>10</sup> standard by either 2016 or 2020 – 22 airsheds recorded pollution levels that would see them fail that standard. Nearly 20 per cent of New Zealanders live in those 22 airsheds. The study estimated that poor air quality causes around 1170 premature deaths in New Zealand each year. By contrast, 307 people died on New Zealand roads last year.

### Car ownership

In 2006, New Zealanders owned more cars per head than almost anybody else in the OECD (with 70 cars for every 100 New Zealanders), topped only by Portugal (78) and the United States (76).

### Greenhouse gas emissions

In 2005, out of 27 OECD countries, New Zealand had the fifth-highest greenhouse gas emissions per person, and we ranked 13th in the world. This is largely down to the fact that agriculture is responsible for practically half of all our emissions – mostly methane and nitrous oxide, which have a very strong, if relatively short-lived, warming effect. The Kyoto Protocol set us the task of reducing our greenhouse gas emissions to 10 per cent below 1990 levels. In 2010, New Zealand's total greenhouse gas emissions were 71.7 million tonnes of carbon dioxide equivalent – 9.8 per cent higher than 1990 levels. The Government has pulled out of the Protocol, but if we were to try to meet our original 2020 obligations, every man, woman and child in New Zealand would now have to reduce their greenhouse gas emissions by 35 per cent.

## NIWA enhancing the value of New Zealand's natural resources

NIWA (the National Institute of Water & Atmospheric Research) was established as a Crown Research Institute in 1992. It operates as a stand-alone company with its own Board of Directors, and is wholly owned by the New Zealand Government.

NIWA's expertise is in:

- Aquaculture
- Atmosphere
- Biodiversity and biosecurity
- Climate
- Coasts
- Renewable energy
- Fisheries
- Freshwater
- Māori development
- Natural hazards
- Environmental information
- Oceans
- Pacific rim

NIWA employs approximately 610 scientists, technicians and support staff. Our people are our greatest asset.

NIWA also owns and operates nationally significant scientific infrastructure, including a fleet of research vessels, a high-performance computing facility and unique environmental monitoring networks, databases and collections.

*Back cover:*

A seahorse (*Hippocampus abdominalis*) off Wellington's south coast. Seahorses are very common around New Zealand shores, but their cryptic camouflage and habit of freezing motionless makes them difficult to spot. [Dave Hansford]



