Water & Atmosphere

November 2014

The water issue

Science and the debate over stream water quality

Waste not:
Cleaning up farm water

Stream of dreams:
Restoring native species to waterways

Poster inside: *'Life beneath the surface of streams'*

New research:
Insects reveal water quality

November 2014

Cover:

This issue takes a special look at the contentious issue of the health of our waterways. (*Dave Allen*)

Water & Atmosphere is published by the National Institute of Water & Atmospheric Research (NIWA).
It is available online at www.niwa.co.nz/pubs/wa

Enquiries to:

The Editor
Water & Atmosphere
NIWA
Private Bag 14901
Kilbirnie
Wellington 6241
New Zealand

email: wa-editor@niwa.co.nz

ISSN 1172-1014

Water & Atmosphere team:

Editor: Mark Blackham

Production: NIWA Communications and Marketing Team

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enhancing the benefits of
New Zealand's natural resources

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New guide to extraordinary marine invertebrates

Where in New Zealand might you find a strawberry sea cucumber?

The answer will be found in New Zealand's electronic identification guides for marine invertebrates, produced to help amateur marine biologists at the beach and in the water.

The third in the series, launched this month, identifies the category of sea life known as echinoderms – which includes sea stars, sea urchins and sea cucumbers.

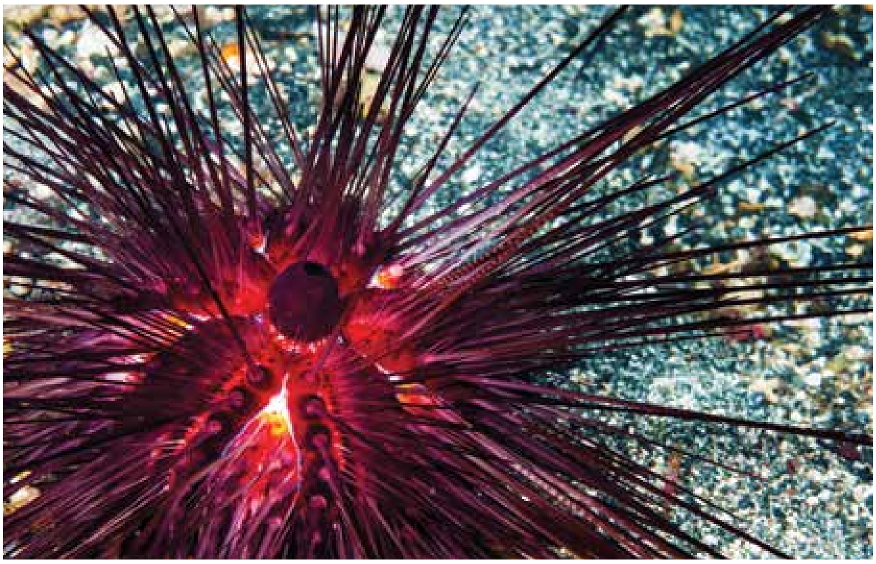
'Extraordinary Echinoderms' is a fully illustrated working identification e-guide to the sea stars, brittle stars, sea cucumbers, sea urchins and feather stars of New Zealand.

These spiny-skinned invertebrates are found everywhere, from the intertidal zone all the way down to the deep ocean trenches and abyssal plains. So you have a good chance of spotting them when you are out and about doing your own investigations of our beautiful coast and oceans.

The e-guide starts with a simple introduction to the different echinoderm groups, followed by a morphology (shape) index, species index, detailed individual species pages and, finally, icon explanations and a glossary of terms. The species pages have high quality images of the animals and describe features that enable you to differentiate the species from each other. As far as possible, NIWA has used characteristics that can be seen by eye or magnifying glass, and language that is non-technical.

This is just one of the e-guides on New Zealand marine invertebrates that NIWA's Coasts and Oceans group is presently developing. 'Awesome Ascidians' is already available – the first in a series of e-guides on sea squirts of New Zealand.

The guides are designed for New Zealanders who live near the sea, dive and snorkel, explore our coasts, make a living from it, and for those who educate and are charged with kaitiakitanga, conservation and management of our marine realm.



Diadema palmeri, a sea urchin fom the Poor Knights Islands. (*Crispin Middleton*)

NIWA says it will be updating the e-guides online as new species are discovered and described.

You can download 'Extraordinary Echinoderms' and 'Awesome Ascidians' for free here: www.niwa.co.nz/coasts-and-oceans/marine-identification-guides-and-fact-sheets.

So now you can get a name and information about the 11-armed spiny sea star you see near a wharf (*Coscinasterias muricata*) or the stripe-armed, star-shaped critter under the rock you turned over at the beach (*Ophionereis fasciata*).

By the way, those strawberry sea cumbers (*Squamocnus brevidentis*) are found on rock walls and platforms under the sea in Fiordland.

Pentagonaster pulchellus, from Wellington. An intertidal to subtidal species, found around New Zealand. (*Rachel Boschen*)

The waves go deep

NIWA's Sally Gray (left) and Tony Bromley prepare to release a weather balloon. (*Dave Allen*)

If you live in the South Island and looked into the sky over June and July, you may have noticed the largest experiment held in New Zealand in the past 20 years.

Two research aircraft, a Gulfstream V jet from the United States and a Falcon 20 jet from Germany, flew up to 20 flights each over the six-week duration of the experiment. These high tech, superfast planes were set up as 'flying laboratories', full of specialised scientific equipment.

Called Deepwave (Deep Propagating Gravity Wave Experiment), the international experiment studied the atmosphere over the Southern Alps.

Deepwave involved scientists working from six sites across the South Island and in Wellington. It was led by the National Center for Atmospheric Research in the United States and the German Aerospace Centre, and funded by the United States National Science Foundation.

Its aim was to better understand how gravity waves evolve and how they can be better predicted. The information gathered will ultimately lead to more accurate weather forecasts.

Gravity waves, which form when strong winds strike a large obstacle such as a mountain range, have not been well studied. They are difficult to see at high altitudes and need special equipment to track and analyse them. But climate scientists consider them extremely important because they carry and transfer momentum and energy in the atmosphere, and so affect the weather and climate.

The Southern Alps offer a unique opportunity for this type of atmospheric research because of the reliability of the westerly wind circulation patterns in the area.

NIWA scientists based in Christchurch forecast the best times for the aircraft to fly, to make the most of the atmospheric conditions.

About 100 people, including 15 NIWA staff, were involved in the experiments, with scientists based in the South Island at Hokitika, Birdlings Flat (near Christchurch), Mt John (Lake Tekapo), Lauder (Central Otago), Invercargill and Haast.

They took a range of measurements that will be integrated with aircraft and satellite data to provide a complete vertical profile of the atmosphere from the ground up to about 100km. A full meteorological station was also set up at Hokitika Airport.

NIWA's Tony Bromley and Sally Gray were at Hannah's Clearing, about 20km south of Haast, releasing weather balloons that fly up to 30km high to coincide with the research flights. Instruments called radiosondes attached to the balloons transmitted a range of atmospheric measurements that were then relayed to HQ in Christchurch.

At HQ, NIWA meteorologist Richard Turner led a forecasting team, providing an overview of how the gravity waves are being generated, and what's generating them.

"In the first instance, we are very interested in how our model predictions stack up against the data and how well we've done in terms of predicting the conditions.

"Ultimately this will lead to improved understanding of the role of gravity waves in distributing momentum and energy in the atmosphere, which should lead to more accurate forecast models."

In brief

Tangaroa in dry dock at Devonport Naval Base. (*Dave Allen*)

A seahorse found off Northland's east coast awaits identification. (*Crispin Middleton*)

Tangaroa gets new tech

NIWA's flagship research vessel *Tangaroa* has had a new hi-tech $1 million sub-bottom profiler fitted to its hull.

Tangaroa spent several weeks in dry dock at Auckland's Devonport Naval Base during June and July. It undergoes a full inspection in dry dock about once every three years. The opportunity is taken to carry out repairs, repaint the hull and replace equipment or fittings.

The new sub-bottom profiler is used to identify and characterise marine sediment layers up to 200m below the seabed. Data generated by the new system, known as the TOPAS PS 18, can be used to study active faults, substrates, hard-ground and canyons.

Other work included engineering deck space to enable the launch and recovery of underwater vehicles for closer inspection and sampling of the seabed. The onboard chiller for stores was upgraded, a new scientific freezer installed, and ventilation was overhauled.

After trialling the new equipment on the return trip from Auckland to Wellington, *Tangaroa* then left for the Tasman Sea on a voyage chartered by GNS Science.

Tangaroa is the only ice-strengthened research vessel in New Zealand, and is the base for NIWA's major offshore operations, covering vast tracts of ocean from the Kermadecs in the north to Antarctica in the south. It was built in Norway in 1991 and spends an average of 300 days a year at sea.

See the technology being installed in this month's gallery on page 32.

Rare fish and habitats found

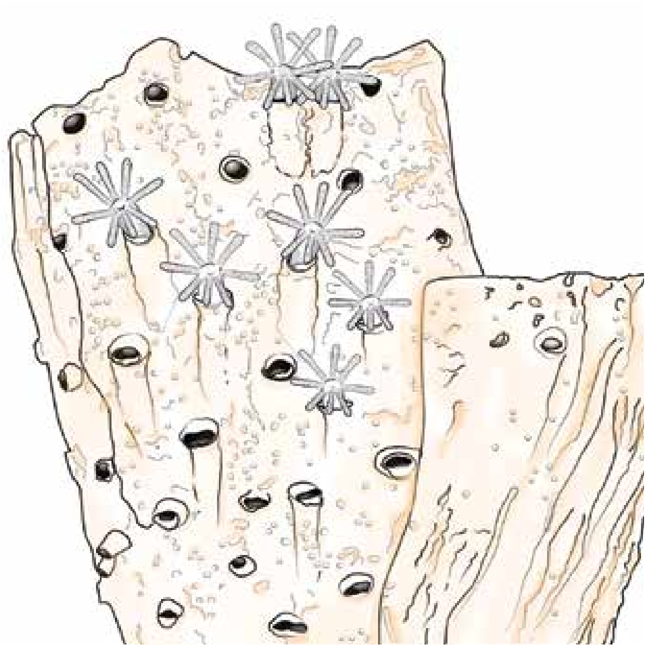
NIWA scientists have discovered rare fish species in shallow water coastal habitats off the east coast of Northland, including a frogfish and possibly a new species of seahorse. They also found a rich diversity of macro-algal meadows, shellfish beds and sponges.

NIWA marine ecologist Dr Meredith Lowe says the information fills gaps in scientific knowledge about biogenic habitats – 'living' habitats created by plants and animals. The survey results are helping to build a national fish-habitat classification and inventory of New Zealand's coastal and shelf zone.

"Our knowledge of what lives in the coastal zone is scant. For instance, while we believe estuaries provide critical nurseries for a range of fish species, we cannot prove that until we know their relative contributions compared to possible alternative coastal nursery areas. During our survey, 'new' snapper nurseries and associated habitats were found in Te Rawhiti Strait, Bay of Islands and inner Doubtless Bay."

The survey used a small beam trawl research net with Go-Pro cameras attached, developed from work by NIWA technician Crispin Middleton. The video revealed a juvenile white shark bumping into the camera bait pot as it swam past, and a group of dolphins talking to each other as they checked out the sampling net down on the seafloor undertow.

The seahorse is undergoing scientific identification to assess whether it is a new species. Dr Lowe says that it will be some time before scientists can confirm its identity and how rare it is worldwide. It is about 3cm long and predominantly brown.



Artist's impression of living Protulophila polyps in a worm tube. (*Dennis Gordon and Erika MacKay*)

'Fossil' discovered living in New Zealand

A marine animal thought to have been extinct for four million years has been found living near Picton. Called Protulophila, the animal forms a network of tiny holes in the chalky tubes of marine worms called serpulids.

Fossil examples were discovered this year by a group of scientists including NIWA marine biologist Dr Dennis Gordon, Dr Paul Taylor of London's Natural History Museum and Dr Lee Hsiang Liow, Dr Kjetil Voje and Dr Seabourne Rust of the University of Oslo. The scientists had been conducting fieldwork at Whanganui where they found Protulophila in a tubeworm from rocks less than a million years old.

This discovery alerted them to the possibility that the animal, previously unknown outside of Europe and the Middle East, might still be alive in New Zealand despite being thought to have been extinct for four million years.

Scientists examined tubeworms stored in NIWA's Wellington-based Invertebrate Collection and discovered examples of preserved Protulophila that had previously been overlooked. The tubeworms had been collected in 2008 in 20 metres of water near Picton.

Finding tiny polyps with tentacles protruding from the network of holes confirmed what palaeontologists had suspected: that Protulophila is a colonial hydroid related to corals and sea anemones. It is best seen through a microscope.

The next step will be to collect fresh samples from Queen Charlotte Sound for gene sequencing.

Aurora Australis sailing through Antarctic sea ice shortly after deploying NIWA's waves-in-ice buoys. (*Alison Kohout*)

Making waves about sea ice

NIWA scientists have made a breakthrough in understanding one of the key processes driving changes in sea ice.

Drs Alison Kohout, Mike Williams and Sam Dean, along with Australian-based scientist Dr Mike Meylan, have been researching how the Southern Ocean's biggest waves affect Antarctic sea ice.

The findings, published in the May edition of *Nature*, show that large waves in the Southern Ocean – those bigger than 3m – are able to break sea ice over greater distances than previously believed.

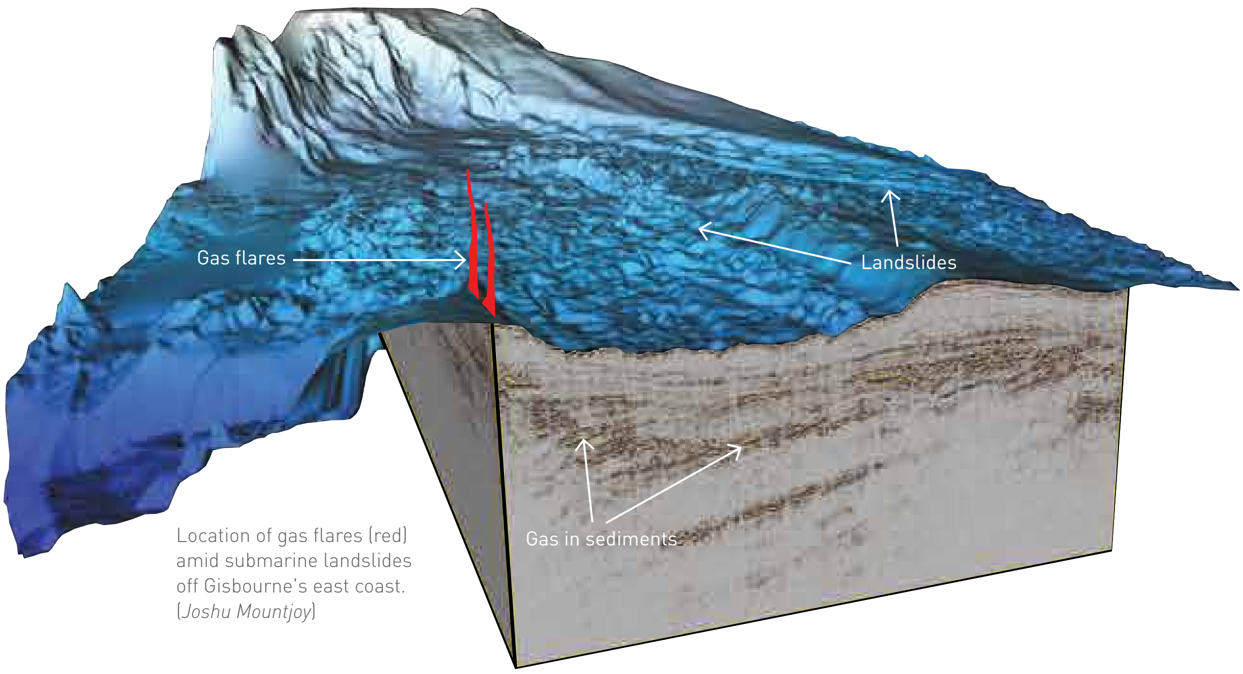
Dr Kohout said the research aims to explain how Antarctic sea ice has been able to increase in some areas yet decrease in others. This is in contrast to the predictions from climate change models that Antarctic sea ice should have already begun retreating. It potentially explains the accelerating loss of Arctic sea ice.

"Our work has suggested that the role of large waves is more relevant that previously assumed," she said.

"In the Arctic, there is a lot of evidence of sea ice retreat, yet scientists have been unable to reproduce the speed of sea ice retreat in their modelling. This suggests something is missing from the models."

Sea ice plays a critical role in moderating the global climate system. The state of the sea ice is an indicator of how climate is changing around the poles.

In brief



Location of gas flares (red) amid submarine landslides off Gisbourne's east coast. (*Joshu Mountjoy*)

Gas off the east coast

A joint New Zealand-German research team has discovered a huge network of frozen methane and methane gas in sediments and in the ocean near the North Island's east coast.

The aim of the project was to find out what causes movement in the area's large active marine landslides up to 15km long and 100m thick.

Using 3D and 2D seismic and echo-sounder technology, the team discovered direct evidence of widespread gas in the sediment and ocean, and indications of large areas of methane hydrate, ice-like frozen methane, below the seafloor.

The team identified 99 gas flares in a 50km^2 area, venting from the seabed in columns up to 250m high. This is believed to be the densest concentration of seafloor gas vents known in New Zealand. The 3D seismic data show that landslides and faults allow the gas built up in the sediment to be released into the ocean.

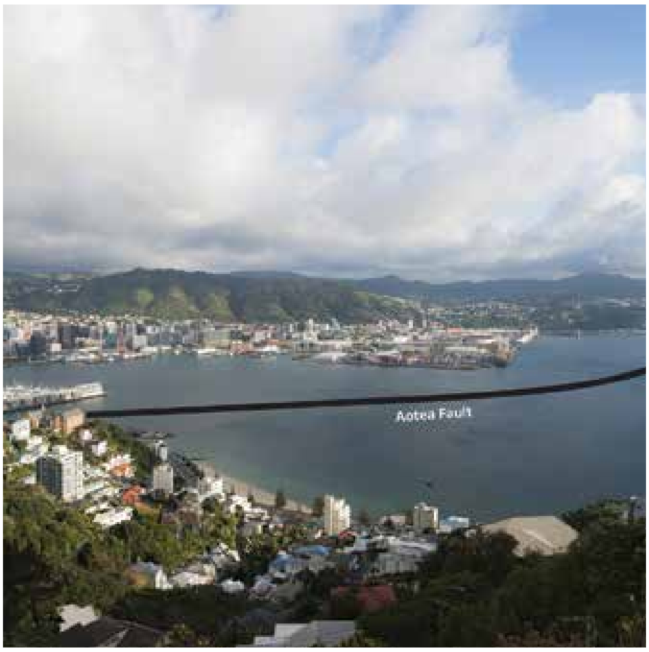
This discovery reveals a hydrate and gas field very different from others known in New Zealand.

"What we have found is high density methane flares in very shallow water, as well as gas building up beneath a large landslide and being released along the landslide margins," NIWA marine geologist Dr Joshu Mountjoy said.

In a recently submitted scientific paper, the team proposed that these landslides might be the seafloor equivalent of glaciers, but with frozen methane instead of ice, or that pressurised gas is causing them to progressively move downslope. The results from this expedition indicate that both of these are possibilities and provide data to carefully test these hypotheses.

The work forms part of a larger project focused on understanding the dynamic interaction of gas hydrates and slow moving active landslides. Dubbed SCHLIP (Submarine Clathrate Hydrate Landslide Imaging Project), ongoing investigations in the project over the next decade will include drilling into the landslides in 2016. This first part of the project is a collaboration between NIWA, GNS Science and the University of Auckland from New Zealand, GEOMAR and the University of Kiel from Germany, Oregon State University from the United States, and the University of Malta.

"The initial findings are very important," says Dr Mountjoy. "Methane is a very effective greenhouse gas and seabed methane release has the potential to dramatically alter the earth's climate. As ocean temperatures change, the methane hydrate system has the potential to become unstable."



The recently discovered Aotea Fault. (*NIWA*)

New faultline for Capital City

The discovery of a new active fault line traversing Wellington harbour is actually good news for the city according to its discoverers.

The two kilometre 'Aotea Fault' runs northeast through Lambton Harbour. It was discovered by NIWA's marine geologists Drs Philip Barnes, Scott Nodder and Susi Woelz.

The scientists said the discovery does not increase the overall risk of an earthquake in the capital city, and gives them the opportunity to learn more about what is going on underfoot.

"Knowing more about Wellington's geological faults does have long-term benefits for the Wellington region. It allows us to be better prepared for the event of a quake, and the discovery can also be incorporated into land use and engineering strategies to minimise risk", said Dr Nodder.

The team of geologists believe the fault line is capable of earthquakes around M6.3 to M7.1, which would be considered moderate to large. The research also suggests that there had been at least two significant earthquakes on the fault in the last 10,000 years.

The discovery was part of the 'It's Our Fault' research programme led by GNS Science.


Auckland experienced its warmest June ever. (*Dave Allen*)

Warmest June

NIWA's June climate summary contained some fascinating statistics, with just about all of New Zealand recording temperatures above normal (by 0.5°C–1.2°C) or well above normal range (over 1.2°C).

It was the warmest June since records began for New Zealand's Seven Station Series in 1909, which monitors Auckland, Masterton, Wellington, Hokitika, Nelson, Lincoln and Dunedin.

The exceptionally warm month meant the average nationwide temperature was 10.3°C, 1.9°C above the 1971–2000 June average.

The Seven Stations average surpassed the previous record for warmest June, 2003, and there have now been nine Junes since 1909 where the departure from average has been greater than 1.0°C.

A persistent lack of southerlies had a profound impact on the monthly temperatures. Only one climate station in Middlemarch experienced a June mean temperature that was not either above average or well above average.

Meanwhile, NIWA's climate scientists are keeping an eye on international climate models as they continue to indicate El Niño conditions developing later in the year.

El Niño typically reaches its peak during our summer, when it is related to stronger and/or more frequent westerly winds over the New Zealand region. Such a climate pattern typically leads to drier conditions in eastern areas of the country and more rain in western areas.

Waste not, want not

To reduce their impact on the environment, farmers are being asked to cut down nutrients and effluent escaping into waterways. **Richard Rennie** examines the state of research into the solutions farmers and environmentalists are looking for.

Given the length of time the nation seems to have been heatedly discussing farm-related pollution of waterways, you could be forgiven for thinking farmers just had to buy a system off the shelf.

It isn't quite that easy. The challenge in reducing the sector's nutrient runoff is that there's no simple answer to the intricate science of nutrient flows. There is huge complexity in preventing, capturing and using effluent and nutrients, and monitoring the results. There are hundreds of different pieces of hardware and many techniques, and as many different pieces of advice as there are environmental consultants.

The complexity has not stopped farmers making changes to their practices. The farming sector now invests millions of dollars annually into nutrient and effluent management and capture. The total investment to date has been estimated at $3 billion.

Waterway fencing alone accounts for almost 10 per cent of that. This has been in response to pressure on farmers to fence riparian strips around waterways. This initiative has accounted for 22,000km of waterways being fenced, at a cost of about $220 million.

Dr John Quinn, a NIWA scientist based in Hamilton, says, however, that public expectation has got ahead of what is currently possible in terms of greater nutrient management, despite these steps.

"Scientific study can provide answers to the most challenging questions, but with nutrient runoff, people have been feeling particularly anxious because the science and farm practices to combat it haven't been developed yet."

Management of nutrient runoff in some form is now commonplace on most dairy farms, and is driven as much by economics as it is by compliance and sustainability desires.

Put simply, reducing nutrient input and re-using nutrient output lowers the costs of running a farm.

Soil scientist Dr Doug Edmeades says the rule of thumb for a dairy farm is that effluent reapplied as fertiliser on a farm is the equivalent value to $25 a cow, or about $11,000 a year for an average size farm.

Integrated monitoring systems have also been developed to optimise application of the valuable waste. They gather weather data to calculate the best times to apply effluent to pasture.

Integrated with nutrient budgeting software, they can then calculate how much additional fertiliser is required. The value of such systems, and the effluent they apply, has even been recognised by fertiliser companies keen to take a responsible approach to managing the losses.

In 2011, fertiliser company Ballance invested in Ag Hub, an online cloud-based farm monitoring company whose software includes effluent management and control.

But the myriad ways nutrients get onto farms, and then into waterways, are trickier than can be caught by the thick fingers of most systems currently on farms.

For over a decade it has been clear to New Zealanders that nutrient and effluent management on farms is also critical to improving the state of rural waterways. The issue of 'clean streams' has become a hot topic for the nation. Moreover, the responsibility has been laid primarily at the feet of dairy farmers.

In 2002, Fish and Game started its controversial 'Dirty Dairying' campaign to highlight the impact of dairy farming on waterways. In 2003, Fonterra struck its Clean Streams Accord with government agencies to undertake on-farm work that would reduce "the impacts of dairying on the quality of New Zealand streams, rivers, lakes, ground water and wetlands", so that "water is suitable for fish, drinking by stock and swimming".

Dairy NZ sustainability strategy leader Dr Rick Pridmore says dairy farmers contributed to some pollution, but are not alone.

The tension

The pressure is on for science to develop solutions. This year the tension over pollution from farms directly curtailed farming expansion for the first time.

- In Hawke's Bay a board of inquiry ruled that the planned Ruataniwha Dam on the Tukituki River could go ahead, but that the river can't take any more nitrogen. So it ruled that nitrogen in the Tukituki can't rise above the current average level – which is about 0.8mg/L. That potentially prevents intensification of farming in the area, which was part of the rationale for the dam.
- In North Canterbury, Ngāi Tahu was denied resource consent to farm 23,000 dairy cows on land next to the Hurunui River. Government-appointed Environment Canterbury commissioners had issued a water plan that allowed for a 25 per cent increase in nitrates in the Hurunui River to accommodate more farming. But Environment Canterbury said adverse effects of the plan to convert 7000ha of forestry land to dairy farms was unacceptable.

Without fencing, cows and their effluent enter waterways. (*Dave Allen*)

What makes a good dairy effluent system?

A system must reliably:

- store effluent until conditions are suitable to apply it to land, and
- apply effluent to land in a controlled way – at a depth and intensity which match the soil moisture and infiltration conditions and topography.

On-farm benefits of good effluent management include:

- fertiliser savings by using the nutrients in effluent, and reducing nutrient losses off the farm
- preventing animal-health issues such as milk fever which can be caused by a build-up of potassium levels in the soil
- improved soil condition from the addition of organic matter, including microbial and worm activity, as well as aeration, drainage and water holding capacity
- complying with council rules or resource consent – this may lead to less frequent compliance visits and reduced monitoring fees.

"Water quality in New Zealand, where it has got worse, has got worse from a large variety of sources. Dairy is one of the causes, dairy is not in denial, but we are just part of the issue."

Pridmore is right.

In May 2014, Christchurch City Council data revealed major contaminants present in the Avon River and tributary streams, including *E. coli* from human waste, zinc from car brakes, and hydrocarbons and copper contaminants.

The report prompted councillors to point out the undue attention on farmers and that it was a wake up call for urban residents.

But no matter what the contribution from all human uses of land, it's farming that is still getting the attention.

The majority of the public still think the quality of waterways and lakes are adequate or better. But according to a Lincoln University report[1], the numbers thinking it is 'bad' or 'very bad' have doubled since 2010.

Solely responsible or not, dairying appears to be making the single largest effort to curb its impact.

[1] Hughey, K.F.D., Kerr, G.N. and Cullen, R. 2013. Public Perceptions of New Zealand's Environment: 2013. EOS Ecology, Christchurch.

Pridmore says dairy farmers contributed more than $5 million per year to help fund research by councils trying to implement the Government's National Policy Statement for Freshwater Management. This included $1 million to help improve Waituna Lagoon in Southland and $1.2 million to assist Waikato Regional Council with its waterways.

"Everybody has a nutrient management plan; everybody has a better effluent system and those aren't cheap – they can be $200,000," he says.

But despite the major investment in infrastructure, no single system offers an 'off the shelf' solution to nutrient loss in dairy systems.

Nutrient tool box

Dr John Quinn says there is no silver bullet because the problem is 'diffuse farm pollution' – that is, the sources of pollution are varied, as are the routes they take into waterways.

While whole-of-farm systems are useful, even these are not sufficiently refined or sophisticated for all catchments.

He says pollution can only be solved by identifying the different pathways pollution is taking to get into waterways on each farm and in each catchment. He says the solution is looking more like "a quiver of armaments to win the battle", than a single silver bullet.

Based in Hamilton, Dr Quinn heads a team of ecologists working on some additional tools farmers can add to their nutrient mitigation 'tool box' in order to contain nutrient losses.

The work starts with recognition that the biological nature of a farming system means nutrient losses are not as easily identified and isolated as they are in an urban environment.

The diffuse nature of nitrogen leaching and phosphate runoff means the industry is also aware riparian planting and waterway fencing will only do so much to curtail those losses. Dr Quinn's team are tasked with research that takes the slippery task of farm nutrient control a step further.

Some ways farmers can reduce nutrient output

1. Prevent cattle entering waterways by using bridges and culverts over regular crossing points, fencing waterways, and riparian planting
2. Install drains to catch effluent washed off stock feed pads and milking areas, and pipe it to storage/ treatment before re-use (e.g., irrigation)
3. Irrigation systems arranged to apply water to pasture monitor soil conditions to ensure water is needed and will soak in, rather than run off or drain through the soil
4. Nutrient budgets and soil testing – keeping account of the amount of nitrogen and phosphorus applied to pasture via any source, to minimise wastage and optimise pasture growth

There is a variety of methods of dealing with nutrient losses in different regions, and even on different farms within a region.

Soil drainage, rainfall and topography can all significantly influence how a farm's nutrient profile responds to management variables like stocking rates, wintering policies and fertiliser application.

"The biggest contrast is between the west and east coasts of the South Island. On the west you are dealing with four metres of rainfall a year, when you only require about one metre to sustain dairying, and then across the Alps you have systems operating on barely half a metre of rain, plus irrigation."

The work by Dr Quinn's team reflects the diversity of the environments across which intensive farming now operates in New Zealand, and the varied attempts to capture the nutrient losses before they end up in waterway systems.


Tile drains act as a rapid conduit for farm effluent. (*Chris Tanner*)


Constructed wetlands intercept and treat tile drainage flows from grazed pasture to natural waterways. (*Chris Tanner*)

Waste not, want not

NIWA wetlands researcher and aquatic ecologist Dr Chris Tanner has over two decades worth of experience researching wetland systems and their use in managing farm nutrient losses. Dr Tanner cautions that the systems are by no means a magic wand to dealing with sediment and nutrient runoff.

"Sediment is relatively easily dealt with, but nitrogen and phosphate require more area to absorb. In farm systems, you are also working with variable flow rates between years, and within seasons."

Having the benefit of some long-term studies on wetland systems in Northland, Waikato and Southland is helping reveal some options farms can adopt. Configurations could include wetland systems with a phosphate filter built on the outlet point.

Dr Tanner says it is easy to underestimate the area required for a functioning wetland system – about two to three per cent of the farm area is required, about four hectares for an average dairy farm.

He suspects within 10 years wetland systems may be de-rigueur on dairy farms, once all lower cost 'best practice' steps have reduced nutrient losses as much as possible.

Say when

How much nutrient and effluent is too much?

The Government's approach for managing fresh water is called the National Policy Statement on Freshwater Management 2014. The National Objectives Framework, or NOF, sets national-level bottom lines for two compulsory values for freshwater; ecosystem health and human health for recreation. Regional Councils are required to manage for these values within designated areas in each region, with community consultation.

The NOF has attributes for which bottom lines (and grades above those) are set and applied to rivers and lakes. The minimum requirement for human health is that the quality should be suitable for wading or boating. For ecosystem health there are bottom lines for the acceptable amounts of river-bed algae (toxic and non-toxic types) and bloom-forming algae in lakes, all of which need to be managed by controlling nutrient levels.

Nitrate and ammonia levels should be low enough to avoid toxicity impacts on all but the most sensitive stream life. Communities can decide on higher nutrient limits to provide greater protection against both toxic and eutrophication effects. The Government says the NOF attributes are a start and that further bottom lines will be set when there is more scientific information.

His work is also studying the use of wood chip filters to capture nitrogen losses, and has recently gained funding for one, along with a phosphate filter at Waituna, Southland.

The wood chips in the filters provide energy for microbial activity that converts the nitrogen present into low impact nitrogen gas.

Collaborating with Dr Tanner is environmental chemistry colleague Dr Chris Hickey who is researching methods to better capture nutrients using minerals. His work is incorporating lessons learned from managing nutrient levels in lakes Rotorua and Rotoiti.

Dosing the lake systems with aluminised zeolite has proved successful in helping absorb phosphates. The challenge for Dr Hickey has been to develop a zeolite type filter that can be applied across many hectares of farm land, and be fitted to the back end of Dr Tanner's wetland or wood chip system design.

"There are still challenges to that. We are examining different compounds to use, including bauxites, and trying to get a better rate of nutrient binding per kilogram of compound, which is not as high as we would like at present.

"You also need to have some sort of wetland system in front of such a filter to remove the sediment first."

Growing algae and capturing gas may also prove valuable methods for lowering a farm's environmental footprint, and delivering bottom line financial return.

Researchers have discovered the methane lost in dairy farm effluent ponds is more significant than first realised, contributing to global warming and the loss of a useful biogas.

Work by NIWA's Dr Rupert Craggs has aided development of a relatively low cost approach to methane containment. Simply covering the first effluent pond in a farm system means the gas can be piped off and used to generate electricity.

Dr Craggs and Stephan Heubeck have developed a simple, low cost, covered anaerobic pond that is installed before the effluent storage pond. This improves effluent quality by removing solids, making irrigation easier, and captures biogas methane for heat and power generation.

Dr Craggs's research has shown that covered anaerobic ponds work well in all New Zealand climate conditions from Northland to Southland, and are economical for farms with over 600 cows, or fewer if the waste from a farm feed or wintering pad can be treated.

Combining effluent energy recovery from covered anaerobic ponds with photovoltaic solar energy production could enable farms to be energy self-sufficient.

"The covered anaerobic pond can be used like a battery, storing the biogas energy when the sun is shining, then using it when it is not."

Farmer Neville Barr (L) and NIWA resource engineer Stephan Heubeck use a gas analyser to measure levels of methane, carbon dioxide, hydrogen sulphide and oxygen from the covered anaerobic digester pond. (*Dave Allen*)

NIWA has several sites (in Taranaki, South Auckland and Waikato) successfully operating with biogas capture, and several others are being commissioned on South Canterbury and Southland farms, one in combination with solar.

Dr Craggs's group is also examining the potential to remove effluent nutrients by growing algae in effluent ponds prior to irrigation, to help farms reduce nutrient loads in areas where nutrient caps will be applied.

The algae and captured nutrients are harvested and can be digested to biogas methane as an energy source and then used as a fertiliser substitute or possibly a protein feed supplement.

Research work has also included a focus on the type of habitat that flora and fauna need to thrive in, even when nitrogen and phosphate levels have been lowered using the methods being studied.

"Many farm water systems, like drains and streams, have been simplified and lost a lot of the structures that would provide shelter and shade for the likes of freshwater crayfish and whitebait," says Dr Quinn.

Work has included trialling wooden structures in stream beds that provide shelter, but also alter stream water velocity and direction, helping 'cleanse' water by pushing it into filtering gravel areas, similar to what happens in aquarium tanks.

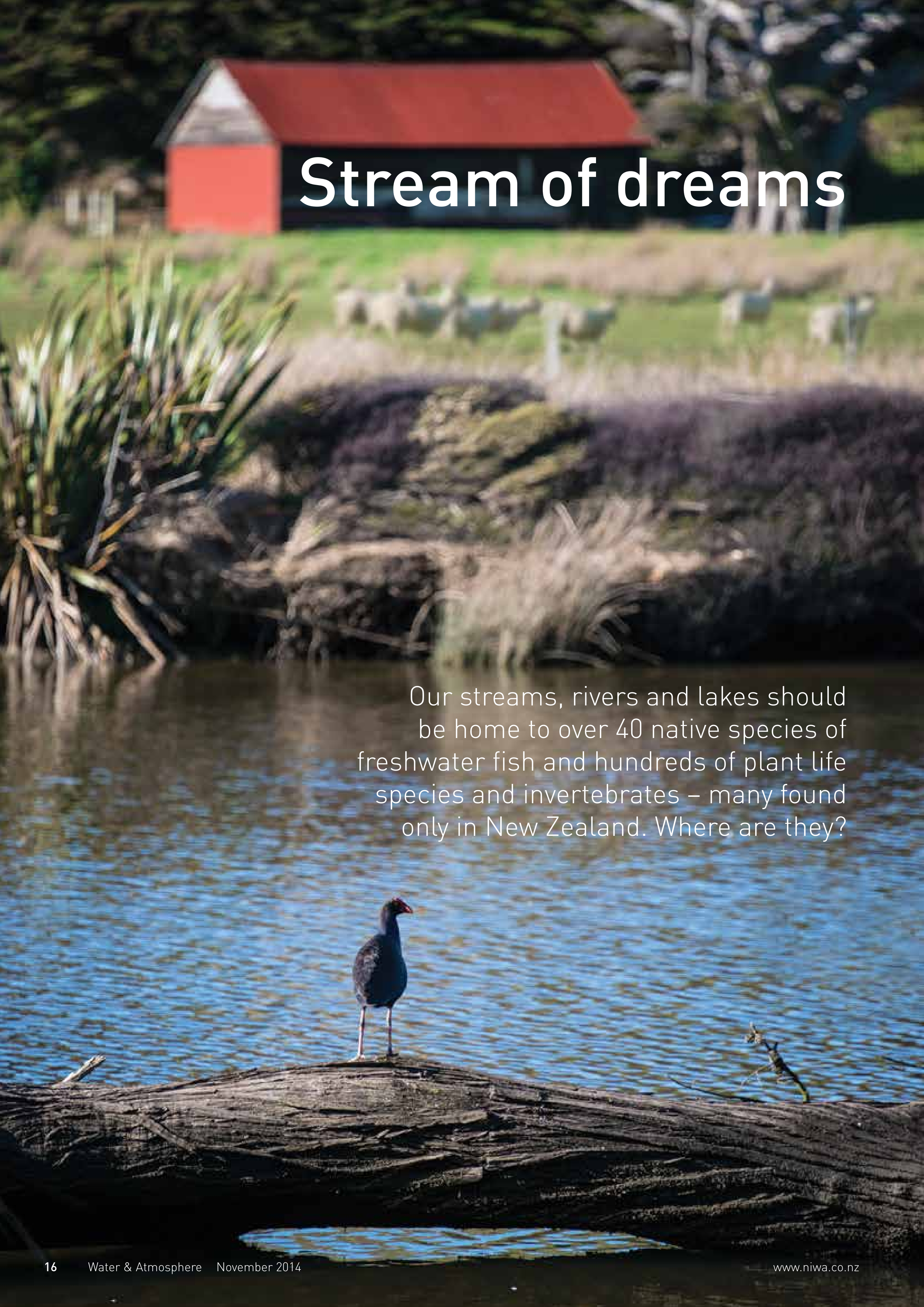
Some ways to reduce runoff with better nutrient management

Phosphorus

- Irrigate dairy shed effluent to pasture
- Reduce wastage from fertiliser by using soil test results
- Avoid soil compaction caused by overstocking
- Plant open-drain filter strips of vegetation along drains and streams (grasses and riparian vegetation)
- Avoid direct laneway runoff to waterways by diverting to pasture
- Don't fertilise near/over streams or drains

Nitrogen

- Optimise farm nutrient inputs with nutrient budgeting
- Provide feed pad systems for wintering animals, with effluent treated via oxidation ponds and irrigated when conditions are safe
- Use natural and constructed wetlands



Stream of dreams

Our streams, rivers and lakes should be home to over 40 native species of freshwater fish and hundreds of plant life species and invertebrates – many found only in New Zealand. Where are they?

Stream of dreams

Crouch along the banks of healthy New Zealand waterways and you can almost hear the hum of life. Beneath the canopy of native trees, insects flit across the ruffled water and crawl across stones. Fish flick through the current, or hide in the eddies.

Regional council macroinvertebrate index monitoring at over 1000 sites over recent years suggests that about 39 per cent of these streams have been moderately to severely degraded by human activities (see side panel). Consequently, there will be many varieties of fish, plant and insect life missing from them – pushed further back into the remaining safe habitats.

However, many streams running through urban, industrial and farm land are being rehabilitated as humans replant stream banks and staunch the flow of sediments and nutrients.

As water returns to normal, it may be swimmable for people, but it can also remain lacking in sensitive species. Scientists are discovering that there are two other factors critical to encouraging sensitive life to return to restored streams: the ability of species to reach newly rehabilitated areas in sufficient numbers to establish populations in the face of competition with resident 'tolerant' species, and a wide variety in habitats within the stream.

In the North Island, for example, a study of nine streams flowing through 0.2km to 4.2km long areas of planted or regenerating riparian forest established 13 to 35 years previously have not seen an increase in sensitive invertebrate stream life. Critical to that result was the fact that areas upstream had not been riparian planted, meaning that the restored areas were really just small islands of good habitat in a stream of poor habitat. In contrast, hill farm streams in catchments adjacent to native forest, where riparian restoration has occurred from the headwaters downstream, have shown shifts towards dominance by sensitive species within a decade.

According to Dr Richard Storey, a freshwater ecologist with NIWA, expectations of life returning to cleaned streams must be tempered by the reality of the wider environment.

"There are a lot more factors involved in restoring life to a stream than water quality. The stream's surroundings, and conditions upstream, are critical.

"There are so many variables involved that the speed and pattern of restoration of species to restored streams is a little bit unpredictable.

"That's not to say removing sediment, heat and nutrient overload from streams does not result in sensitive stream life returning. It does happen. Tools like riparian management can produce an increase in life-related monitoring indexes over time.

"At the moment we can't be sure of how soon they return, or which species will return," Storey says.

Restoration of life to streams is dependent on sources of colonists.

"Sensitive fish, insects and plants need to come from somewhere else. Often that is national parks, reserves and other forested areas. The closer the cleaned areas are to existing colonies, the more likely they are to be colonised," Storey says.

A NIWA study of streams close to Egmont National Park found that riparian protection leads to an increase in 'EPT richness'. EPT refers to the number of species belonging to three large 'orders' (groups) of aquatic insects – commonly called mayflies, stoneflies and caddisflies.

"These insects are generally quite sensitive to habitat and water quality, so a greater number of species present means that habitat and water quality must be improving," Storey says.

Ironically, the streams closer to the National Park showed less improvement than those further away. The scientists suspect the Park was already providing colonists before restoration occurred, so there was less room for improvement.

NIWA is attempting to bridge a gap in knowledge about the dispersal capabilities of insects and fish.

"We are unsure how far each species is capable of reaching, and the order in which each species colonises. If a degraded habitat is dominated by a few 'tough' species, then those could prevent others coming in after it has been restored."

Kōkopu. (*Dave Allen*)

Dragonfly. (*Brian Smith*)

Lamprey. (*Rod Morris*)

Unmodified riparian strip on a farm. The majority of strips are now fenced, and some planted with native flora. (*Dave Allen*)

Stream life

The biggest family of native freshwater fish are the galaxiids, named after their stunning spotted patterns that resemble starry galaxies. The most well-known galaxiid is īnanga (the most numerous whitebait of the five species) which, like most New Zealand native freshwater fish, has a lifecycle that begins as an egg sheltered by streamside vegetation, until they're swept out to sea before returning to the fresh water as juveniles.

Streams, rivers and estuaries not only provide transport for migratory fish, but they are also critical in moving nutrients and providing drainage for the landscape. Leaves and organic material are processed by moving water into fine particles which provide food for organisms downstream like caddisflies and freshwater shrimps.

Where water tumbles over clean pebbles, some caddisflies build their own protective houses out of rocks, sticks and sand. Whole, purpose-built communities of insects interact under the water's surface. Caddisflies, along with other macroinvertebrates (meaning they have no backbones and can be seen without a magnifying glass or microscope) are often used as an indicator of water quality. In a good, healthy stream you're likely to find dozens of different types within just one square metre of streambed. They enjoy the shelter of overhanging plants that would have lined most New Zealand waterways before human settlement.

Giant kōkopu, floating ferns, giant dragonflies and aquatic plants bunch near the banks, providing shelter and habitat.

Aside from providing food and shelter, streamside plants can also regulate water temperature, making the stream more hospitable to fish and insects while minimising the risk of choking algae blooms. They can also provide a buffer along the stream banks that filters harmful sediment and nutrients and also protects the bank from erosion during floods.

As an ecosystem, the plants, insects and fish of New Zealand's waterways are heavily co-dependent, but are also surprisingly resilient. With proper management of riparian areas and strategies to reduce pollution from industrial, residential and farm runoff, our rivers and streams can be abundant with life.

Stream of dreams

A NIWA study in Hawke's Bay is using intermittent streams, those that regularly dry up, to discover how far colonists from nearby perennial streams can reach when the streams start flowing again. In a related study, genetic differences between populations allow scientists to map where the colonists have come from.

What's good about streams?

There's human benefit from rehabilitated streams.

Whaingaroa Harbour Care has spent close to two decades voluntarily planting native plants and fencing along riparian strips of farms around Raglan.

The organisation's leading light, Fred Lichtwark, says that fencing and planting is "a vital component of good farm management".

He says the 40 farms that have participated in the scheme have experienced fewer stock losses and better stock health. No longer are cows dying in boggy streams, getting sick from drinking water polluted by their own faeces, or stressed by lack of shade and shelter.

Farmers have also been able to increase the amount of stock on their farms thanks to better pasture quality.

Lichtwark says less sediment and nutrient runoff has dramatically cleaned water in the harbour. The improved habitat has led to the return of flounder, whitebait and other marine life. He cites, for example, the return to sea grass, which is acting as a snapper nursery.

The job isn't finished though. Along with more work on farms, Fred has his eyes set on the pollution coming from urban environments: "Urban development has some pretty negative impacts on the harbour as well."

Before and after images of Whaingaroa Harbour. (*Fred Lichtwark*)

"These studies will help tailor restoration efforts to fit what life does naturally," Storey says.

Work by NIWA's freshwater team is confirming the importance of particular habitat features in the restoration of stream life, as well as clean water.

"One habitat feature we think may be important is emergent rocks – those with their top out of the water. Insects can land on these and crawl underwater to lay their eggs.

"We find rocks like these usually covered with insect eggs, and we suspect they may be critical for some insect species to complete their lifecycle. If they are absent, then those species can never really establish a self-sustaining population at that site."

Natural vegetation cover is critical. The riparian vegetation needs to shade the stream to keep the water temperature low enough for some sensitive native species, and to prevent sunlight fuelling over-growth of aquatic plants and algae. Aquatic plant life is important as a food source and hiding place for insects and fish, but too much growth clogs the stream and forces them out. Riparian vegetation cover also drops wood and leaves into the streams, providing more food, but critically, giving more variability to the stream flow – and thus more habitats.

Fallen logs and branches cause changes in water flow, where water trickles, riffles and tumbles over and around the material. This creates habitat and refuges where invertebrates and fish can crawl, graze and hide.

NIWA has trialled large wood additions to pasture streams at Whatawhata, Waikato. The work by Aslan Wright-Stow, John Quinn and Paul Franklin indicates that the additions to headwater streams (2–3m wide channels in 300ha catchments) enhances physical habitat diversity.

The scientists added treefern logs in a combination of sill-log dams (logs laid horizontal) and angled flow deflectors. The structures remained in place through an annual cycle of storm flows with little maintenance.

Surveys six weeks and one year after wood addition show that native fish and koura were using the structures.

The study demonstrates how relatively inexpensive and small-scale changes can make immediate improvements for aquatic life. But large-scale changes are still necessary to coax the native species out of our pristine or slightly impaired streams and into colonising restored streams.

As scientists learn more about what it takes for life to move back into clean streams, those restoring the streams stand a better chance of ending up with more than a clean but barren waterway.

Beneath the *surface*

STREAM HEALTH AND ITS EFFECT ON LIFE

The health of a stream reflects the environment within, the environment surrounding (the stream banks), and the environment upstream (the catchment). Intensive, poorly managed agricultural development in a catchment can severely degrade stream health, while restoring natural habitats and water quality can support a vibrant stream ecosystem. When we change environmental conditions, we help or harm stream life.

A ***severely*** degraded stream

Severely degraded streams are typically found in highly changed landscapes offering little or no protection of waterways. In such streams, stream beds fill with fine sediments and mud, stock damage stream banks and temperatures are high. Nutrients enter the water without filtering, providing an over-abundance of food for aquatic plants and filamentous algae, which choke the waterway. Leaves and wood, natural food for invertebrates, disappear because riparian forest has been cleared. These streams can't support many sensitive fish or invertebrate species. However, even these waterways can support some life.

Invertebrates	Plants	Fish
01 Oligochaeta 02 *Chironomus*	03 Filamentous algae and invasive introduced aquatic plants (e.g. hornwort)	04 Shortfin eel

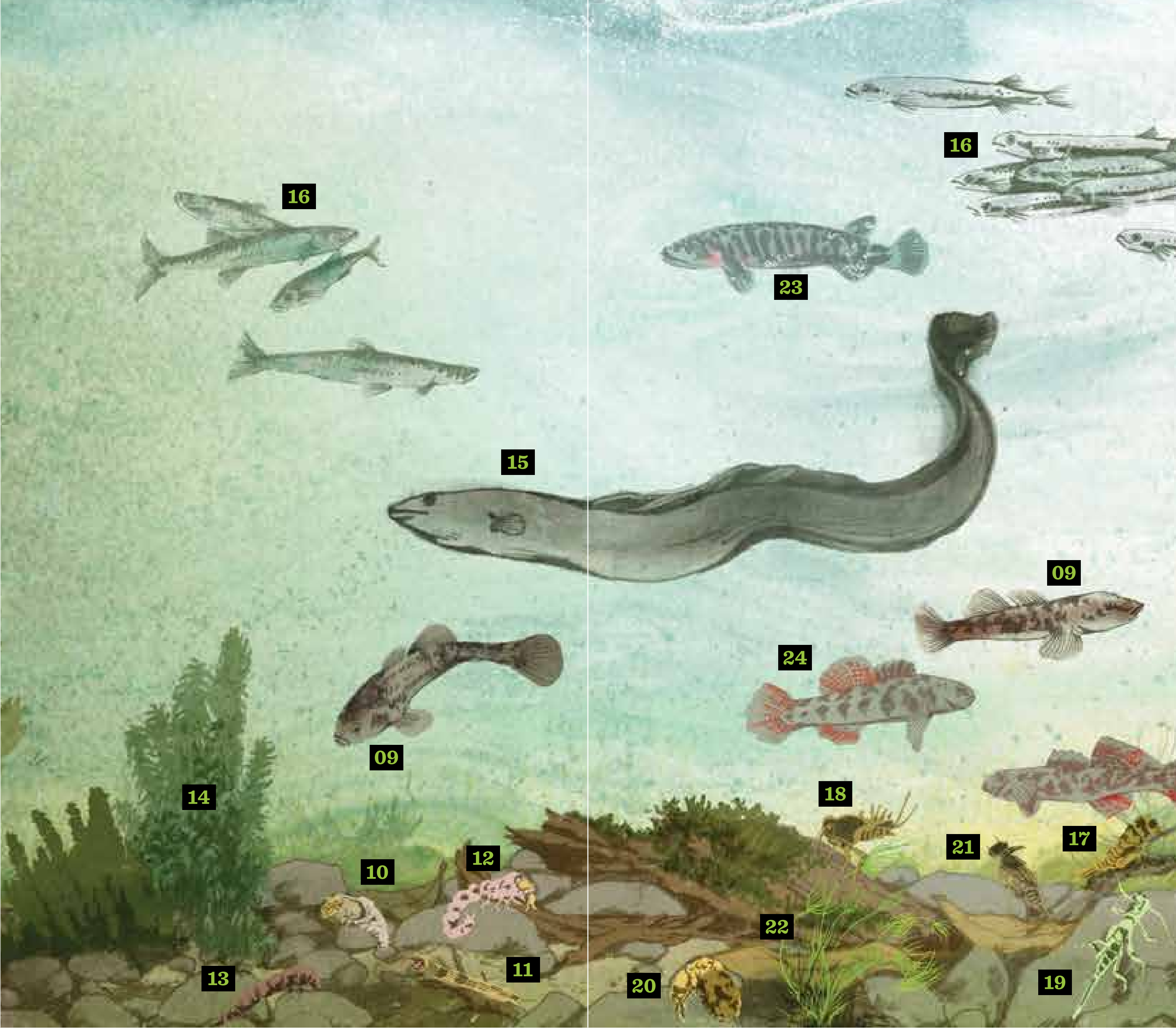
A ***moderately*** degraded stream

A moderately degraded stream might be one that has a small amount of stream protection – such as some riparian vegetation, or stock exclusion by fencing and stock crossings. Typically the stream bed will have some areas filled with fine sediments but also sections with larger rocks and some wood. Plant growth may still be excessive in some sections. Fish and invertebrates commonly found in moderately degraded streams include species that tolerate silty, turbid, nutrient rich environments.

Invertebrates	Plants	Fish
05 *Potamopyrgus* 06 Kōura 07 *Hydropsyche*	08 Densely growing invasive plants such as *Lagarosiphon* and *Egeria*	09 Common bully

FACTORS LIKELY TO HARM STREAM LIFE

- **Increased nutrients** such as nitrogen and phosphorus from farming practices.
- **Increased sunlight and water temperature** through reduced shade.
- **Fish migration barriers** such as culverts and dams.
- **Fine sediment deposits** in stream beds, such as silt, clay, and mud.
- **Toxic chemicals** like pesticides and herbicides.
- **Channelisation** caused by digging and straightening stream channels.



A *mildly* degraded stream

Mildly degraded streams are likely to have stock excluded from most of the channel and stream banks. Riparian vegetation provides shade and food resources for stream life, and can also filter particles and chemicals running off the land after rain. These streams have a wider variety of flow types than more degraded waterways, and diverse stream bed materials (pebbles, cobbles, rocks and large pieces of wood). Water temperature and nutrients are lower, as are the amounts of fine sediments. Aquatic plants are unlikely to choke the stream. Invertebrates, which have a life stage that relies on the presence of riparian vegetation, can be supported by these waterways.

Invertebrates	Plants	Fish
10 *Pycnocentrodes* 11 *Hudsonema* 12 *Psilochorema* 13 Elmidae	14 *Myriophylllum*, curled pond weed, native pond weed, and *Elodea*	15 Longfin eel 16 Īnanga/smelt

A *healthy* stream

Healthy streams have total stock exclusion, a wide variety of habitat and flow types, stable stream banks, low inputs of nutrients, and plenty of oxygen in the water. They have large areas of riparian vegetation on both sides of the waterway which keep water temperatures cool, provide habitat for invertebrates like mayflies and stoneflies, and link the stream to sources of colonist fish and invertebrates.

Invertebrates	Plants	Fish
17 *Ameletopsis* 18 *Coloburiscus* 19 *Stenoperla* 20 *Helicopsyche* 21 *Deleatidium*	22 *Chara*, *Nitella*, and moss	23 Banded kōkopu 24 Redfin bully

FACTORS LIKELY TO HELP STREAM LIFE

- **Riparian vegetation** provides shade, food, and habitat.
- **Clean gravels** in a variety of sizes.
- **Complex channel-forms** provide habitat niches.
- **Stabilised banks** reduce erosion and fine deposits, and provide cover for fish.
- **Large pieces of submerged wood** create habitat.
- **A natural flow regime.**

Dragonfly. (*Brian Smith*)

Thirty-nine per cent of monitored New Zealand streams have streambed life that indicates 'moderate or severe degradation'

Data collected by regional councils on river bed invertebrates throughout the country suggest that 39 per cent of the monitored streams have been degraded in some way by human activity. These sites are biased towards pasture catchments (55 per cent more sites than would occur if chosen randomly).

Macroinvertebrate Community Index (MCI) scores calculated from streams sampled around New Zealand can be used to deduce the state of the water. Invertebrates are sensitive to water quality, so their presence can indicate stream health.

Based on the types and sensitivity of macroinvertebrate life found, Aslan Wright-Stow, a freshwater ecologist with NIWA, calculated that 22 per cent of the streams regularly surveyed by regional councils have clean water, and 39 per cent have been mildly impacted (sensitive species are usually sustainable and it is difficult to directly attribute human influence). Thirty-nine per cent of streams have been moderately (sensitive species are less frequent than tolerant species) or severely degraded (sensitive species are generally not present).

The data use the sensitivity (to organic enrichment) of invertebrates as a means of assessing water quality. The data were sourced from State of the Environment monitoring (regional council data for wadeable streams) published by the Ministry for the Environment and represent five-year median MCI values from a total of 1008 stream reaches (there may be more than one reach per stream). It is an indicator and does not measure drinking water quality. The estimate is based on data from sites sampled predominantly from pasture locations (68 per cent). So clean water environments are likely to account for a greater proportion of streams than indicated in these monitoring results.

	Clean water	Mild impact	Moderate impact	Severe impact
% of NZ streams (in MfE's online database)	22	39	27	12

Betting the farm

New Zealand's rain fuels world-leading agriculture, but the challenge for farmers is when and how much? **Mark Blackham** went to Fieldays this year to find out how technology is helping the farmer understand weather.

Experience meant everyone 'knew' that it was going to rain this year at farming's biggest gathering of products and services, Fieldays at Mystery Creek near Hamilton. But the question of exactly when it would rain, and how much, was answered by Chris Brandolino of NIWA, the official forecaster for the event.

Using a new service called FarmMet, Brandolino was able to forecast the weather for Mystery Creek – at 112 hectares, about the size of a small dairy farm – with a high degree of accuracy.

His regular forecasts were broadcast around the site every few hours. And there was plenty of rain – 112.6mm in total, including Tuesday, the non-public day. Thursday, was the wettest, with 45mm of rain.

Where once a weather vane and wisdom of the almanac helped farmers prepare for rain, advances in weather science are fuelling a revolution in farm use of weather forecasting.

The advances come from a combination of new weather monitoring technology including data from weather stations to satellites, steadily improving forecast models, and computers powerful enough to calculate local forecasts.

It has been shown in the US that today's two-day forecast is as accurate as the one-day forecast was in 1988. The seven-day forecast now is as accurate as the five-day forecast was then.

The accuracy of modern forecasting is worth real money to farmers. If you know the moisture content of soil and the amount of rain due tomorrow, if any, you can decide when and how much to irrigate, apply fertiliser, and even judge stock levels on paddocks. This maximises grass and crop growth, and minimises expenditure on fertiliser, electricity, water, and hardware maintenance.

The whole supply chain of the agricultural sector benefits from improved weather forecasting. The range of decisions affected by weather and climate is considerable; from scheduling of planting/harvest operations, choices of crops and herds, crop sequencing and rotations or stocking rates, land use, insurance and finance arrangements, and processing and storage.

TV3 News interview with Chris Brandolino at Fieldays 2014. (*Dave Allen*)

Economic studies into the value of weather forecasting have found they can add 1–2% to the value of agricultural output. The studies are also indicating a new dimension to more accurate forecasts: anticipation of economic responses. Farmers aware of impending dry or wet periods can adjust production ahead of the supply and demand changes that are likely to arise.

In addition, forecasts enable farmers to reduce the costs of weather disasters by taking action ahead of them.

Advances in the science of weather forecasting are now attracting big money. Global giant Monsanto last year paid $930 million for The Climate Corporation, which specialises in local weather prediction and analytics. Monsanto estimates that there is $20 billion of "untapped yield opportunity," if farmers use "data science."

NIWA's similar service, FarmMet, was launched at Fieldays this year. It is based on the best international science, tailored by New Zealanders for New Zealand to provide forecasts localised to the customer's farm.


NIWAFarmMet
Accurate weather forecasts tailored to your farm
NIWAFarmMet
farmmet.niwa.co.nz


Bradfields
CASE IH

Finessing the forecast

NIWAFarmMet's accurate, near farm-scale weather forecasts are the outcome of complex number crunching using extraordinary computational power, multiple local and global data sources, and models that continually check against locally recorded data and adjust their outputs accordingly.

Fieldays technology

This year's Fieldays had a particularly appropriate theme for the science sector.

"Managing resources for a competitive advantage" summed up the practical role science has in assisting farmers achieve greater productivity and profit.

The challenge of this theme was embraced by many exhibitors displaying innovative solutions using technological advances to improve efficiency on the farm and embrace a new generation of tech-savvy farmers.

Waikato Milking Systems introduced a product called the Bail Marshal. It had been designed to enable all technology devices on a milking system to work together seamlessly and continually communicate with each other.

Also on show was an electronic drench gun receiving data via wifi to calculate exact dosages needed. Then there was a capsule device placed inside a cow's rumen which measures temperature and pH levels and can deliver the data to a farmer's smartphone.

The growth of data-driven technology accessed by farmers from mobile phones was particularly evident at Fieldays, offering a glimpse into the future where everything a farmer needs to know is available on one device at the touch of a button.

Automation – from feeding to milking – was also a prominent theme, driven partly, agricultural leaders say, by New Zealanders' love of innovation.

It is innovation that has helped the dairy industry reach annual exports of more than $13 billion, helped by a $450 million spend on research and development by the agricultural sector spread across business, government and higher education.

Farming today is about engineering, electronics, information technology and a range of science disciplines. All of which, Fieldays Chief Executive Jon Calder says, has led to the kind of innovation that has made New Zealand an agriculture superpower.

Minister Steven Joyce and Prime Minister John Key at NIWA's Fieldays exhibit. (*Stephen Barker*)

FarmMet launch at Fieldays. (*Dave Allen*)

"NIWAFarmMet draws on a number of different weather 'models' – highly sophisticated computer programmes – to produce local two-day, six-day and two-week forecasts for farmers," explains NIWA's Chief Scientist, Climate and Atmosphere, Dr Murray Poulter.

"Our own high-resolution model for New Zealand, run on our supercomputer in Wellington, provides the two-day forecasts. They're the most detailed and accurate in the NIWAFarmMet package. Medium-resolution six-day forecasts are delivered via a global model. Two-week forecasts are the combined and 'downscaled' outputs from an ensemble of models, and provide a low-resolution 'heads up' of weather expected during the fortnight ahead.

"Each model solves complex mathematical equations that describe how the atmosphere changes, incorporating changing pressures and flows, and the weather that will develop as a result. They use data from a wide range of local and global sources including ground- and ocean-based monitoring stations, satellites, aircraft and weather balloons. They run on incredibly powerful supercomputers."

Alongside the big global data, a local monitoring station plays a critical part in ensuring farmers are given the most accurate picture possible of the weather expected at their place, Dr Poulter says.

Betting the farm

"Our two-day model works by producing discrete forecasts for points on a 12km grid covering the entire country. But because New Zealand's terrain is so varied, within any 12km square there may be mountains, basins, ridges, valleys, lakes or the sea – all of which can have a marked influence on local weather and climate.

"So we need to modify the grid forecast by anchoring it to a nearby point that best represents the climatological conditions on the farmer's property. That's where the local monitoring station comes in."

FIELDAYS FACTOIDS

300+	One-to-one demonstrations of NIWAFarmMet given to farmers.
450+	Brochures on NIWAFarmMet given away to farmers.
25	Frenzied minutes, on day one, when simultaneous visits by Prime Minister John Key and Science and Innovation Minister Steven Joyce made the NIWA stand the centre of action and attention.
5000	Packets of NIWA lollies given away to sweet-toothed visitors.
1200	NIWA rain ponchos given away to soaked visitors during the first two days.
24	Live rural weather presentations delivered by NIWA forecaster Chris Brandolino.
40	Throat lozenges consumed by Chris Brandolino to sustain his voice.
12	Width, in metres, of screens positioned around the Fieldays complex on which Chris's Mystery Creek forecasts were broadcast up to six times daily.
384	Collective hours spent by NIWA staff on their feet, manning the stand.
179	Entries into the draw to win an iPad Air and 12-month subscription to NIWAFarmMet. Congratulations to lucky winner Mr Paul Smith of Hawke's Bay.
21	Separate media entities that ran stories on NIWA's activities at Fieldays.

Subscribers to NIWAFarmMet enter their address as part of the online registration process. The website then automatically selects the NIWA monitoring station closest to their property. The farmer can change that station if they believe a nearby alternative will better represent the climate on their property.

"The selected station provides data on the current weather at that location – effectively giving the models the correct 'starting point' for their forecasts," Dr Poulter explains.

"It also contributes to a process of continual forecast improvement. The models aren't perfect; they may have biases – perhaps a tendency to under-estimate temperature or windspeed at a particular location. So the data measured locally are used to remove those biases and correct the forecast".

"The forecast system compares the last six weeks' of measured data with their own forecasts generated for that period. Any discrepancy is adjusted out before the next forecasts are produced. It's an ongoing process. The models are continually looking back and comparing, then finessing, their next forecasts."

The local station also provides data for the range of climate products – including accumulated rainfall, growing degree days, and days with frost – that form part of the NIWAFarmMet package. These products enable farmers to compare current conditions with past seasons and long-term averages.

NIWA continues to look for other ways to improve the accuracy of its forecasts – not only for farmers but other end users with specific forecasting needs.

"Improving resolution – reducing the size of those grid squares – is a key way we can deliver better forecasts," says Dr Poulter. "The smaller the squares, the more of those terrain-related microclimates we can factor into our base forecasts. It's a high priority for us. Watch this space.

"We're also expanding our monitoring network, prioritising those areas where we currently have fewest stations. As our network grows, we'll be much better placed to provide end users with a data source that truly represents the climate at their location.

"The models will do the rest!"

For more information:
http://farmmet.niwa.co.nz

Dr Murray Poulter
Chief Scientist, Atmosphere & Climate
Murray.Poulter@niwa.co.nz


Waikato Times

Not warming to climate change

The latest climate change reports from the Intergovernmental Panel on Climate Change (IPCC) reinforce the urgent need to reduce global greenhouse gas emissions as well as to adapt to the impacts of climate change. **Michelle Sutton** finds that the news is mixed for New Zealand's agricultural sector.

The fifth round of IPCC reports began in September 2013 with an update on the latest science (known as the Working Group I report). This report restated that warming of the climate system was unequivocal and that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid 20th century.

At the start of 2014, the IPCC released a second report discussing the likely impacts of a changing climate, how people are adapting and may adapt, and the vulnerability of people, environments and ecosystems to climate change (known as the Working Group II report).

This report included a chapter that focuses on Australasia. The New Zealand lead authors of the Australasian chapter are NIWA climate scientist Dr Andrew Tait, AgResearch scientist Dr Paul Newton and New Zealand Agricultural Greenhouse Gas Research Centre scientist Dr Andy Reisinger.

Dr Tait, who hopes the report will be "a wake-up call", says the world's climate will continue to be affected by ever-increasing concentrations of carbon dioxide and other greenhouse gases in the atmosphere.

"New Zealand is projected to get hotter, have heavier rainfalls and experience more days when the fire risk is extreme."

Flooding in rural Northland. (*John Stone, Northern Advocate*)

Drought is expected to increase in frequency, even in Southland and Otago, and flooding is predicted to more frequently impact much of New Zealand's low-lying areas, as heavy rainfall events are projected to increase in intensity.

"The big ones will be even bigger. A present-day 1-in-50-year rainfall could be more like a 1-in-20-year event by the end of the century," Tait says.

In fact, the new IPCC work suggests many of the impacts are already being experienced by the agricultural sector.

Droughts, floods and changing weather patterns are an increasing problem for farmers around the world, and the consequences fit with patterns predicted in the last IPCC report in 2007.

It may not be all bad news. Recent studies have indicated that warmer temperatures may mean strong spring growth in cooler parts of New Zealand, and better yields and new crop types in traditional agricultural areas.

Productivity losses from warming may be offset by the enhanced fertilisation effect of increased atmospheric carbon dioxide. This was suggested by a 2013 report from the Ministry for Primary Industries on New Zealand's agricultural adaptation to climate change, Four Degrees of Global Warming, co-authored by NIWA scientists. This could boost productivity by an estimated 30 to 40 per cent on average, depending on the climate change scenario, as long as nutrients and water are not limiting.

But globally, scientists are becoming more ambivalent about the impact of climate change on agriculture. There are some indications from studies overseas that rising carbon dioxide levels could reduce the effectiveness of herbicides, encourage pests and plant disease, and may even reduce the protein level in plants.

A literature summary published in the journal *Agricultural Economics* at the end of last year found scientists studying the effect on agriculture had experienced "a transition from relative optimism to significant pessimism".

A slip closes State Highway 1 north of Towai. (*Michael Cunningham, Northern Advocate*)

Don't wait

New Zealand's agricultural sector needs to prepare for climate change, rather than wait until the implications hit home, warns a climate and agriculture researcher.

The worst thing farmers can do is ignore climate change just because the implications are not fully understood, says Andy Reisinger, a coordinating lead author for the IPCC Fifth Assessment report. He is also Deputy Director (International) of the New Zealand Agricultural Greenhouse Gas Research Centre.

Reisinger likens the need for some adaptation actions to putting on a seat belt – it's a prudent action even though you don't expect to actually have an accident.

"You don't want to try to put on a seat belt when you realise you are going to crash – it's too late by then, and the same is true for dealing with climate change," he says.

Farmers and agriculture land owners need to think through their options now so they can be prepared for a variety of outcomes in the future.

"There are still many uncertainties about what climate change will mean for farmers in New Zealand, with issues such as the amount of rainfall change in some New Zealand regions, changes in pests and diseases, effect of higher carbon dioxide concentrations and, not the least, policy responses. It's important to be prepared for as many of these scenarios as possible to safeguard your land, income and future."

In the short term, farmers could best prepare by being able to survive greater variability in climate, feed supply and income. Simply put, higher temperatures and shifting rainfall patterns, with a broad trend towards more droughts in many regions, would impact on food supply, productivity and animal health. Some of those changes are expected to be positive for parts of the country, but greater variability would also imply more extremes in returns at the farm gate.

However, the full implications of climate change for New Zealand farmers needed to be understood in the international context.

"Looking at climate change's impact on New Zealand alone, it would be easy to lose sight of the international situation and how global changes flow back onto New Zealand farmers," Reisinger said.

The impact of climate change on other countries is expected to increase commodity prices, but also influence international markets more generally; as an export-dependent nation, such changes could be critical in shaping land use and strategies to adapt agriculture in New Zealand.

Farmer, Angela Hunt surveys a dry dam which is normally used to supply stock with drinking water, Wairarapa. (*Dave Allen*)

New Zealand impacts at a glance

Climate

Warming; with rising snow lines, more frequent hot extremes, less frequent cold extremes and increasing extreme rainfall related to flood risk. Annual average rainfall is expected to decrease in the north-east South Island and northern and eastern North Island, and to increase elsewhere.

Water resources

Increased water runoff in the west and south of the South Island, and reduced runoff in the north east of the South Island and the east and north of the North Island. Annual flows of eastward rivers with headwaters in the Southern Alps (e.g., Clutha, Waimakariri, Rangitata) will increase in response to higher alpine precipitation, especially in winter and spring.

Flooding

Flood risk is projected to increase due to more intense extreme rainfall events driven by a warmer and wetter atmosphere. The 50-year and 100-year flood peaks for rivers in many places will increase (large variation between climate models and greenhouse gas emissions scenarios), with a corresponding decrease in return periods.

Wildfire

Climate change is expected to increase the number of days with very high and extreme fire weather in many, in particular eastern and northern, parts of New Zealand. Fire season length will be extended in many already high-risk areas, and so will reduce opportunities for controlled burning.

Professor Tim Naish, Director of the Antarctic Research Centre, Victoria University of Wellington, worries about whether New Zealand is ready to adapt. He warns, "New Zealand is under-prepared and faces a significant 'adaptation deficit' in the context of the projected impacts and risks from global average warming of +2 to 4°C by the end of the century."

One of the benefits of the new IPCC report, according to Dr Tait, is that it stresses the importance of adaptation. He says it "is a chance to restate and re-emphasise the climate change vulnerability and adaptation issues that we face".

Farm management skills are also central to the quality of adaptation. The IPCC chapter on Australasia cites studies that measured the ability to respond to projected climate-change-driven variations in seasonal pasture growth. In Hawke's Bay, changes in stock numbers and the timing of grazing were techniques used to maintain farm income in the face of variable forage supply, but not over the longer term. In Southland and Waikato, projected increases in early spring pasture growth may negatively affect pasture quality, yet, if quality is preserved, animal production could be maintained or increased.

Many adaptations are already in play on farms today, such as new planting and harvesting dates to account for seasonal changes, and different crop selections to account for warmer temperatures and pests.

The IPCC's Fifth Assessment report says people may soon see some very surprising land-use changes, such as the introduction of crops and fruits in regions that had never considered them previously.

Studies have indicated that crops such as soybeans, rice and sorghum could be grown here if the climate gets warmer and wetter, and fruits such as avocado and a wider range of citrus could be grown in more areas.

Not warming to climate change

Modelling cited in the recent Working Group II report, for example, also suggests that good choices of cultivars and sowing dates could increase our wheat yields under climate change.

At the same time, problems may emerge for existing agriculture. A 2012 technical paper from the Ministry for Primary Industries expected a range of changes in crop diseases and pests ("Climate change impacts on plant diseases affecting New Zealand horticulture"). For example, apple black spot may thrive, but grapevine downy mildew would not increase significantly. The risk of the dreaded kiwifruit bacterial canker known as Psa would decrease in some regions like Northland but not change in places like Nelson.

This suggests subtle regional shifts in agricultural production over time as the effects are felt differently across the range of agriculture.

An intriguing problem raised in the IPCC report is that New Zealand may be so good at on-farm adaptation that we actually delay the degree of transformation response required by the nation as a whole. Better crop and stock management techniques may enable us to maintain production against the disease, pest and growth impacts of climate change. But this adaptation may mask the extent to which certain types of farming are no longer viable in regions.

So we may put off the most difficult adaptation: wholesale shifting of locations for entire industries, or the dissolution of industries and initiation of new ones.

When it finally occurs, the transformation may be all the more jarring. New Zealanders who have been surprised by the scale of economically driven land transformations in the past two decades may recoil at the scope of environmentally driven transformation.

The major message in the latest IPCC material is that incremental adaptation is happening right now, almost imperceptibly. Yet science is clearly identifying specific climate impacts on agriculture – impacts that should be responded to consciously with organised and large-scale adaptation, and even displacement, of our traditional agricultural sectors.

Upper-end projections for New Zealand

A 2013 report from the Ministry for Primary Industries, co-authored by NIWA scientists, Four Degrees of Global Warming, estimated how New Zealand weather might change under a scenario where the global temperature increased by an average of four degrees from pre-industrial times.

It suggested that the greatest temperature rises are likely to be in inland and eastern areas of New Zealand, with the biggest rises in winter and the least in summer. Some areas, such as eastern South Island, may warm by approximately 5.3 degrees.

Frost will become a rare sight, with almost none in most lowland sites in the North Island and none in South Island coastal regions like Marlborough, Canterbury and Southland, the report says.

Consequently, growing-degree days, or the number of growing days it takes for plants and pasture to reach maturity, will improve significantly, by between 50 and 100 per cent in most locations.

This would lengthen some growing seasons considerably, and ease temperature limitations for some crops. However, it would also reduce winter chilling for crops such as pipfruit and stonefruit and may allow some pest species to survive through winter.

If temperatures are four degrees warmer, then the intensity of heavy rainfall events is projected to increase by around 30 per cent. Increases of between 50mm and 150mm per day are expected in many locations and, if expected stronger westerlies increase uplift and rainfall over the Southern Alps, these changes could be even larger.

Average annual water discharge is projected to increase in all six catchments analysed by the report: the Clutha, Ahuriri, Waimakariri, Rangitata, Ashley and Rangitaiki.

While increases in extreme maximum rainfall volumes will lead to higher flood flows, more and longer dry spells may also see lower low flows. This means less water will be available during times of highest irrigation demand. River flows are expected to alter seasonally as less snow accumulates on the ranges in winter and, consequently, less melts over summer and spring.

Even though growing seasons may lengthen, temperature increases of this magnitude are likely to result in a decline in pasture production for both sheep/beef and dairy, due to extreme warming, and summers with more days above the heat stress threshold of dairy cattle will become more common.

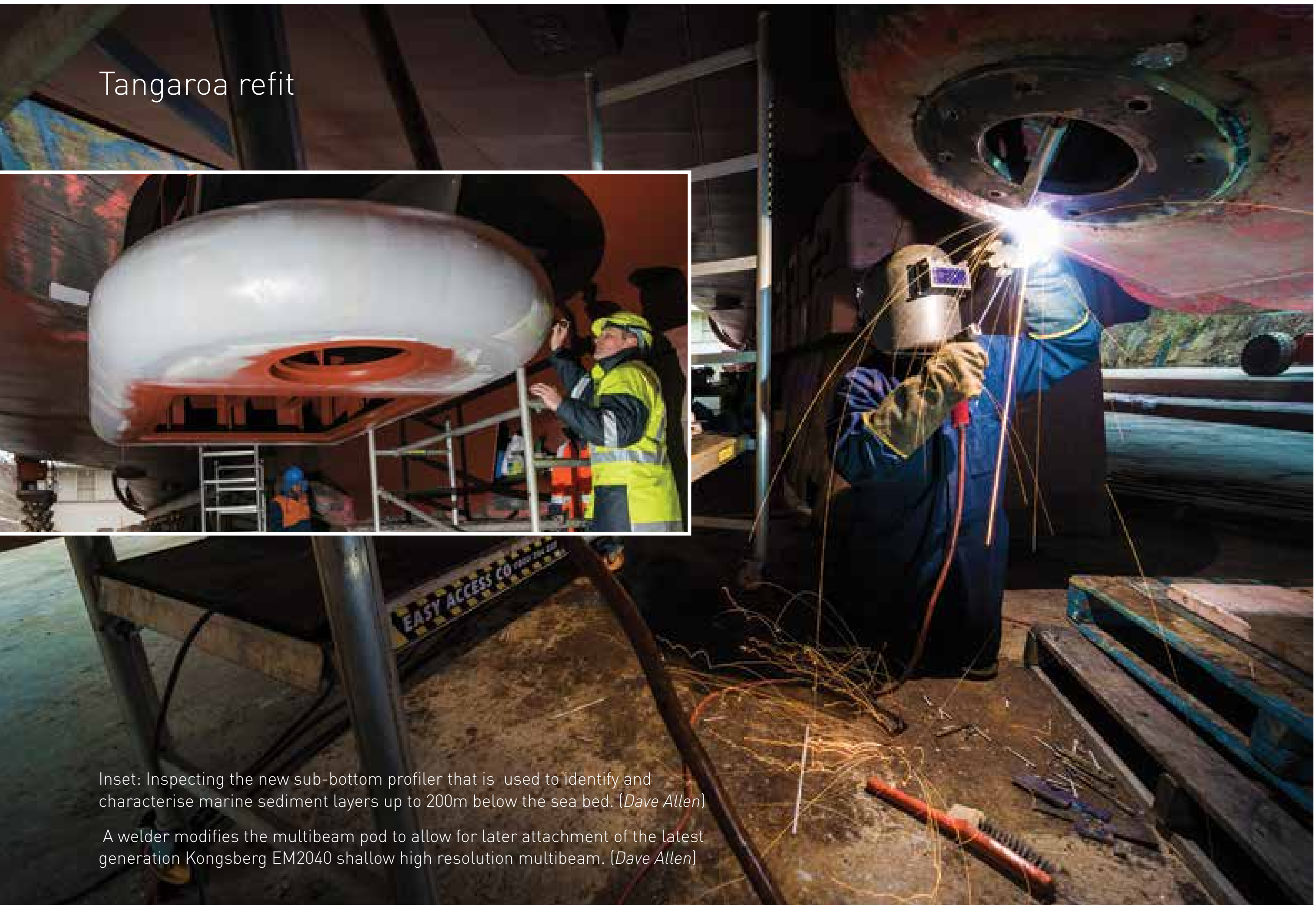
Northland and northern Waikato may experience more heat load and, without adaptation, heat stress could undermine production, reproduction and animal welfare. Adaptations include shifting to more heat-tolerant breeds, milking only in cooler months and providing more shade or indoor cooling for stock.

Tangaroa survey

Close-up on *Tangaroa* during its recent inspection and additional fitout.

Tangaroa in dry dock at Devonport Naval Base. (*Dave Allen*)

Tangaroa refit



Inset: Inspecting the new sub-bottom profiler that is used to identify and characterise marine sediment layers up to 200m below the sea bed. (*Dave Allen*)

A welder modifies the multibeam pod to allow for later attachment of the latest generation Kongsberg EM2040 shallow high resolution multibeam. (*Dave Allen*)

NIWA Marine Physics Technician Brett Grant servicing the Acoustic Doppler Current Profiler. The ADCP unit allows detailed measurement and mapping of water current speed and direction at depths down to 600m along *Tangaroa*'s path. (*Dave Allen*)

Profile

Under the weather

Why did the weather forecaster move to another country? Because the weather didn't agree with him.

With the benefit of hindsight, even **Chris Brandolino** can laugh at that.

Several months since swapping the United States for New Zealand, NIWA's newest meteorologist has negotiated a new country, new city and new job with what appears to be all the easiness of a long, lazy summer afternoon.

The high price of good mozzarella is about the most disappointing aspect he can drum up after a long pause spent thinking about the downsides of his Kiwi lifestyle.

For a New Yorker with Italian heritage who loves making pizzas – and boasting about how tasty they are – this is a big deal. That, and an absence of decent dill pickles apparently.

But Brandolino is getting used to how we roll. He goes barefoot more often than not, corrects himself when he says vacation instead of holiday and, crucially now he's an Aucklander, knows his flat white from his soy latte.

His NIWA colleagues are also getting to know him – as is the rest of New Zealand.

Brandolino is the new face of NIWA Weather. The 39-year-old has joined NIWA's team of climate scientists to help the organisation fulfil its core responsibility to use its science to help people understand our climate.

This is not the first time NIWA has tasked a meteorologist with such a public role, but it is the first time it has employed a TV weatherman and former talk show host.

Brandolino, who graduated with a Bachelor of Science in Meteorology from the State University of New York, has joined NIWA after several years on WSYR-TV in Syracuse, New York. Before that, he worked at the Australian Bureau of Meteorology in Perth and also has many years' experience as a TV meteorologist for a rival Syracuse station.

His forecasting stretches all the way back to his early school days. By age 6, he had already found his niche. At school he was constantly reprimanded by his teacher for staring at the sky out his classroom window. Eventually she realised what was captivating him, and asked him to provide a weather forecast to his classmates every lunchtime, in exchange for a penny.

A natural talker, and even more comfortable in front of an audience, each lunchtime he would stand on a chair in front of class and deliver his weather predictions.

"My mom said I was always checking out the clouds as a kid. It just went from there."

His first break in television came about a month after he graduated, when a friend working at a Syracuse TV station phoned him up and suggested he apply for a part-time forecasting job.

He got the job and gradually worked his way up to becoming the station's morning and midday forecaster, broadcasting several times a day to a huge audience.

"What I love about the weather is the power of nature. I really enjoy telling people about it and knowing that people depend on you when they're making plans. It makes you feel like you have value and contribute to someone's day-to-day life."

He married wife Sarah in 2002, and the couple honeymooned in Sydney. They loved it and were determined to experience more of the Down Under lifestyle. In 2008, they moved to Perth with two-year-old daughter Sydney and six-month-old son Dominic, to enable Brandolino to take up a position at the Australian Bureau of Meteorology.

After two years, he was lured back to Syracuse and took up a role as a TV weather presenter and co-host of a morning talk show.

The pace was frenetic. He would be at work before 3am to study the latest weather maps and compile the graphics for his forecasts, which started on air at 5am.

Then, the station decided the show would begin at 4.30am and he found his days starting even earlier. As early as 2am he was studying weather maps, and by now with another child – a daughter named Sofia – he worried family life was starting to pass him by.

The opening at NIWA provided the perfect opportunity to gain a better work/life balance, as well as the opportunity to once again experience life in a new country.

He arrived in January, towards the end of the traditional Kiwi summer shutdown. TV stations were screening advertisements advising their news shows would resume shortly after being off air for a few weeks. He was shocked. "That would never happen in the US."

His first few weeks at work were spent familiarising himself with the finer points of New Zealand. He studied the climate, Māori pronunciation and culture, and learned about historic extreme weather events such as the Wahine storm and Cyclone Bola.

NIWA's new forecaster, Chris Brandolino. (*Geoff Osborne*)

And as he puts it, he spent time with colleagues 'geeking out' about the weather.

Then came the Christchurch floods, ex-Tropical Cyclone Ita and drought in Northland. These gave Brandolino a much more immediate perspective of the kinds of climate that New Zealanders are exposed to.

At the beginning of May, NIWA introduced him to the media, when he took over the role of responding to media enquiries about its monthly climate summary and seasonal outlook.

On his first television appearance, he explained the likelihood of an El Niño weather system developing later in the year and delivered some good news on winter temperatures.

In June he was part of the team promoting NIWA's weather products tailored for farmers at the National Agricultural Fieldays at Mystery Creek, near Hamilton. NIWA is the official forecaster for Fieldays, and Brandolino provided hourly weather forecasts from the NIWA stage in the main pavilion, as well as introducing the new FarmMet forecasting service to farmers.

New Zealanders can expect to see a lot more of him – Brandolino plans to be wherever the weather is, explaining what's going on and why.

Look out for him. He's the one with the American accent and the long repertoire of weather jokes.

Shooting the breeze with Chris Brandolino

Do New Zealanders talk about the weather more than Americans? If so, why?

Funny, I've been asked that question many times since arriving in the country. I would say no. Kiwis, Americans, Canadians, Australians, all nationalities talk about the weather. And we all talk about it a lot!

What do you like about our weather?

Trying to figure it out and then communicating the information.

What does slip, slop, slap mean to you?

A good night! But I think it might have something to do with sun protection.

What's the best thing an American can do to adapt to the Kiwi lifestyle?

Learn how to not be so uptight.

What perplexes you most about New Zealanders?

Loaded question, eh? I've observed in people a puzzling mix of the celebrated Kiwi friendliness and a reserved nature that is sometimes surprising.

Auckland or Wellington?

Tough. Really tough. I do enjoy Auckland's climate. I LOVE the beach. However, I feel much more 'at home' in Wellington. Maybe it's because of where I grew up, Wellington seems more like a natural fit with my personality (climate, landscape, etc.).

What's the worst weather you've ever experienced?

Driving through heavy snow (where you literally can't see 30 metres) is frightening, I think the worst is the 1998 Labour Day storm in New York State. Wind gusts exceeded 190km/hr in some locations. I recall waking up to constant lightning at 12:30am and seeing a flag pole swaying left to right violently… and, for the first time, being legitimately scared during a thunderstorm. I was without power for an honest week.

You've also lived in Australia. Who's nicer, Aussies or Kiwis?

Ouch, another loaded question. Will this be read only in New Zealand? If so, then Kiwis, of course!

What's your favourite song that mentions the weather?

Some Like It Hot by the late, great Robert Palmer. I challenge anyone not to like it!

Follow Chris Brandolino on Twitter: @NiwaWeather

C-CALMing the waters

When Northland Regional Council (NRC) and Whangarei District Council (WDC) joined forces in 2011 to develop a wide-ranging strategy for improving water quality in Whangarei Harbour, they needed a reliable estimation of the contaminant load affecting the harbour, and an accurate analysis of where key contaminants were coming from.

"We needed to know which contaminants and catchment zones were really problematic in terms of harbour health," explains NRC Policy Analyst Ben Tait. "That knowledge would enable us to target the right areas with our strategy, and take effective mitigating actions."

NRC and WDC turned to scientists in NIWA's Urban Aquatic Environments Group for help. Dr Annette Semadeni-Davies applied NIWA's sophisticated contaminant load computer models to the task.

Highly valued

Whangarei Harbour is highly valued for the significant economic, environmental, recreational and cultural opportunities it offers to the people of Northland.

Local iwi source kai moana from the harbour's sheltered coves and bays. The 105km² body of water is an important nursery and feeding ground for commercial fish species, and supports a wide range of recreational pastimes. The harbour's diverse habitats include mangroves, saltmarshes, seagrass meadows, intertidal flats, subtidal channels, rocky reefs and sand banks.

Long-term monitoring by NRC has shown that human activity is placing increasing stress on the health of the upper harbour – the area closest to Whangarei City. At times, contaminant levels are elevated.

Semadeni-Davies used NIWA's Catchment Land Use for Environmental Sustainability model (CLUES – see niwa.co.nz/freshwater-and-estuaries/our-services/catchment-modelling) to estimate quantities of nutrients (total nitrogen and total phosphorus), total suspended solids (TSS) and faecal indicator bacteria (*E. coli*) arriving in the harbour from rural diffuse sources (those that cannot be attributed to a discrete source such as an outfall).

She then employed a recent addition to the NIWA toolkit, the Catchment Contaminant Annual Loads Model (C-CALM), to evaluate TSS loads, along with dissolved and particulate zinc and copper, originating from diffuse sources in urban catchments.

Stormwater outfall into upper Whangarei Harbour. (*Crispin Middleton*)

Great flexibility

"We've developed C-CALM as a toolbar for ArcGIS 10.1," explains Semadeni-Davies. "It's based on the Auckland Council Catchment Loads Model and relates the annual contaminant load from a particular source to the annual contaminant yield of that source, and the extent of the source within the stormwater catchment area.

"It partitions metals into particulate and dissolved forms, using pre-set particle size distributions to simulate the range of particle grain sizes for sediments from different sources."

C-CALM can then adjust the load to account for any treatment facilities, such as filters, wetlands, wet-detention ponds and catch-pits, lying between the source and the receiving body of water. It does this by querying a treatment performance library, which contains customised values for each treatment option and catchment characteristic. Model users can also specify their own level of contaminant for a generic treatment option.

"This gives the model great flexibility for assessing the effectiveness of different stormwater treatment options," Semadeni-Davies says.

C-CALM's results are supplied as grouped layers in ArcMap – allowing geo-visualisation of contaminant sources – and as a table, which can be copied directly into reports and other software for further analysis.

They proved exactly what NRC and WDC needed.

"The results have been very useful," says Tait. "They're likely to assist with assessment of potential contaminant load limits for the harbour catchment.

"C-CALM and environmental monitoring showed us that heavy metals are not a significant contaminant. Instead, high sediment-accumulation rates and reduced water clarity in some waterways draining into the harbour are more pressing issues in terms of impact on ecosystem health. That discovery is now informing our management planning."

Outputs from C-CALM and CLUES, adds Tait, showed the relative yields between urban and rural areas, "helping us to target more efficient sediment-mitigation actions".

Planned mitigating steps include an upgrading of the Whangarei wastewater reticulation network and treatment plant, and a continuing focus by NRC on promoting and supporting good practice among primary producers in the catchment area.

C-CALM is ideally suited to local authorities with water quality management in their mandate. It is freely available to non-commercial users.

Contact
Dr Annette Semadeni-Davies
Urban Aquatic Scientist
Email: c-calm@niwa.co.nz

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 and estuaries
- Māori development
- Natural hazards
- Environmental information
- Oceans
- Pacific rim

NIWA employs approximately 600 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 damselfly rests on a streamside leaf. (*Brian Smith*)

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