WATER & ATMOSPHERE

June 2017

The freshwater issue

What is happening to New Zealand's freshwater?

Raising the bar
How to measure swimmable rivers

Preparing for the worst
Samoa is tackling hazards head-on

Freaky critters
Surprises at an invertebrate collection

WATER & ATMOSPHERE

June 2017

Cover: This is a natural color satellite image of the Rakaia River in the Canterbury Plains in New Zealand's South Island. (*Satellite Imaging Corporation*)

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enhancing the benefits of
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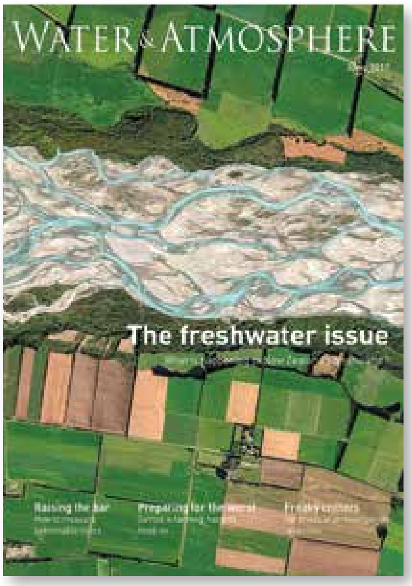

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In brief

Glacial pace

Using computer modelling, scientists from NIWA and Victoria University have uncovered why some New Zealand glaciers advanced between 1983 and 2008, but are now retreating again.

"We found that lower temperatures caused the glaciers to advance, rather than increased precipitation as previously thought," says lead author Associate Professor Andrew Mackintosh from Victoria University's Antarctic Research Centre.

"Some glaciers may experience small-scale advance over time due to regional climate variability, but overall they will retreat."

The research notes that New Zealand glaciers were very sensitive to temperature change.

"If we get the 2 to 4 degrees of warming expected by the end of the century, our glaciers are going to mostly disappear."

Glacier lakes in Aoraki/Mount Cook National Park. (*Fotolia*)

Big fish under threat?

World-leading research into the effects of climate change on yellowtail kingfish is taking place at NIWA's Northland Marine Research Centre.

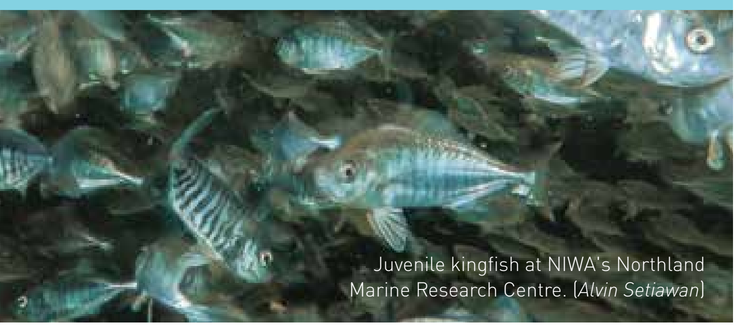
The study is the first of its kind and NIWA scientists were joined by renowned ocean acidification researcher Phil Munday and members of his laboratory from James Cook University in Queensland for the research.

Munday says, "We are working with yellowtail kingfish larvae in big tanks, replicating the warmer and more acidified conditions expected at the end of the century."

Until recently, ocean acidification research has focused on shellfish survival and adaptation. The effects of climate change on larger pelagic (ocean-going) species like yellowtail kingfish is yet to be fully understood.

"Kingfish are important, not just to commercial and recreational fishers in New Zealand and Australia. People throughout the Pacific rely on these fish for their daily sustenance."

Because of the size of the project, results from the trials won't be known for some months.



Juvenile kingfish at NIWA's Northland Marine Research Centre. (*Alvin Setiawan*)

Sounds of the Strait

The sounds of whales and dolphins rarely seen in New Zealand waters have been recorded by NIWA marine ecologist Dr Kim Goetz in a pioneering underwater sound project.

Last year, Goetz deployed seven acoustic moorings in Cook Strait to record the sounds of marine mammals. The moorings were retrieved in December 2016, and results from a preliminary investigation of the data have revealed some exciting findings.

Data shows what are likely to be the first recordings of some species of beaked whales in New Zealand waters. These included Cuvier's, and possibly strapped-tooth and Gray's beaked whales.

"Beaked whales are very elusive, deep-diving animals which can spend over an hour on a single dive and surface for a very short time, so they are not often documented", Dr Goetz says.

Cuvier's beaked whales were recorded at all mooring locations, including Queen Charlotte Sound.

Passive acoustic mooring deployment from RV *Tangaroa* in Cook Strait. (*Hamish McCormick*)

Old fish, new fish

A 20-day journey by NIWA's research vessel *Tangaroa* to the Kermadec Islands resulted in the discovery of many species either new to science or not previously found in the area.

On board were scientists from seven New Zealand organisations, allowing research to be undertaken from the intertidal zone of the islands down to 300 metres deep.

Two hundred and thirty-six fish species were recorded on the voyage. These included three likely new to science, 60 new records for the Kermadec region, and 20 new to New Zealand's Exclusive Economic Zone. More than 250 invertebrate species were also provisionally identified.

Voyage leader and NIWA fisheries scientist Dr Malcolm Clark says, "Because the Kermadecs is an area where there is no fishing, we are able to measure natural variability and natural change free from some of the main human influences that occur close to mainland New Zealand."

Callionymidae, Macauley Island, Kermadec Islands. (*Carl Struthers*)

Instrument shootout

The precision of NIWA's instruments was illustrated in February when the Dobson spectrophotometer based at NIWA's Lauder atmospheric research centre was put to the test against five other units from around the world.

The units had travelled from as far afield as Colorado and Japan to assemble on a Melbourne field for their five-year calibration against the regional standard.

The two-week shootout of the ozone testing units at the Bureau of Meteorology's (BoM) Melbourne facility showed Lauder's Dobson unit was within one per cent of the World Standard Dobson.

When the clouds parted, they started three inter-comparisons to test that the instruments met the standard for the international Network for the Detection of Atmospheric Composition Change.

The Lauder unit's performance meant no physical maintenance was required, only minor software updates. NIWA's Arrival Heights (Antarctica) Dobson spectrophotometer will be brought up from Antarctica for testing later this year.

Carbon uptake by indigenous forests

NIWA has submitted a proposal to the Marsden fast-start fund to investigate the signs of surprisingly large carbon uptake by indigenous forests.

Last year NIWA reported spotting fourfold higher carbon dioxide (CO_2) fluxes in the Fiordland region than previously estimated. NIWA atmosphere-ocean scientist Dr Sara Mikaloff-Fletcher says carbon uptake at these strong levels is usually associated with peak growth of recently planted forests and tends to slow as forests mature.

"This amount of uptake from relatively undisturbed forest land is remarkable and may be caused by processes unique to New Zealand or part of a wider global story."

Preliminary observations from New Zealand coastal and inland sites show that terrestrial carbon sink fluxes can be traced on regional scales. The proposal is to investigate further using a unique observational model that combines measurements of well-established isotopic tracers with the first southern hemispheric measurements of new isotopes.

(More: Water and Atmosphere, October 2016. https://www.niwa.co.nz/files/Water-and-Atmosphere-October-2016_web.pdf)

Sara Mikaloff-Fletcher. (*Dave Allen*)

NEWS

Kaikoura quake continuing to reverberate

The massive impacts of November's magnitude 7.8 Kaikoura earthquake continue to be unearthed, with NIWA's seafloor mapping off the Kaikoura and Marlborough coast revealing new fault ruptures.

After research showed that huge mudslides from the earthquake had wiped out all organisms living in the seabed of the Kaikoura Canyon, recent near-shore mapping conducted by NIWA and GNS Science scientists on NIWA's near-shore research vessel *Ikatere* revealed a previously unknown fault in the seabed about 10km northeast of Kaikoura Peninsula.

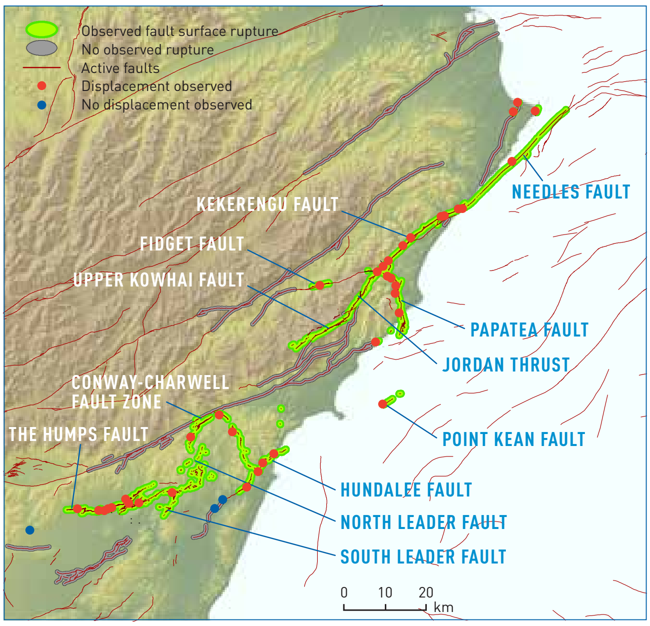
The new fault has been named the Point Kean Fault, after Point Kean at the tip of the peninsula. While it is not clear how much the fault moved during the earthquake, it is likely to be the fault responsible for the uplift around Kaikoura Peninsula.

To the north, the Papatea Fault rupture leaves land and breaks into a complex network of seafloor scarps up to 6m high that continue for about 5km offshore.

While movement on what is known as the Needles Fault, an offshore continuation of the Kekerengu Fault, had been detected by scientists on board *Tangaroa* shortly after the earthquake, the smaller *Ikatere* was able to get closer to shore and map it in more detail.

Rupture along the fault was traced along the seabed for a total of 34km, from Cape Campbell in the north to where it connects with the onshore Kekerengu Fault in the south.

The southern-most offshore fault, the Hundalee Fault, was mapped from where it enters the sea at Oaro to near the head of Kaikoura Canyon. Comparing bathymetry data to pre-earthquake data from 2013 showed a 2m-high scarp had formed in the seabed, but did not appear to go all the way into the canyon.



New fault maps track ruptures and landslides. (*NIWA*)

As well as mapping fault scarps, the NIWA scientists also mapped the seabed in the Kaikoura Canyon, just to the south of Kaikoura Peninsula, to determine any changes to its shape since the last survey in 2013.

This new mapping revealed that huge amounts of mud had been shaken from the top of the canyon, with more than 1000 landslide scars mapped along 30km of the canyon rim. This mud tumbled down into the canyon floor and flowed more than 350km along the deepsea Hikurangi Channel, wiping out all seabed organisms in its path.

A week-long investigation in January was funded by the Natural Hazards Research Platform. The project had two aims: to map the offshore faults ruptured when the earthquake happened, and to investigate changes to the slopes at the head of the Kaikoura Canyon, a renowned biodiversity hotspot and marine reserve area.

"In 2013, everything at the head of the canyon was smooth and draped in mud," said NIWA marine geologist Dr Joshu Mountjoy. "Our new data shows that the earthquake resulted in a huge slipping event. Almost every part of the upper slope had mud removed from it."

Dr Mountjoy said the amount of debris that cascaded through the canyon was massive.

"Some individual landslides are more than three times the size of the landslides that damaged the road to the north of Kaikoura."

NIWA marine ecologist Dr Dave Bowden said the impact was staggering.

"We surveyed exactly the same area we did in 2006 and, while fish were still found in the area, this time we didn't record evidence of a single organism living on or in the seabed over a stretch of nearly 6km. Nothing. It was quite sobering, and a catastrophic event for the ecology of the canyon."

However, Dr Bowden said the change in the canyon opened the way for important research.

"We suspect that events like this might happen every few hundred years in the Kaikoura Canyon. It will be very interesting to follow what happens from here, and I will be highly surprised if it doesn't regenerate."

Stuart Mackay

Hapū joins forces with NIWA in tuna research

Local hapū and NIWA are working together to find out more about juvenile freshwater eels or tuna in streams connecting to the Wairua River in the Wairoa catchment in Northland.

For six years, local hapū collective Ngā Kaitiaki O Ngā Wai Māori has been working with Northpower, NIWA, the Ministry for Primary Industries, Department of Conservation and other agencies to move juvenile eels over the dam as they swim upstream as part of their life cycle.

Ngā Kaitiaki O Ngā Wai Māori and NIWA are now looking at how the juvenile eels, moved over the dam, are surviving. Knowledge gained from the project will help Ngā Kaitiaki O Ngā Wai Māori and supporting agencies in their work to increase tuna populations in the Wairua River catchment.

"There's very little research being done in New Zealand to learn more about what makes stream habitats suitable for elvers, or juvenile eels, to thrive," says NIWA scientist and project leader Dr Erica Williams.

"The Wairua River area is like a living laboratory for elver research. So this project is going to be really useful. The more we know about elvers the more effective we can be in helping eels or tuna thrive, not just in this river, but in others around New Zealand as well."

Ngā Kaitiaki O Ngā Wai Māori representative Allan Halliday said there had been long-standing concerns about the declining tuna population.

"This is the result of changes to the landscape like the dam on the Wairua River. This project with NIWA combines mātauranga Māori, or Māori knowledge, and modern day science. We're blending our two cultures and working together so we can overcome the many obstacles facing tuna on a daily basis."

The four-year project involves monitoring elvers in streams connected to the Wairua River to assess their health and numbers over time.

The project is a component of a new research programme called Cultural Keystone Species, funded by the Ministry of Business, Innovation and Employment.

The Wairua elver research is also supported by the Living Water programme, a partnership between Fonterra and the Department of Conservation – which is working with dairy farmers, iwi, conservation groups, councils, schools and other agencies to improve the health of the Hikurangi sub-catchment.

Panorama: John Morgan

Raising the bar for swimmable rivers

The government recently released the 'Clean Water' package of proposed reforms, aimed at making more of our rivers swimmable. But how is 'swimmable' to be measured, and do these measures stack up?

When the proposals were released there was considerable confusion about the swimmable rivers component related to *E. coli*. Much of this confusion was centred around the proposed new way of grading microbiological water quality for swimming, and whether this would expose swimmers to greater health risk or not.

Given this confusion, and to help people make informed submissions on the proposals, NIWA prepared a report that independently analysed the proposal's technical merits.

NIWA has about 200 staff with expertise on freshwater, including a well-recognised world expert in this specialist area, Graham McBride. Graham and a US colleague with complementary expertise, Jeff Soller, were the ideal people to do this analysis.

Their technical report, released in May this year (see below), backed the government proposal to grade the suitability of rivers for swimming on the basis of how often they exceed *E. coli* thresholds.

They found that the Clean Water proposals would clearly raise the bar from the current minimum requirement (for wading quality) of a median *E. coli* less than 1000 per 100 millilitres to one of less than 130 per 100 millilitres to meet the proposed swimmable waters requirement.

In addition to meeting this median requirement, the Clean Water proposals introduce a grading system that determines a river's suitability for swimming, based on the proportion of time it is beneath *E. coli* thresholds that equate to various risks of infection. For example, the minimum threshold for swimming requires that for 80% of the time *E. coli*

iStock

concentrations are below 540 per 100 millilitres. This means that for a random swimmer on a random day the infection risk is no more than 3.1%.

> "Moving from the old wading water quality to the new swimming quality raises the bar significantly"

The report's analysis shows that under the provisions of the current National Policy Statement for Freshwater Management, 97% of measured sites comply with the minimum standard. However, under the Clean Water swimmable proposals only 43% of these sites would comply, and significant improvements would be required to raise this to the government target for 90% of rivers and lakes to be swimmable by 2040.

So, moving from the old wading water quality to the new swimming quality raises the bar significantly, but is the proposed swimming quality bar set at the right place?

In a comparison of different approaches to defining swimmable waters, the report concludes that the Clean Water proposals fall in the middle of approaches taken overseas. The Clean Water proposals are more stringent than the European approach, but less stringent than the United States (although there are caveats to these comparisons because of the different sampling and statistical approaches taken).

The report also compared the stringency of the Clean Water swimmable threshold with the equivalent in the current National Policy Statement (while recognising that the NPS does not actually have swimmable waters as a minimum requirement). This comparison shows that the Clean Water proposal is less stringent, with 43% of sites meeting its swimmable threshold versus 30% using the NPS swimming threshold. But then the NPS swimming threshold is set very high – equivalent to 'Excellent' in the EU system.

The report points out that Clean Water also proposes that when a single sample of *E. coli* is above a trigger threshold then authorities must alert the public and continue daily sampling until *E. coli* returns to acceptable levels. This requirement recognises that even in waters that are of high quality most of the time there may be short periods when *E. coli* levels are elevated and they are unsuitable for swimming.

Graham McBride and Jeff Soller's report was influential in shaping NIWA's submission on Clean Water, and it has helped many others as well. From my perspective, science-informed policy is always good policy.

John Morgan is Chief Executive of NIWA

Find the NIWA Technical Report at:
https://www.niwa.co.nz/sites/niwa.co.nz/files/Swimmability Paper10 May 2017 FINAL.pdf


Fotolia

Stepping into the river

NIWA discusses this year's most asked question – what is happening to our fresh waterways?

Dave Allen

No one in New Zealand is far from a river. This year, the most asked question is whether those rivers are swimmable.

This question has been part of what the Prime Minister's Chief Science Advisor, Sir Peter Gluckman, calls "a complex and at times confusing public discourse about freshwater."

One problem is that the swimmable quality of water is not the only, nor the best, measure of water quality.

Many of the more than 1000 waterways monitored by NIWA and regional authorities are degraded by human activity in many ways other than water borne pathogens such as strains of *Escherichia coli* (*E. coli*).

The type of degradation varies widely and wildly, depending on how people use land and how water drains to the river. In places, water is contaminated with sediment or nutrients. In others, there's chemical toxins. In still others, the water flow is altered, channel straightened and river routes modified.

Some of these things affect human safety. All of them affect the habitat of hundreds of species of fish, invertebrates and plants.

Gluckman says the "inevitable" human impacts, and the physical, chemical and biological characteristics, of fresh water are so great that "No single measure is sufficient to understand the state of freshwater."

Gluckman says there is no choice but to have "nuanced definitions [of water quality] that take into account what is an acceptable risk, consideration of the seasonal changes, [and] the relationship to extreme weather events."

The challenge to politicians and the public, to scientists and environmental and industry advocates is that the impacts of such complexity must be interpreted and communicated clearly.

This story starts to answer Sir Peter's challenge by identifying the myriad of ways we all contribute to degrading our waterways, and some of the solutions we can be part of.

NIWA's Freshwater and Estuaries team is led by Chief Scientist Dr John Quinn. New Zealand's longest river, the Waikato, flows past his Hamilton home on its journey from the clear upper reaches near Taupo to murky lowland.

Quinn says debate over the Waikato is a microcosm of the nation's struggle with water quality.

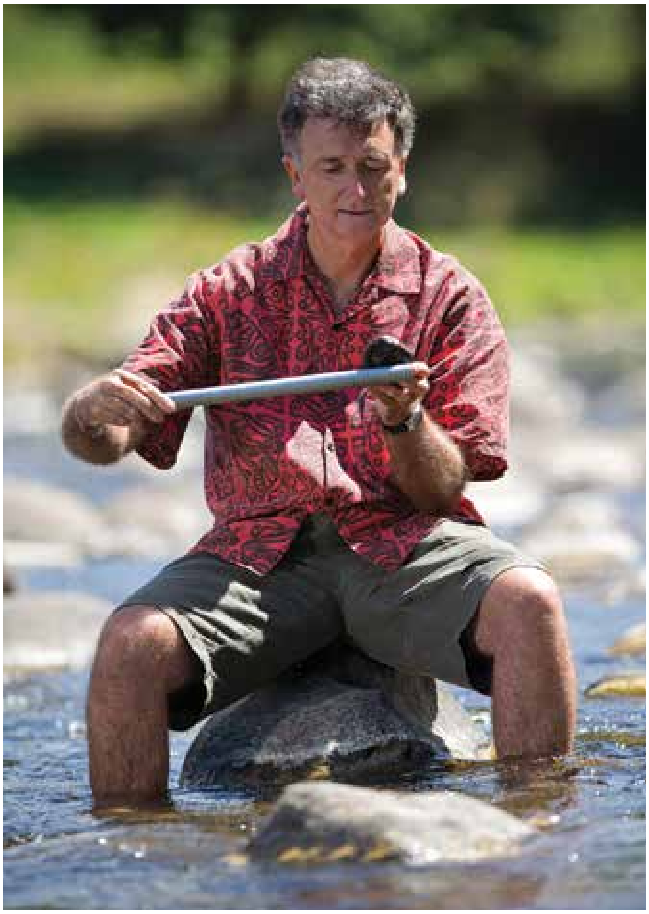
"People want healthy rivers and lakes they can be proud of – where they can swim and fish safely and know that ecological health is good. But many no longer meet the mark because of the way we have used the land and engineered rivers.

"Reversing this is challenging because society also values the things that put pressure on our freshwater.

"No one is removing the hydro-dams that interfere with flow of sediment, fish and water, but also generate clean and renewable energy, help to manage flooding, and provide a world-class rowing lake. We're not removing the roads and paved cities that flood rivers with contaminated storm water. We're not closing down agriculture, but we do expect lower footprint farming systems. Can we really expect to be able to have our cake and eat it too?"

The Waikato River drives nine hydro-power stations. It carries waste from 80 direct discharges such as treated town sewage, treated waste from factories, and 1600 smaller discharges into tributaries, and runoff from more than 2000 dairy farms in the Waikato and Waipa catchment.

- 'Swimmable' is a very incomplete measure of water quality.
- 1000 rivers are monitored by NIWA and regional authorities, and most are degraded in some manner at some point in their course.
- New Zealanders have changed rivers in many ways, some have been changed irrevocably.
- The damage is to quantity and quality of water habitats, as well as to water quality.
- Waterway quality is best measured by multiple factors; such as *E. coli*, ecotoxicity, clarity, nitrogen and phosphorus levels, and the health of plant, insect and fish populations.
- There will be hundreds of fixes, implemented by every New Zealander in their working and personal lives, along every stretch of waterway.



NIWA Chief Scientist, Freshwater and Estuaries John Quinn. Quinn's team took on the boldest attempt so far in New Zealand to test how well a river meets everything expected of it. (*Geoff Osborne*)

> **"Can we really expect to be able to have our cake and eat it too?"**

The quality of the Waikato River has been a concern for many decades. Impetus to do something about it came with the settlement of Waikato-Tainui's claim for the river and the iwi-Crown agreed Vision and Strategy that sets out an aspiration for its improved health.

The river has been witness to a large regional effort to reduce damage to waterways. Direct sewage discharge from Taupo township was stopped in 1995. Two-thirds of dairy farms have switched to land treatment of dairy effluent. It has been estimated that the Waikato River Authority has put $60 million into 170 restoration projects, including a million native trees planted along the river and its tributaries.

Quinn says "The real question is how to fix things so waterways can sustain what we want from them now."

Quinn's team took on the boldest attempt so far in New Zealand to test how well a river meets everything expected of it. Last year, NIWA worked with the Waikato River Raupatu Trust to compile a "report card" on the Waikato River for the Waikato River Authority.

Thirty subject experts from 10 organisations combined science with the views and knowledge of community interests to give the river catchment a C+ grade.

This was the average of the scores given to specific stretches of the river and its tributaries and lakes. The grades reflected measurements across eight different indicators: water quality, water security, economy, kai (food), ecological integrity, experience, effort and sites of significance.

"We regarded this a low grade, because it fell significantly short of people's expectations of a healthy river," Quinn says.

The murky big picture

Quinn believes the recent focus on what is "swimmable" disguises the complexity of the problem and its solution.

"Being swimmable is not a great measure of a river's overall health or quality. You can swim at Lake Ohakuri, for example, but it has lost its koura and has high mercury and arsenic levels in its sediments.

"Pathogens, indicated by *E. coli*, may directly hurt people, but there's a whole lot more human activity that's damaging flora and fauna.

"Aside from water quality, the four biggest pressures on water ecosystems are stress caused by invasive species like hornwort and koi carp, loss of natural connectivity due to

What is water quality?

Water quality refers to the physical, chemical and biological characteristics of a water body.

These determine how and for what purpose water can be used, and the species and ecosystem processes it can support.

Factors measured include pH, dissolved oxygen, suspended sediment, nutrients, heavy metals and pesticides.

Quality measurements can also include key biological and biochemical variables, such as invertebrate and fish composition, the abundance of algae, and oxygen demand. These provide broader measures of ecosystem health.

Multiple measurement variables are used in virtually all assessments of water quality, creating a rich picture of the state of the water.

In an attempt to rank sites and simplify communication, composite indices of water quality have been developed. While these indices can have their uses, they are problematic and can disguise specific problems within a waterbody.

barriers we've built along our rivers, flow and water level changes and riparian habitat damage."

The breadth of NIWA's work on freshwater gives an indication of the complexity and range of human impact.

For example, teams of scientists are working on ways to treat human wastewater in towns and on farms, installing fish passages in channelled waterways, reducing the flood of rain channelled by urban and road stormwater, calculating downstream impacts of water take, building wetlands and riparian strips to stop nutrients washing from farms, and halting the degradation of lakes by invasive exotic plants and fish, nutrients and fine sediment.

Good old days?

Is freshwater quality getting better or worse? The trends are mixed in data published for the period from 2004 to 2013.

"There's general improvement for contaminants like *E. coli* that get into water from surface runoff and stock in streams. There's between one-half and almost two times more sites that have improved over the last decade rather than degraded in *E. coli*, ammonium, clarity and dissolved phosphorus," says Quinn.

"Yet there are more streams deteriorating than improving in nitrate levels, which mainly travels via groundwater. There are 55% more sites with rising nitrate levels than those with improvements."

Quinn says people's recollections are often correct, but they sometimes have rose-tinted glasses when they compare rivers of their past with the current situation.

> **"people's recollections are often correct, but they sometimes have rose-tinted glasses"**

"Forty to 50 years ago a lot of rivers had serious pollution from very poorly treated point source sewage and industrial discharges. These are now largely cleaned up.

"When I studied the Manawatu River in the 1980s it had regular blooms of 'sewage fungus' and fish kills due to very low oxygen levels. The river was polluted by crudely treated sewage, and effluent from dairy and meat works.

"Back then people were not aware of cyanobacterial mats on the river bed, though they existed. Today, those things would generate bathing warnings and newspaper headlines."

Dead eels recovered from traps on the Manawatu River, 1984. (*Manawatu Evening Standard*)

Testing waters

With so many rivers, streams, lakes and wetlands, knowing exactly what is going on is a massive challenge.

Collectively, New Zealand's regional councils, unitary authorities and NIWA monitor more than 1000 river reaches and approximately 80 lakes. Data is periodically aggregated and analysed for national scale assessments of river and lake state and trends.

A river network

NIWA runs the National River Water Quality Network (NRWQN) – a network of 77 sites on 35 rivers that are evenly distributed over the two main islands of New Zealand.

The NRWQN river catchments together drain about half of New Zealand's total land area. Sites were selected so that a national perspective of state and trends of water quality could be developed. On most rivers there are two or more sites representing an upstream "Baseline" site (lightly impacted) and a downstream "Impact" site (reflecting the impacts of humans on water quality).

All the sites are monitored for water quality and biology either monthly, seasonally or annually.

Water quality is notoriously variable. NIWA environmental chemist Dr Neale Hudson says the fact that waterways are not monitored more regularly creates “a lot of holes in our nation’s cheese”.

“We’re missing a lot of what is going on in the waterways between sampling occasions and between sampling locations.”

However, Hudson says NIWA has cracked the practical and scientific challenges of continuous water quality monitoring.

Equipment has been converted to battery power and upgraded to communicate data and status by cellphone. Measuring protocols have been created to guide where equipment is placed, and for how long, to ensure accurate readings.

“No stretch of water is the same at any one time – making water measuring a complex business. But we’ve built systems that provide a lot of confidence in the results,” Hudson says.

If it’s not feasible to measure water quality everywhere, what do we do about the water quality in places where we aren’t sampling?

Linking predictive models, built from national monitoring, and the River Environment Classification has enabled a new approach to filling the spatial gaps in coverage of freshwater information between monitoring points, says NIWA environmental modeller Dr Doug Booker.

NIWA has recently released a free app – NZ River Maps (https://shiny.niwa.co.nz/nzrivermaps/) – that uses these

Neale Hudson analyses water quality using a scan spectrolyser. (*Dave Allen*)

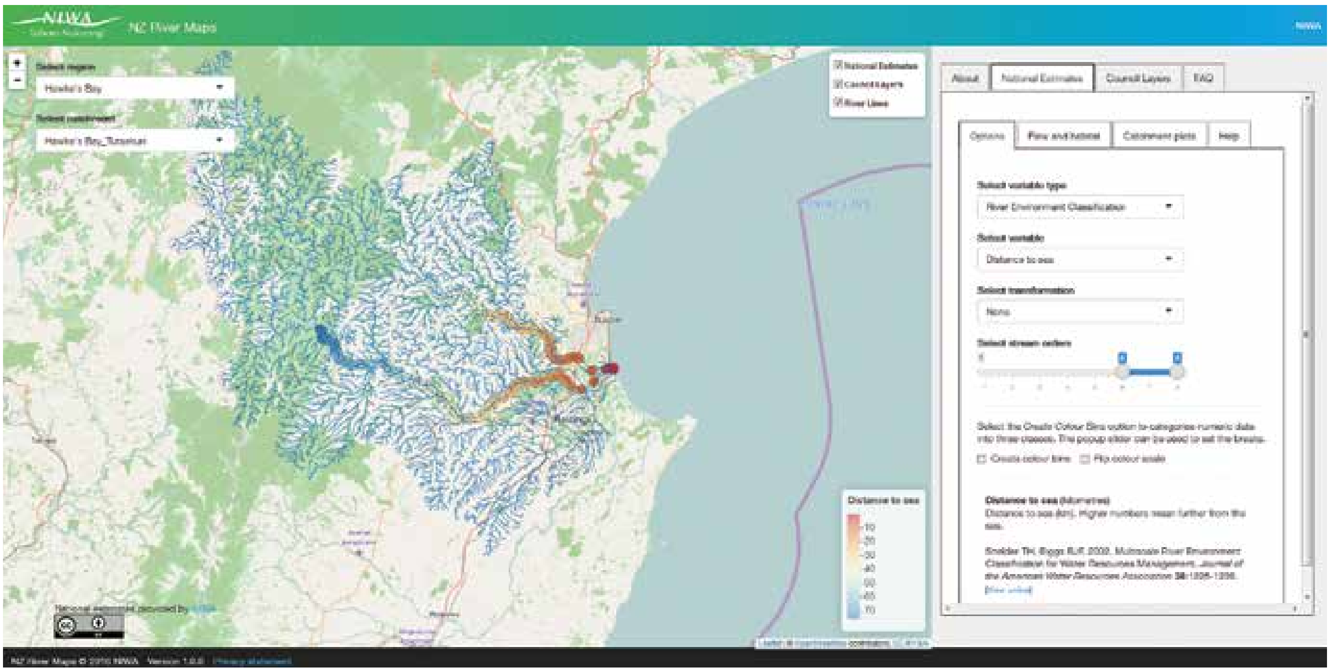
model predictions to show patterns across New Zealand’s rivers in about 100 attributes covering hydrology, water quality, fish distributions, invertebrate metrics, suspended and deposited sediment and fish and bird habitat.

No more assumptions

Dr Scott Larned, NIWA’s Manager of Freshwater Research, is looking even further ahead to understand the ecological processes that muddy the picture of our human impact.

“You can’t fit a river inside a test tube. We can’t yet run tests that replicate everything that happens in a river, and how that changes moment to moment.”

A recent paper by NIWA scientists analysed streams from which dairy stock were excluded by fencing. Even where stock had been excluded for years, positive responses in aquatic communities were generally weak.



An example of NZ River Maps display of predicted median Total Nitrogen concentrations across third order and larger REC river reaches in the Ahuriri, Ngaruroro and Karamū catchments. (*NIWA*)

Stepping into the river

"It's common sense that exclusion stops direct waste input and habitat destruction by livestock. However, some sediment and nutrients still get into rivers in other ways.

"The legacy of decades of erosion, fertiliser and pesticide use, urban development and other activities may take decades to clear. The sensitive species that have been lost need to recolonise and compete with the tolerant, weedy species that have moved in – so ecological recovery can lag behind improvements in water quality and habitat.

"The links between specific activities and ecological conditions in freshwater are often unclear. There's a shortage of cause-and-effect relationships. Those relationships are needed to predict effects of future activities, including restoration. They provide evidence for making land management recommendations."

Larned thinks timeframes for improving water quality can be shortened by moving from assumptions about human impact on land cover (bush, plantation forest, pastoral and urban) to measurement of specific activities on each block of land.

"When we link what we see in the water to exactly what we're doing on land we will get much better at understanding water quality problems and how to reduce and prevent them."

A new measure of water

Quinn thinks the "swimmable" test is the first in a series of measurements that will become familiar to the public.

Scott Larned, Manager Freshwater Research says the ecological timescale of water defies human demand for quick answers. (*Dave Allen*)

"Water is too critical to our lives to be satisfied by superficial questions and simplistic answers. You cannot use one measure to determine the state of a very complex system.

"It's all connected. That creates deep issues we're just unravelling. But it means that every action we take can have multiple benefits, if we are strategic.

"We've got to consider multiple things in the water, and the habitat around it."

He says this more holistic view of the health of our freshwaters needs to include measurements of ecotoxicity, clarity, nitrogen and phosphorus levels, flow regimes, economic uses, ecosystem services, cultural values and the health of plant, insect and fish populations.

About 200 NIWA staff have expertise in freshwater

Some of NIWA's Hamilton freshwater scientists (from left) – Andrew Swales (Estuarine Physical Processes); Fleur Matheson (Aquatic Biogeochemist); Neale Hudson (Environmental Chemist); Cindy Baker (Freshwater Fish); Mary de Winton (Freshwater Ecologist); Rupert Craggs (Aquatic Pollution); Brian Smith (Freshwater Biologist). (*Dave Allen*)

> **"We all impact on fresh water. There will be hundreds of fixes required, and each of us will need to be involved"**

He predicts the measurements will be used by communities doing their own versions of the Waikato River report card.

"The report card method identifies and balances all our uses – economic, environmental and cultural," Quinn says.

"We cannot pin blame and remedial work on just one section of society. We all impact on fresh water. There will be hundreds of fixes required, and each of us will need to be involved."

For further study

- The river monitoring network: https://www.niwa.co.nz/freshwater/water-quality-monitoring-and-advice/national-river-water-quality-network-nrwqn
- Map on swimmable locations: https://www.lawa.org.nz/explore-data/swimming

Water everywhere

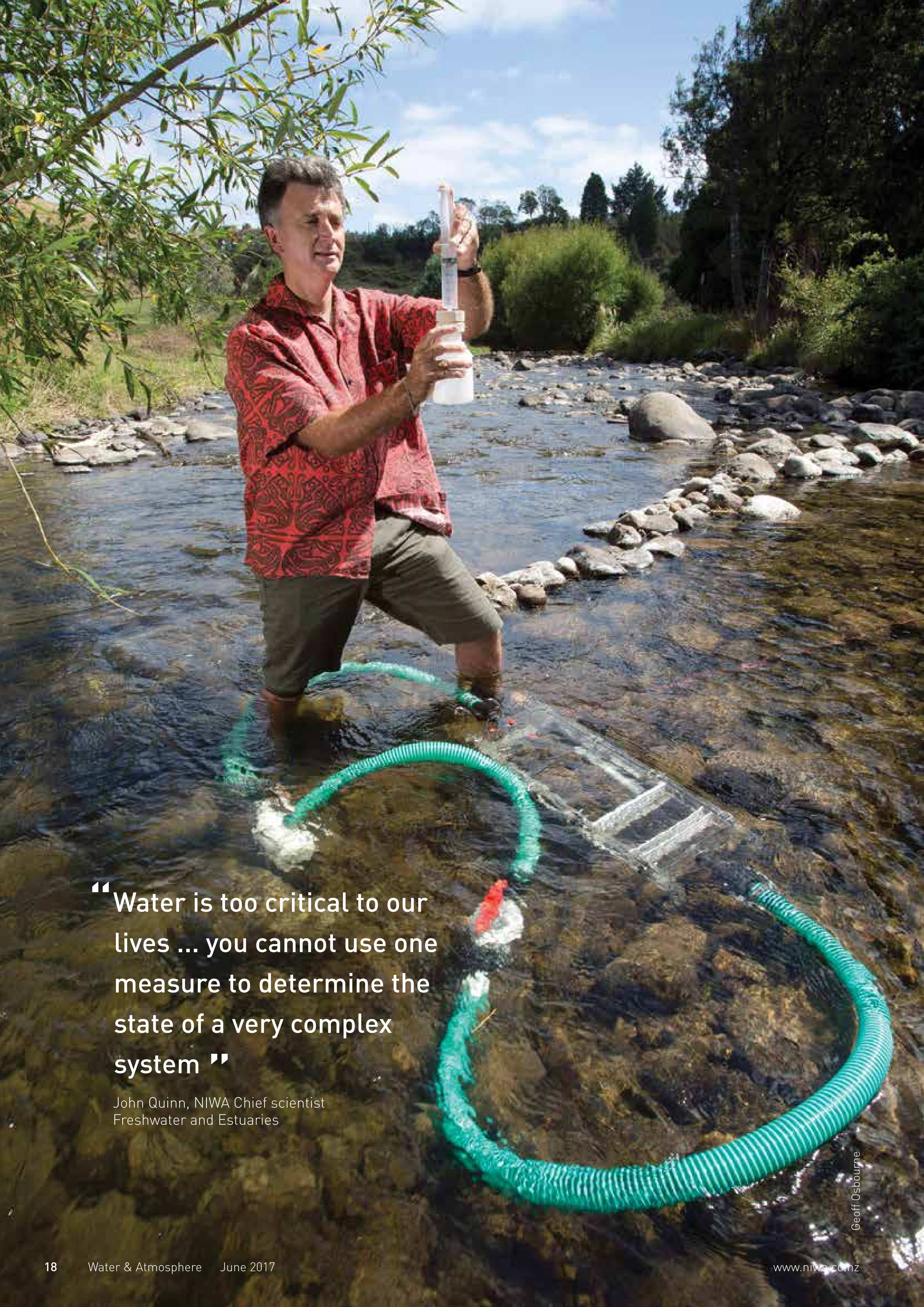
New Zealand has one of the highest volumes of water per capita flowing to the sea through some of the shortest waterways in the world, over the course of days rather than months (unless dammed).

The flow rate changes dramatically due to rain, and the water often passes through an extreme range of geography – from mountain, bush, forest, pasture and towns.

And there are other complications – water is not uniformly spread and much of it is in places where people are few (like the West Coast), flows are highly variable over time and predicted to get more so with climate change, and water that is available for use after allowing for environmental values is often fully-allocated (sometimes over-allocated) in the drier regions of the east coasts of both islands and Northland.

About half of New Zealand's river length is fed by water coming from largely indigenous land cover, while 45.7% comes from pasture land, 5.1% by exotic forest and 0.8% by urban land cover.

Some of NIWA's Christchurch freshwater scientists (from left) – Doug Booker (Hydro-ecological Modeller); James Griffiths (Hydrologist); Mandy Home (Te Kūwaha); Phil Jellyman (Freshwater Ecology); Murray Hicks (River Geomorphology); Amy Whitehead (Quantitative Freshwater Ecologist); MS Srinivasan (Hydrologist). (*Dave Allen*)



> "Water is too critical to our lives ... you cannot use one measure to determine the state of a very complex system"

John Quinn, NIWA Chief scientist
Freshwater and Estuaries

Geoff Osbourne

Dairy turns the corner

John Quinn believes the dairy industry has been responsive in the tools it has adopted to reduce its impact on waterways.

"There has been a lot of improvement in dairy industry practice in the last 15 years.

"Dairy shed effluent management has improved and is more professional, and the majority of streams on dairy farms are now fenced to exclude cows.

"Things like the Farm Enviro Walk Toolkit and Sustainable Dairying Water Accord have increased adoption of a range of good environmental practices. These advances have been industry-led, rather than driven by government rules."

Quinn notes, however, that the reduction in impact per farm has been offset by the expansion of dairying into areas that used to be dominated by drystock farming, which generally has a smaller footprint.

That is why Quinn still thinks the single biggest thing that can be done to improve our environment is to reduce the footprint of agriculture to both meet the nation's greenhouse gas reduction commitments and improve freshwater quality and ecosystem health. And to incentivise this by finding high value markets that will pay for the value of advanced environmental practices and associated healthy food.

"It's a big 'single thing' to complete, but without that level of strategy the little things any of us do won't really matter," he says.

Dave Allen

Kaniwhaniwha riparian buffer, Waikato region. (*John Quinn*)

In the shade

More than 97% of streams running through dairy farms are now fenced, so cows are out of waterways.

Waterways are still receiving *E. coli* and *Campylobacter* from other unfenced stock and wild animals. They're also getting microbial pathogens from land runoff when it rains. A 2005 NIWA study found that rain can wash a million to a billion *E. coli* bacterium per square metre of hillside into streams.

Riparian strips can help. These are the areas where plants grow alongside streams. They trap and absorb nutrients and microbes, including *E. coli*, in surface water. In the best conditions, riparian strips can remove at least 60% of nitrogen and 65% of phosphorus from runoff and groundwater.

There's even more to riparian strips than the benefits to water quality.

Trees holds together river banks, which stabilises them as habitats for insects and prevents silting and cloudy water that disturbs fish. The shade of trees creates cooler and more humid conditions, which insects need, and prevents over-growth of plants in the stream. Their branches and leaf litter provides direct habitat and food for many of the insects that like riverside conditions for only parts of their life stages, particularly larval, before moving to other habitats.

NIWA has recently started two new programmes looking at riparian management.

One project will work with highly trained and supported citizen scientists to use existing riparian restoration projects as a "natural experiment" to identify design features that result in success over the next four years.

The other will develop riparian and constructed wetland design methods that achieve better water quality outcomes while minimising implementation costs. It will focus on the known hotspots of runoff and transport of contaminants.

Mawaihakona Stream Restoration group, Upper Hutt. (*Allan Sheppard*)

Citizen swim test

People are becoming alarmed to find water quality warnings in largely populated spots where councils conduct regular microbial testing.

Resource limitations mean that not all spots on a river can be checked, and it's often up to the public to use their own judgment as to water quality.

"This is particularly a problem for rivers where potentially toxic algae (cyanobacteria) can be present in numerous places," says NIWA Resource Management Scientist Juliet Milne.

"Public concern about the quality of our rivers and lakes has led to increasing interest in water management and monitoring – there is a growing move towards 'citizen science', with community groups wanting to do their own monitoring," says Milne.

Community groups want to measure real-time changes in a waterway's appearance such as rubbish present, odour, deposited sediment, and nuisance plant growth, which all influence perceptions of water quality and "swimmability".

"Ultimately, monitoring will better reflect what people care about," says Milne.

NIWA is educating community groups and local residents on how to monitor waterways in the regions. Since the 1990s, NIWA has provided environmental community groups and farmers with the NIWA-designed Stream Health Monitoring and Assessment Kit (SHMAK) to self-monitor waterways.

NIWA recently updated the kits to include an *E. coli* test for use in a study testing the efficacy of community monitoring. The results from community monitoring efforts in nine regions were then compared with regional council-collected data.

> "... there is a real role for citizen science in New Zealand"

"The results matched well enough to show there is a real role for citizen science in New Zealand," said NIWA Freshwater Ecologist Dr Richard Storey, who has conducted extensive research into community-based monitoring of New Zealand streams.

"Councils can only afford to monitor waterways on a limited basis. There are more than 600 volunteer environmental care groups in New Zealand and there is an increasing desire to take positive action, including monitoring. By empowering community groups to undertake testing themselves, and providing them with testing equipment, we can increase the amount of accurate monitoring around the country."

NIWA is now working on an app that will allow users to upload monitoring data from mobile devices to a purpose-built public website providing real-time, user-friendly information about water safety and swimmability.

Nature knows best?

Returning water to our waterways after we've used it in our homes, on farms and in industry is a complex and challenging process.

Large centres have traditionally employed mechanical treatment systems to clean up wastewater. These systems are able to process large volumes, but the flipside is that they are expensive to build and have high operational costs.

For smaller centres, that's a problem. Oxidation ponds have been the go-to solution for small and medium-sized communities for the past 30 years. Relatively cheap to build and easier to maintain, these work well at removing suspended solids and lessening biochemical oxygen demand. But the problem is they're highly inconsistent when it comes to removing pathogens and nutrients.

NIWA has been working to take the pond concept to the next level, with work on developing and improving smaller scale, eco-tech wastewater treatments.

"Oxidation ponds have been a great workhorse for New Zealand," says Dr Rupert Craggs, Principal Scientist - Aquatic Pollution. "But now our aspirations for water quality are so much higher."

NIWA and the Waipa District Council are working together to demonstrate the use of enhanced pond systems to achieve cost-effective, efficient wastewater treatment. At the Cambridge wastewater treatment plant, the use of two one hectare shallow ponds has been shown to maximise algal productivity and nutrient removal.

Given the system requires a comparatively large land area to work, smaller communities with land available stand to gain most. And, as well as the land requirement, there's another variable – the sunlight that fuels the processes involved in cleaning up wastewater.

"Because it's a natural system reliant on sun-driven power, the caveat is that there can be variation with seasonal conditions," says Craggs. "Our focus is now on designs to take this into account, and considering additional treatment elements."

But what of water quality? Can a natural wastewater treatment system trump a mechanised plant?

"A natural system can be designed to perform as well as a mechanised system, and better in some cases. There's also the co-benefit of recovering resources from the wastewater (such as bio-gas) as well as providing treatment."

The Cambridge Wastewater Treatment Plant uses NIWA-developed technology to cost-effectively treat, and recover energy and nutrients from, wastewater. (*Jason Park*)

Toxic mix

In the early 20th century, coal miners used canaries in mines as an early-warning signal for the dangerous build-up of toxic gases.

The birds, being more sensitive to toxic gases than humans, would develop symptoms of carbon monoxide poisoning well before the miners, who would then have a chance to take action to protect themselves.

Technology has advanced a long way since then, but bioassays – measures of how potent a substance is by its effect on living cells or tissues – continue to be a critical measure of the impact of contaminants on various environments.

> "Coal miners used canaries in mines as an early warning signal ... technology has advanced a long way since then"

In NIWA's freshwater ecotoxicity testing work, a range of organisms including invertebrates, fish and algae, are exposed to different concentrations and combinations of contaminants in laboratory conditions to gauge response.

"This allows us to establish thresholds for short-term lethal exposure, for example, to longer term sub-lethal impacts on lifecycles," says Dr Chris Hickey, NIWA Principal Scientist - Ecotoxicology and Environmental Chemistry.

"The key thing is that it provides solid numeric data on how much (contamination) is too much and the diagnostic tools needed for toxicity identification."

While testing informs the development of water quality guidelines, one of ecotoxicology's greatest values is in its application to monitor the impact of specific stressors in site-specific situations. It is increasingly being used to provide reliable information to industries trying to meet their resource consent requirements under the Resource Management Act.

That is no surprise given how New Zealand's vast network of waterways are subject to a wide range of usages and resulting stressors. Freshwater is used in commercial, industrial, residential and recreational situations, and waterways can be affected by multiple contaminants from many different sources.

"There isn't a one-size-fits-all (test) for all environments," says Hickey. "Bioassays using both standard and native species tests complement other biological monitoring techniques used to establish the health of New Zealand's aquatic ecosystems".

Bankwood (Kukutaruhe) Stream fish pass, Hamilton. (*Jacques Boubée*)

Free passage

Tide gates stop fish from accessing 1100km of waterways in the Waikato River catchment. Thousands more kilometres are made inaccessible by other structures such as culverts, weirs and dams.

Nationwide, there are likely tens of thousands of structures in our rivers, with between 30% and 50% of these structures impeding migration of fish in some way. The result is fewer fish in our rivers.

NIWA Freshwater Ecologist Dr Paul Franklin sees the problem first-hand in his work.

"We see fish massing by human barriers, trying to continue their upstream movements. A few make it past, but many do not. Some will find alternative habitats, but many are eaten. You often see shags collecting fish below the barriers."

Some native fish are more affected by migration barriers than others. Inanga (*Galaxias maculatus*), the main whitebait species, are weak swimmers and cannot climb. They are highly susceptible to being blocked by in-stream structures. However, koaro (*G. brevipinnis*) and juvenile eels (*Anguilla australis* and *A. dieffenbachii*) are very good climbers and can even make their way past waterfalls.

Franklin says the good news is that there is almost always a way of building new structures in a more fish-friendly way, and to retrofit existing structures to allow more fish past.

"We helped design and install a rock fish ramp and baffles where the Bankwood (Kukutaruhe) Stream was piped into the Waikato River in Hamilton. Within a year, the number of fish species upstream of the culvert had doubled and there are now many more fish in the stream."

Providing fish passage is required by law and many regional regulations. The Tasman District Council has recently made it mandatory to fix fish passage at all existing culverts.

"We've known the importance of providing fish passage for decades, but designing effective fish passes for our native fish has been challenging," Franklin says.

"A big problem has been the gap between ecologists and engineers, but we're now doing a better job of speaking the same language."

NIWA and DOC are currently drafting fish passage guidelines that will help policymakers and engineers with the best methods of constructing fish-friendly structures.

NIWA is part of a national advisory group leading the development of new resources to improve management of fish passage.

A new research project just underway will improve understanding of how and why fish behave at structures. This will help us do an even better job of building fish-friendly structures in the future.

Flipping lakes

As freshwater storage and supply sources, New Zealand's lakes serve as critical gauges of the overall health of many water catchments and ecologies.

There's good news and bad news in what these gauges are revealing, says NIWA Chief Science Advisor Dr Clive Howard-Williams.

"While about one-third of our monitored lakes are ranked good or very good, and one-third are ranked moderate in terms of ecosystem health, we have a long way to go to restore the one-third that are ranked poor or very poor. Most of these are in lowland areas.

"There are some grounds for optimism in that over the past 10 years of monitoring, more lakes have shown improvements than have worsened."

The introduction of pest fish species, aquatic weeds and nuisance algae had seriously undermined the ecological health of lakes.

"Aquatic weeds have impacted on the native vegetation of lakes in the high country as well as lowland New Zealand, and the lake edges, or littoral zones, have been most impacted," says Howard-Williams.

"Pest fish such as koi carp and catfish prey on native species and in some cases have markedly contributed to declines in ecosystem health."

Coastal lakes and the shallow lakes of the Waikato were in particularly bad shape.

"Lakes reflect land use in a catchment and can also modify downstream aquatic systems. The shallow lakes of the Waikato, for example, have suffered from excessive nutrient inflows from farming in their catchments and, in particular, from pest plants and fish that have significantly altered lake habitats."

NIWA is working with a range of partners on a series of research programmes aimed at improving the health of New Zealand lakes, says Howard-Williams.

"NIWA is looking at improved catchment management where lakes are receiving waters in the catchment. Some of this is directly funded through the National Science Challenge 'Our Land and Water', which seeks to minimise environmental effects in an improving agricultural economy."

Monitoring lake ecosystem health. (*Rohan Wells*)

Calculated risk

Imagine if you could foresee what would happen to your home in a severe flood or tsunami, and then work out how to prevent or reduce the impact before any such event occurred.

That's what NIWA and GNS Science's joint RiskScape tool does for suburbs and whole cities.

Sadie Mills

Dave Allen

The power of the RiskScape tool in supporting risk-based decision-making explains why NIWA is leading a three-year project to tailor RiskScape to weather and geological hazards threatening urban areas and infrastructure in Samoa and Vanuatu.

RiskScape is already used in New Zealand to forecast economic and human impacts of disaster events, such as earthquakes, flooding and tsunamis. It identifies how to reduce risks through developing plans, strengthening infrastructure, building barriers, or buying insurance.

The tool converts asset and hazard information into likely impacts on a locality or region – calculating, for example, likely building damage and replacement costs, human casualties, economic losses, business disruption, and the numbers of people injured and displaced.

NIWA project leader Dr Kate Crowley says the Samoa and Vanuatu project is no ordinary tailoring task.

"We will use the process of tailoring RiskScape to understand their specific country issues and needs, and teach people how to use and adapt it themselves in the future."

An early phase of the training has been visits to New Zealand by disaster management officers from Vanuatu and Samoa, in which they have been introduced to RiskScape.

Crowley says this will be the first time that RiskScape has been used for drought and tropical cyclone impact forecasting. It could lead the way towards rapid and targeted emergency response in the Pacific and in New Zealand.

"There is a significant lack of hazard-informed planning, which time and again leads to loss of homes, livelihoods and, in the worst-case, lives.

"It is exciting work, because timely information about potential hazard impacts can save lives."

Stefan Reese

Kate Crowley, leading a RiskScape project in Vanuatu and Samoa. (*Dave Allen*)

Six of the best

Helping Pacific partners fine-tune RiskScape for their own purposes is not the only challenge of the three-year programme. RiskScape will be tailored by applying it to real-life risk reduction.

Crowley visited Vanuatu and Samoa in September last year to hold two-day workshops to identify which hazards the government felt best suited to the tailoring exercise, and which risk-reduction issues they really wanted to crack. A wide range of stakeholders were invited to each workshop – from national planners and infrastructure providers to emergency services.

They considered the purpose of impact modelling, the demands of scenarios covering multiple events at the same time, the types of assets most valuable and most at risk, and how information would be best delivered.

"The result of the conversations is that we will tailor the tool by applying it to six of the toughest risk-reduction issues," Crowley says.

Samoa chose to tailor RiskScape by applying it to tsunami risk and loss modelling for response planning; near real-time impact forecasting for tropical cyclones; and landslide risk round Mt Vaea for development planning.

Vanuatu's case studies were looking at the impact of volcanic ash on Tanna Island; tropical cyclone impact; and impact forecasting for agricultural production from drought and extreme rainfall.

The case studies will be co-developed and implemented over the next two years of the project.

PARTneR is being funded through the New Zealand Partnerships Fund administered by the Ministry of Foreign Affairs and Trade, and is managed by NIWA in collaboration with five partners: the Samoa Disaster Management Office; the Vanuatu Disaster Management Office working with the Vanuatu Meteorology and GeoHazards Department; GNS Science and the Pacific Community – Geoscience Division.

Preparing for the worst

By Sally Laven

Titimanu Alain Simi was a young boy when two deadly cyclones hit Samoa in quick succession.

Tropical Cyclone Ofa struck in 1990, killing seven people on the islands. Eighteen months later, Tropical Cyclone Val hit, leaving 16 people dead across Polynesia, crops ruined and eighty per cent of Samoa's homes damaged.

The tall, quietly spoken Samoan remembers the rush to get to a secure shelter after his house, its roof leaking, flooded in the night.

"I remember my dad and my uncle having to take us kids, carrying us to the church in the rain and wind. They tried nailing down the roof, but it was hopeless."

Some years later, at university in Fiji finishing his Bachelor of Environmental Studies, Titi recalled his shock at seeing the images of the devastation left by the tsunami which swept onto Samoa in 2009.

"The scale of the disaster really affected me," said Titi, who was relieved his immediate family lived inland and were unhurt.

"It was something new that we hadn't experienced before."

Titi returned to Samoa the following year and was affected by the stories he had heard about the utter devastation many had experienced. This included his relatives, whose beach resort on the south coast was completely flattened by the disaster and a tourist killed.

Now as a Disaster Management Officer with Samoa's Ministry of Natural Resources and Environment, Titi is helping to prepare his country for future cyclones and other natural hazards.

He spent several weeks at NIWA in Wellington learning how RiskScape works and how it would be used in Samoa to help forecast the impact of cyclones and tsunamis, and reduce the risk of landslides on Mt Vaea, the mountain overlooking the Samoan capital, Apia.

Titi said RiskScape came at a pertinent time for the Disaster Management Office, which had been working to ensure all government bodies included risk planning in their policies.

"I think this tool will help enhance that and also strengthen collaboration between ministries."

Titi is looking forward to utilising RiskScape during the formulation of development plans for the slopes of Mt Vaea.

If a major landslide occurred on the mountain, not only those living there would be affected. Businesses, infrastructure and people in Apia might also be hit.

NIWA is helping Samoa plan to avert the disasters caused by cyclones and tsunami. (*Graham Smart*)

Titimanu Alain Simi. (*Dave Allen*)

Titi said data collection and consultations had already begun among the growing number of settlements on Mt Vaea.

"A lot of the families requested better drainage, better roads. So, with the information this tool can produce, it will certainly support putting these things in place and can also help inform regulations and policies.

"For example, if someone wanted a permit to build a new house, consideration would be given to the risks illustrated by the tool."

Titi said one of the main challenges over the next couple of years would be just getting everyone on board back home.

"Getting data from relevant partners can be quite a challenge, so I guess the challenge for me will be to convince people they should."

But he did not anticipate it would be too difficult.

"They say a picture is worth a thousand words. For example, we can have a map and highlight areas where landslides can occur and show them this is what will happen.

"I'm still learning about the tool. The more I learn, the more ammunition I'll have to convince people to take this on board."

The collaboration with NIWA also involves training local staff how to use RiskScape.

"One of the good things about the project, one of its core components, is to train the local people back home to use the tool," said Titi.

"We will firstly need to know what kind of data is needed and why, and as we move on to the next stage of the project we will learn how to use the tool.

"The challenge for me is to sell the tool, but once people understand what it's for and what it can do for us, I'm confident they'll be on board and see its importance," said Titi.

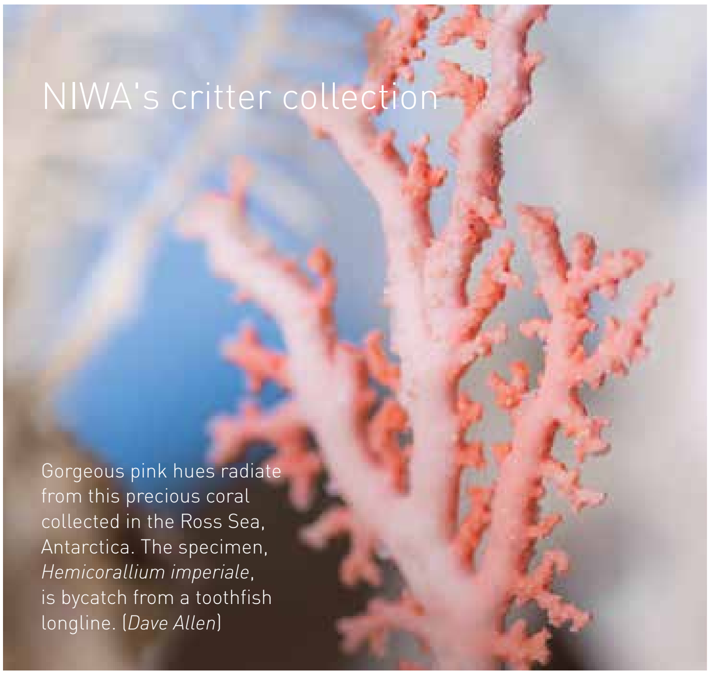
"It's a powerful tool and it will certainly mean better informed decision making."

"Yikes!"

What happens when the public encounter critters at NIWA's National Invertebrate Collection ... in pictures.

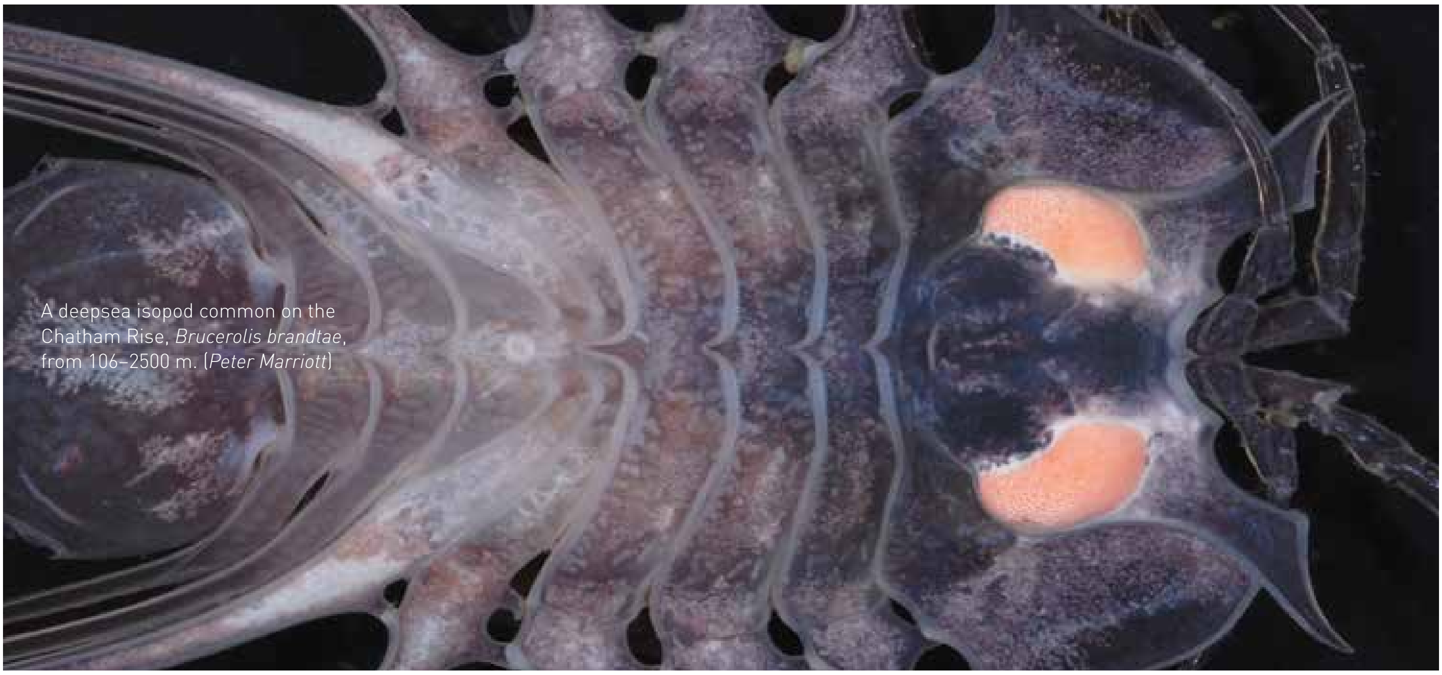
A hermit crab found on muddy sea floor 247m deep in the middle of the Chatham Rise. (*Peter Marriott*)

NIWA's critter collection



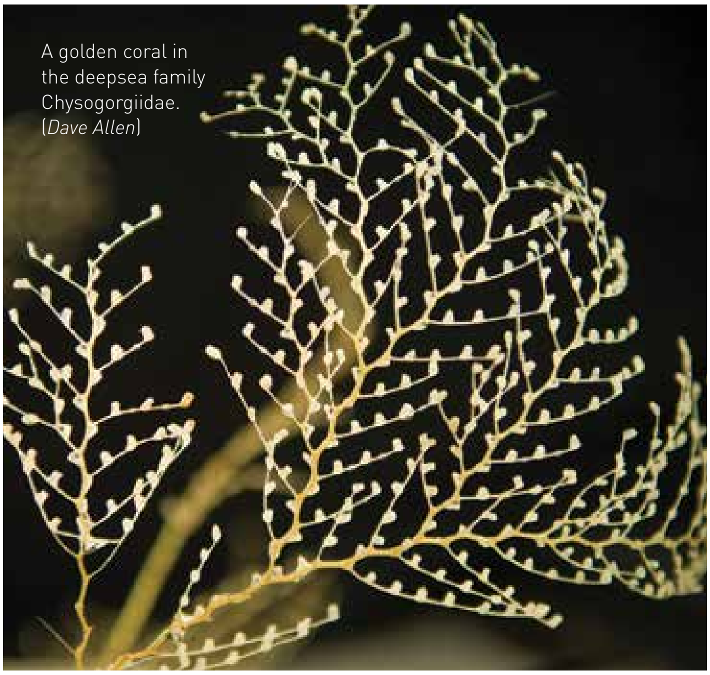
Gorgeous pink hues radiate from this precious coral collected in the Ross Sea, Antarctica. The specimen, *Hemicorallium imperiale*, is bycatch from a toothfish longline. (*Dave Allen*)

The snake star *Asteroporpa australiensis* on its host primnoid coral, *Perissogorgia vitrea*. These specimens were collected in the Bay of Islands at 65m. (*Peter Marriott*)



A deepsea isopod common on the Chatham Rise, *Brucerolis brandtae*, from 106–2500 m. (*Peter Marriott*)

An unnamed deepsea octopod from 400m on Rumble III seamount on the Kermadec Ridge. (*Rob Stewart*)



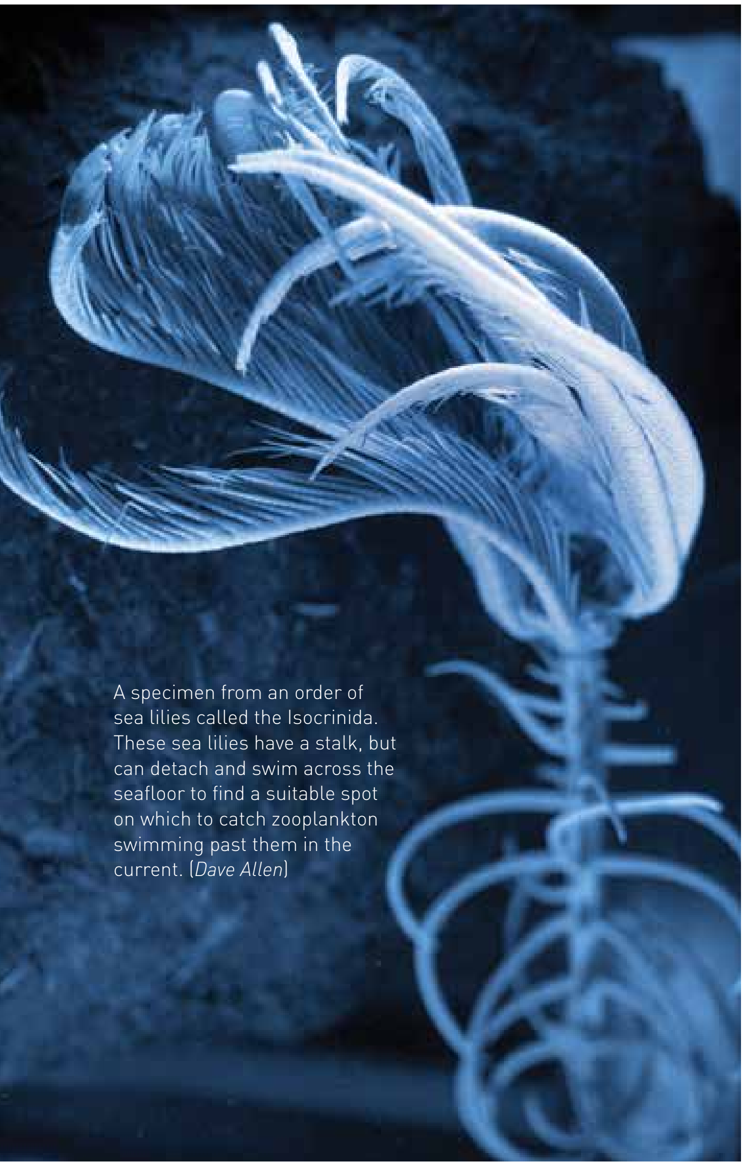
A golden coral in the deepsea family Chysogorgiidae. (*Dave Allen*)

NIC Collection Manager Sadie Mills shows a collossal squid beak to students from the WHOI Sea Education Association. (*Dave Allen*)

Marine Biologist Dr Kareen Schnabel shows Science and Education Committee members a specimen of the Ram's Horn squid, *Spirula spirula*. (*Dave Allen*)

NIWA's critter collection

A hermit crab with an associated anemone-like zoanthid hexacoral, *Epizoanthus paguriphilus*, growing over its shell. These species are widely distributed around the NZ EEZ from 500 to 2000m deep. (*Peter Marriott*)



A specimen from an order of sea lilies called the Isocrinida. These sea lilies have a stalk, but can detach and swim across the seafloor to find a suitable spot on which to catch zooplankton swimming past them in the current. (*Dave Allen*)

A future marine biolgist holds a giant sea slater *Bathynomus giganteus*. (*Paddy Bleakley*)

The NIWA Invertebrate Collections Team: marine biologists Caroline Chin, Sadie Mills, Dean Stotter, Diana Macpherson. (*Dave Allen*)

Another way to measure river health

There's another way of measuring the health of rivers – the health of invertebrate populations that need them, says John Quinn, NIWA Chief Scientist, Freshwater and Estuaries.

If you're worried about whether you can swim in a river, spare a thought for the invertebrates (insects, snails, shrimps and worms) that depend on waterways for their survival.

One measure of water quality is the variety and sensitivity of invertebrates that live in and around waterways. This signals not only what is in the water, but also the extent to which humans are disrupting things like water flow. An invertebrate-life measurement, called the macroinvertebrate community index (MCI), is increasingly used to determine the ecological health of waterways.

How does an MCI work?

The MCI works off a list of tolerance scores to organic pollution, ranging from 1 (very tolerant) to 10 (very sensitive), developed for each type of invertebrate from field observations.

It multiplies the average of the scores for the invertebrate types in a sample by 20, giving a 'score' that could theoretically be between 20 and 200. In reality, the invertebrate community at pristine sites includes a mix of very sensitive and moderately tolerant types, meaning an MCI score is rarely above 150.

What do MCI measurements tell us about New Zealand's water quality?

Recent NIWA and regional council studies using the MCI show water quality in urban streams is typically 'poor' (median less than 80). Water in pastoral and exotic forests is typically good (median 100–110), while water in natural bush is 'excellent' (median 120).

Can I swim in water that measures high on the MCI scale?

Most probably, but not necessarily. Invertebrates don't usually respond directly to the pathogens that make swimmers ill.

Does somebody count the number of invertebrates?

Measuring MCI doesn't require a count of all the invertebrates in a sample – just the number of types (for example, species). Samples are collected in a net held downstream of an area of streambed as stones are turned over so that the creatures attached to stones or within the bed are washed into the net. The sample may be sorted live on site or, more usually, later in the lab after preservation in a type of alcohol. A person with taxonomic skills examines creatures and debris caught and picks out different types for closer examination under a microscope, as required, until all the types present have been recorded in the 'species list'.

How do we know it is an accurate measure of the quality of water?

Various studies have shown that the MCI varies roughly in proportion to levels of organic and nutrient enrichment in the water. It is not a perfect measure because it is affected by events such as flooding that can scour out invertebrates, as well as the amount of shade at a site, which can affect the response of algal nutrient enrichment. However, knowledge of these influences is built into protocols for sampling and considered when interpreting results. The MCI just uses the presence of invertebrate types, not their abundances, but there are quantitative versions that do this, and work is ongoing on developing ways to use invertebrate species counts to evaluate other stressors, such as toxic metals and the energy flow through the food web to fish.

Why are insects important to stream ecology?

Invertebrates play key roles in stream ecosystems on top of their intrinsic biodiversity value. They convert primary energy inputs to streams, from leaves that fall in and algae and bacteria growing on the streambed in response to light and 'catchment tea' (dissolved carbon from soils), into food for fish such as whitebait, eels and trout, and birds. In the process they keep the streambed clean and recycle nutrients, keeping the stream healthy and productive.




Clockwise from top left: Caddisfly Olinga; Snail, *Potamopyrgus antipodarum*; Caddisfly, *Hydrobiosella*; Caddisfly larva, *Polyplectropus*. (*Brian Smith*)

Profile

Where the water is clean

Erica Williams' story starts with the website of Moerewa School, where pupil Tyra-Lee explains her connection to a very special place in her small Far North town.

"Tuna Town is a little swimming hole in Moerewa. It's an adventurous place where my friends and I play clay fights and race to the little island there. We jump off the banks and trees into the water.

"I think that Tuna Town is really special because my whole family knows about it, and all my friends go there with me. It was here long before Moerewa town was built. Interesting things have happened there, such as finding special taonga while exploring the forest and finding a dead sheep in the water.

"The story goes that before Moerewa was established, two cab drivers use to always drive back and forth from Moerewa to Kawakawa. The cab drivers would always stop at an old hut near where Tuna Town is and they would always see big tuna hanging from the eel line like clothes hanging from a clothes line. This shows how many tuna used to swim in our rivers. When they saw all the tuna hanging there they thought to name it Tuna Town, and the name has remained ever since.

"The only thing that could make Tuna Town even more special is if we could swim and feel safe knowing that the water is clean. I hope that in the future Tuna Town can be still around for other generations to enjoy."

Tyra-Lee's description of the importance of Tuna Town – and her hopes for its future – is something Dr Erica Williams, a scientist with Te Kūwaha, NIWA's Māori environmental research team, closely identifies with.

Like Tyra-Lee, Erica grew up in Moerewa, learning first-hand the importance of tuna to the Māori community in particular.

"Tuna to this day sustains a large part of that community. It's part of a hunting and gathering tradition that's incredibly important to Māori.

"It's not only about the activity itself and feeding your family; it's also about the place and all the knowledge that's associated with that place, with the stories that are passed down. It's not just about getting some kai for the table; it's also about whanaungatanga and kaitiakitanga.

"Really that's a big reason why I do what I do now."

Erica (Te Arawa, Ngāti Whakaue, Ngāti Pikiao, Te Whānau ā Apanui) started at NIWA as a technician in the eco-toxicology lab in 1995 after completing a Bachelor of Science degree at the University of Waikato.

As a member of NIWA's freshwater fisheries team, Erica studied fish populations and the downstream migration of tuna (freshwater eels) and fish passage through culverts. She completed her PhD at the University of Auckland, investigating the effects of a group of contaminants called polycyclic aromatic hydrocarbons on shellfish.

While hesitant to put her decision to become a scientist solely down to her culture and upbringing, Erica says it is definitely a major influence on her career progression at NIWA.

"Growing up in that (small rural town) environment, you don't think it's any different to anywhere else in New Zealand. But when you get to university, you realise that not everyone has had those very special and privileged opportunities and experiences.

"University isn't necessarily a case of opening up a world of opportunities; in some ways, it narrows things down. I realised the way I was brought up was much more broad and holistic.

"At that time, there was hardly any focus on Māori research needs. I'm sure there were people working on it, but there were very few Māori scientists. In my course at the University of Waikato there were four of us, and we could pick each other out in a huge lecture theatre.

"That was part of my generation, over two decades ago. It's the way New Zealand was. Everything was pretty mainstream, especially at universities. There weren't the same options available as there are now."

It was a similar situation at NIWA until key people within the organisation, such as Dr Charlotte Severne, recognised the importance – and value – of being much more inclusive of Māori in its scientific work. Today, Te Kūwaha is the spearhead of NIWA's commitment to scientific partnership and collaboration with Māori.

"We (Te Kūwaha) represent a Māori voice inside a predominantly Pākehā organisation, and we try to make sure that as much of the funding that NIWA has the privilege to seek and secure has at least considered a Māori-driven research component.

"It's quite a daunting, but very important job, and we're getting better at it all the time. It's not only about making a case to the Crown that this is required; it's also about showing our own staff that there's a point of difference, a benefit to be gained, by adding that Māori-driven research component into their work and taking a holistic approach."

Erica Williams with her daschunds Pippi and Scout. (*Dave Allen*)

Māori tradition and science are not mutually incompatible, Erica says. In fact, partnering with Māori makes for better scientific outcomes.

"Bringing the two approaches together adds a lot more strength and gives scientists a much broader understanding of what's going on. Māori provide a massive historical context that we may not otherwise draw on or be aware of, which also helps to interpret results – local knowledge is incredibly important. Many scientists are starting to recognise that."

At the moment, much of NIWA's scientific collaboration with Māori is happening in the freshwater space. That's no surprise, says Erica.

"Freshwater is one of the most important taonga that Māori relate to. There are stories, songs and oral histories all related to waterways. So much of Māori life was, and is, connected to them."

Māori have a keen sense of kaitiakitanga – guardianship – over our waterways, and they are concerned about their health now and in the future.

"Enough is enough – that's what I hear a lot from kaumātua and kuia around the country.

"It's an issue for all New Zealanders, but most people don't realise that Māori are the ones working with the hydro-dam operators, councils, government departments, and conservation and community groups – they are the ones maintaining all of these relationships and making sure conversations are happening across organisations."

With NIWA scientists like Erica working successfully in partnership with Māori, special spots such as Tuna Town have a brighter future as places where the water is clean and there's plentiful kai that is safe to eat.

Just as Tyra-Lee hopes.

Water, water, everywhere ... and safe to play in?

For the first time, it may be possible to provide near real-time analysis of water contamination and safety levels to deliver timely public health risk warnings to recreational water users.

A team headed by NIWA's Dr Rebecca Stott and Dr Lucy McKergow are trialling New Zealand's first ColiMinder industrial water testing equipment. This revolutionary piece of equipment provides fast, comprehensive measurements of microbial water contamination, including key indicator bacteria such as *E. coli*.

The ColiMinder can provide an answer within 15 minutes, compared to the 24 hours it takes the tools currently used in New Zealand.

"Typical monitoring of faecal pollution relies on culturing water samples, and takes a considerable amount of time to analyse. The culture-based laboratory methods used by councils and NIWA, such as the Colilert method or membrane filtration assays, take about 24 hours to culture and quantify *E. coli* bacteria, and that doesn't include the time taken to collect the sample and bring it back for analysis," says Dr Stott.

The ColiMinder uses a different method of analysing bacterial enzymes that delivers an answer within 15 minutes. It can be accessed remotely and can cope with numerous analyses, one after the other. This will allow about 40 measurements to be made in 24 hours. It also has the advantage that it can detect *E. coli* bacteria that are still alive, but that are not readily cultured using conventional methods.

NIWA freshwater scientist Juliet Milne with Dr Clair Conwell from Greater Wellington Regional Council collecting water samples from the Porirua Stream, with the ColiMinder in the foreground. (*Dave Allen*)

The team took the ColiMinder into the field to test the instrument and calibrate it for freshwater analysis. By chance, a storm hit the Piako River area during the sampling period, and the team was able to get both base flow and flood level measurements.

"It gave us a real chance to see what the ColiMinder was capable of in different conditions," says Dr Stott. ColiMinder's high frequency time series data compared favourably with laboratory tests, but also revealed some interesting microbial daily cycles under base flow conditions.

Applications abound

Having successfully tested the ColiMinder in storm conditions in a rural Waikato River catchment, ColiMinder is currently in use in an urban catchment in Porirua with Greater Wellington Regional Council. High resolution information from ColiMinder is providing more detail on the microbiological quality of the Porirua Stream, which enters the Te Awarua-o-Porirua Harbour near a popular waka ama launching site.

The NIWA team is also looking to apply the instrument in different water environments, including coastal areas and estuaries.

"It is difficult to get measurements for estuarine environments where saline water meets freshwater, so we are working with the ColiMinder manufacturer to establish a unique test for this," says Dr Stott.

"Once we have a comprehensive body of knowledge across different sites and environments, the ColiMinder research can be applied to a range of water types.

"There are a number of councils interested in using the technology and working with NIWA.

"It could prove invaluable for aquaculture – providing mussel farmers with real-time information on contaminated river plumes coming their way.

"ColiMinder could provide spatial and temporal information for mitigation projects, including the impact of riparian planting intercepting farm runoff and improving waterways."

With last year's *Campylobacter* outbreak in Hawke's Bay still fresh in our minds, tools like ColiMinder have the potential to help understand and provide early warning of health risks from faecal microbial contamination of water supplies.

"A collaborator at Montréal Polytechnique in Canada has three ColiMinder instruments for research on drinking water supplies sourced from a lake. This knowledge could be applied to regions here where raw water is sourced from rivers or lakes," she says.

With the ColiMinder now part of NIWA's suite of advanced water monitoring systems, New Zealanders will have more assurance when it is safe to go back in the water.

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 650 scientists, technicians and support staff.

NIWA 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.

NIWA
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