ESTUARY BLUES
Keeping track of muddy waters

EYES DOWN UNDER
Robot maps the Kaikōura Canyon

FROM SKY TO SERVER
Managing the weather data deluge

TSUNAMI ALERT
A job for the buoys

Water & Atmosphere

FEBRUARY 2021

THE FUTURE SHAPE OF WATER

Tough decisions ahead for freshwater management

Water & Atmosphere

February 2021

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Elliott Bowie

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NIWA
Taihoro Nukurangi

Cover: Early morning irrigation near Rangiora. The amount of irrigated land in Canterbury has doubled in the past 15 years. (*Stuart Mackay*)

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Building back with science

With a new Government in place and a new year upon us, Aotearoa New Zealand faces the daunting task of building a fresh and resilient, post-Covid economy. Chief Executive John Morgan looks at the role NIWA can play.

NIWA Environmental Monitoring Technician Evan Baddock gauging the Mararoa River near Te Anau, Fiordland. (*Dave Allen*)

> **"I am confident in the power of research to unlock solutions"**
>
> John Morgan

Our borders remain largely closed and many, particularly in the tourism and education sectors, are still reeling from the impacts of the past 12 months. But the Reserve Bank has also signaled our economy is performing better than expected and vaccines are on order.

With a massive public investment programme already underway, the Government is firmly focused on rebuilding our social and economic fabric.

Environmental science will play a key role in guiding the transition to a resilient future, and NIWA is prioritising work across our three research platforms to support this recovery.

Take, for example, our programmes around the effective management of freshwater resources. Reliable flows are critical to our renewable energy output and they underpin our primary export earnings. Access to future supplies will also determine our ability to develop new growth opportunities.

But that growth cannot come at the cost of healthy ecosystems or the taonga species and aquatic values we all cherish. Complex freshwater management decisions, anticipated by September's national policy statement, lie ahead and they will need the support of robust science.

NIWA is working across the sector to find innovative and sustainable solutions to the pressures on our water resources.

Researchers are engaged with power companies to understand the competing pressures of user demand and climate change. Hydrologists are developing new models to enable local authorities to better forecast catchment dynamics, and our innovative Irrigation Insight portal literally gives farmers a grass roots view of the benefits of better irrigation decisions.

NIWA's SHMAK toolkit helps communities monitor the health of their own waterways, and our Te Kūwaha team partner with hapū and iwi to support a wide range of freshwater and wetland recovery projects.

I acknowledge there is much to do to ensure our freshwater resources are used both more effectively and wisely. In particular, significant work lies ahead in developing better models to understand the complex interactions of both abstraction and land use on waterways.

But I am confident in the power of research to unlock solutions and fresh directions, and NIWA is putting our environmental science capabilities firmly behind New Zealand's post-Covid recovery.

IN BRIEF

ETNZ

BACKING OUR BOAT

NIWA's forecasting team is strapping in for an intense couple of months ahead as Emirates Team New Zealand prepares to head out on the Hauraki Gulf to defend the America's Cup.

NIWA is providing race-critical support to Emirates Team New Zealand as the official supplier of weather forecasting and marine current information to the defence campaign.

Members of the public can get a taste of what that involves – both above and below the water – by heading down to Spark's 5G Race Zone at Auckland's Wynyard Quarter.

The free, 60-minute experience runs through till the end of March and includes interactive displays explaining how NIWA science is helping a fast boat, sail even faster.

CYCLONE WATCH

Forecasters are keeping a close watch on conditions north of New Zealand as this summer's La Niña weather pattern raises the cyclone risk.

New Zealand normally averages one ex-tropical cyclone per season, but the last La Niña weather event during the 2017/18 summer brought ex-cyclones Fehi, Gita and Hola.

The heightened cyclone risk comes as New Zealand experiences a third marine heatwave in four years and follows last year's record warm winter which saw temperatures 1.14°C above average.

Seven of New Zealand's 10 warmest winters on record have occurred since the year 2000.

Dave Allen

Dave Allen

TAONGA AT RISK

Seven native freshwater species are at particular risk from climate change.

New research, carried out by Te Wai Māori Trust and NIWA, looked at 10 taonga freshwater species. Each was measured for its exposure to climate change and its ability to respond.

Tuna (longfin eel) and piharau (lamprey) were ranked as most at risk. Tuna (shortfin eel), kākahi (freshwater mussels) and three fish species (īnanga, banded kōkopu and kōaro) were all rated as highly vulnerable.

Kōura (freshwater crayfish), giant kōkopu and aua (yellow-eyed mullet) were found to be at moderate or low risk.

IN BRIEF

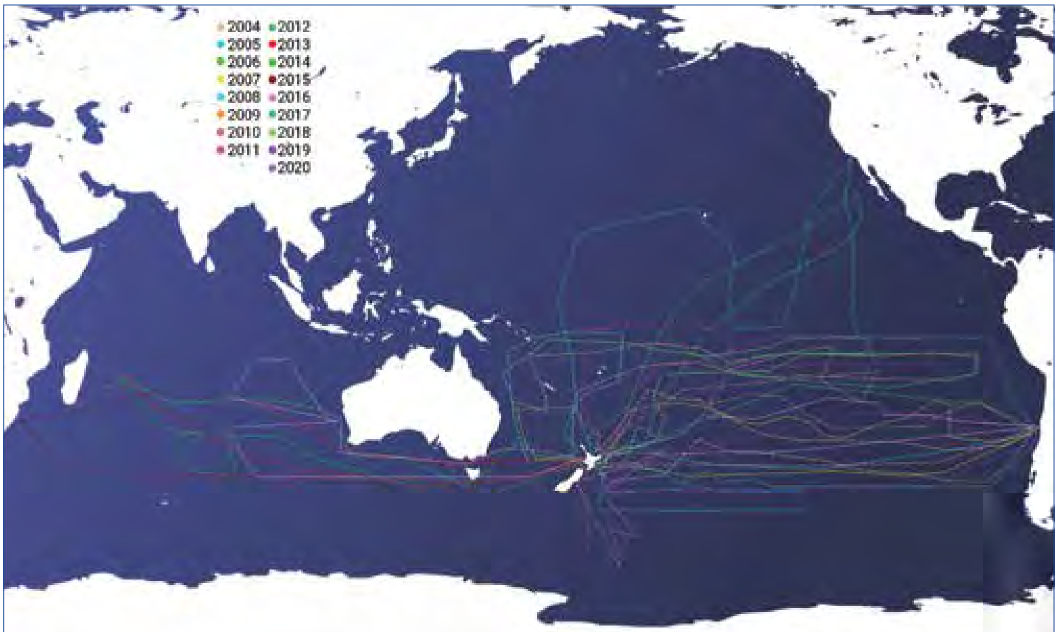
OCEAN LOCKDOWN

Ocean monitoring duties amid a global pandemic saw research vessel *Kaharoa* and her six-person crew face a gruelling 75-day voyage deep into the Indian Ocean.

Covid-19 restrictions meant the crew could not disembark during the two-and-a-half-month voyage, making it the longest single trip *Kaharoa* has made.

The team successfully deployed more than 100 ocean monitoring floats in the waters west of Australia as part of the Argo international science project.

Argo maintains a worldwide network of more than 3,800 floats, monitoring ocean conditions and the role they play in our climate and weather systems.



Argo deployment voyages by RV *Kaharoa*.

SUBMARINE SCAN

NIWA scientists returned to the waters around Whakaari/White Island in August 2020 to survey the seafloor after the 2019 fatal eruption.

The area is known for its underwater canyons and thermal vents, and researchers were scanning the island's submarine environment for significant physical changes or new areas of volcanic activity.

Marine geologists aboard RV *Tangaroa* used multibeam echo-sounders to track large sediment deposits caused by the eruption and to detect gas traces bubbling through the water column.

Methane and carbon dioxide readings taken during the 9-day voyage will also help build a detailed map of features on the seafloor.

Pascale Otis

Alvin Setiawan

HATCHING A NEW CATCH

A breakthrough by aquaculture scientists at NIWA's Northland Marine Research Centre (NMRC) looks set to pay dividends for New Zealand's salmon farming industry.

Commercial operators want to scale up Chinook salmon production, but existing hatcheries are struggling to generate the number and quality of juvenile fish required.

Recent trials at NIWA's land-based aquaculture facility at Ruakākā show production can be ramped up if hatchery densities and conditions are optimised.

The next stage of the programme will see young salmon transferred to the NMRC's recirculating aquaculture system to assess the benefits.

HIGHER GROUND

About 430,000 New Zealanders live within tsunami evacuation zones, according to an investigation carried out by NIWA scientists.

The national assessment was carried out to improve disaster management by identifying vulnerable populations living within tsunami risk areas.

It found nearly 10 per cent of New Zealanders – including 150,000 children and elderly – currently live within designated evacuation zones.

Population exposure is highest in Auckland, followed closely by Canterbury and the Bay of Plenty. A total of 139 retirement homes were identified within existing evacuation zones.

FLOOD PLANS

A NIWA-led research team has launched an ambitious five-year programme to create the first comprehensive analysis of the country's flood risk associated with climate change.

Flooding is already one of New Zealand's most costly natural hazards and flood events are expected to increase as a warming climate brings higher rainfall and rising seas.

However, our current understanding of flood hazard and vulnerability varies widely across regions.

The $15.3 million research project will draw together iwi, councils, central government and industry, with land-use information helping to map flooding hotspots across the whole of New Zealand.

The Endeavour-funded programme aims to build flood-resilient communities and will involve widespread collaboration with other CRIs, National Science Challenges and universities.

Dave Allen

Dave Bowden

DEEP SOUTH

NIWA's *Tangaroa* will arrive back in Wellington in mid February with a wealth of new Antarctic oceanographic data after a 45-day research expedition to the icy waters of the Ross Sea.

About 40 NIWA researchers and crew, along with colleagues from Otago University, have been working round the clock as *Tangaroa* carefully tracks her way along the coast of the southern continent.

The main focus of the multi-disciplinary scientific voyage is to investigate key environmental and biological processes in Antarctic waters and to assess likely responses of the Ross Sea Marine Protected Area to future change.

The Ross Sea is the largest Marine Protected Area in the world, and the voyage is part of New Zealand's long-term commitment to scientific monitoring in the region.

Norse goddess reveals seabed secrets

A large, orange Scandinavian robot gives NIWA's marine geologists an in-depth look at changes to the seafloor off Kaikōura.

Dr Joshu Mountjoy, voyage leader, on board *Tangaroa*. (*Lana Young*)

The 2016 earthquake left an all-too-visible trail of destruction across Kaikōura's landscape. Buildings were shattered, road and rail links severed, and massive scars cut across hillsides and coastal terraces alike.

What wasn't so immediately obvious was the impact the 7.8 magnitude quake had on the deep underwater canyon just hundreds of metres off the coast.

The Kaikōura Canyon starts less than a kilometre out from land, as the seabed plunges to depths of more than 600m, and eventually to 2000m, creating a formation of channels and ravines which fan 60km out into the Pacific Ocean.

Cold currents rising from the deep bring nutrient-rich waters into the canyon system, helping to create a uniquely productive habitat nourishing organisms ranging from small seafloor invertebrates through to the region's iconic dolphins and whales.

Marine geoscientist Dr Joshu Mountjoy describes the canyon as the bridge between the land and the ocean, connecting sedimentary systems, capturing carbon and supporting rich ecosystems.

Multibeam seabed surveys carried out by NIWA's research vessels *Tangaroa* and *Ikatere* after the 2016 quake revealed dramatic changes. Huge amounts of mud and sediment, estimated at 850 million tonnes, were shaken from the canyon rim, flowing down the underwater channels and out into the Pacific.

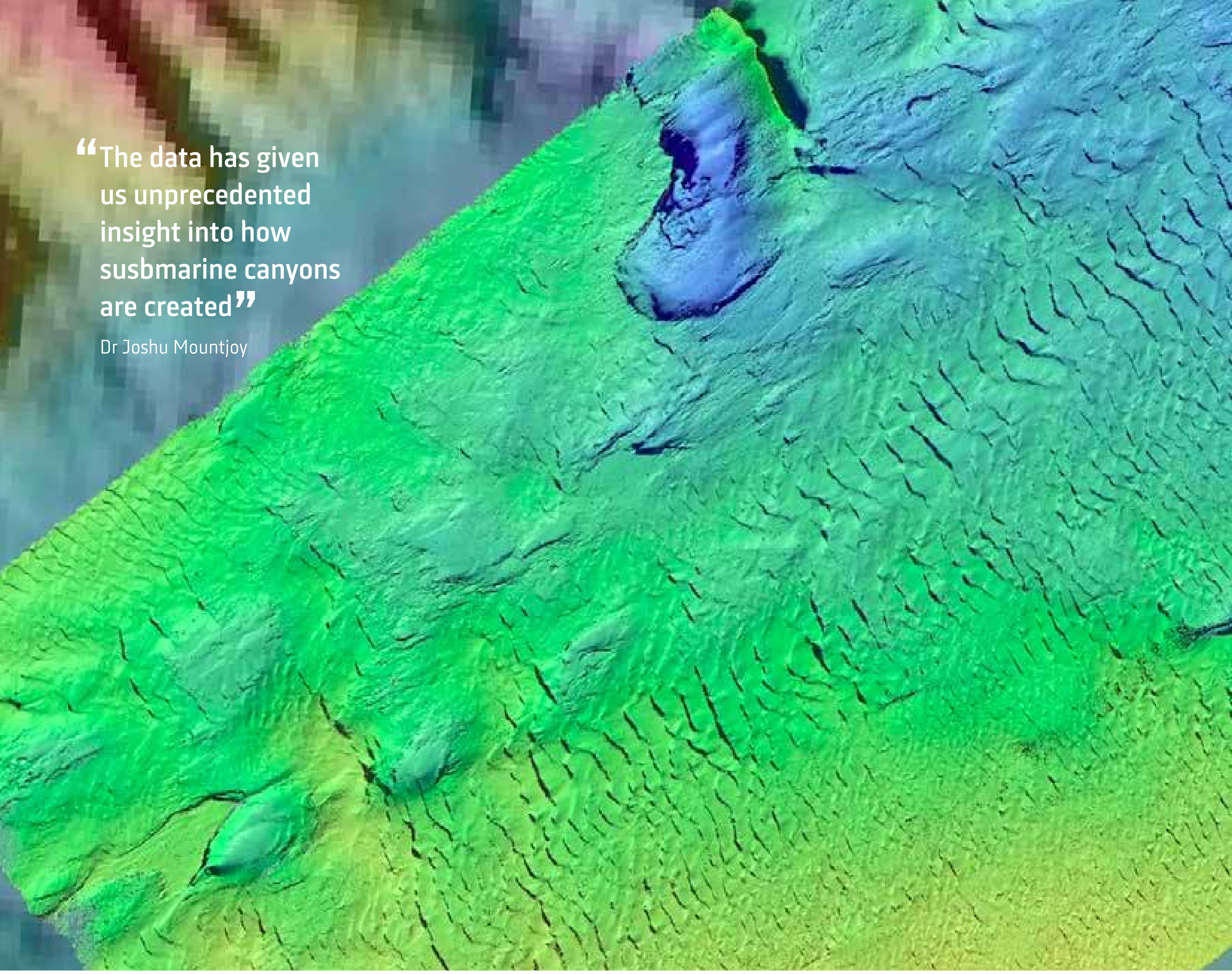
This massive submarine sediment flow, tracked at least 700km to the north, instantly turned the canyon floor from a biodiversity hotspot full of marine life into a barren, almost uninhabited seascape.

Late last year Mountjoy led another team of researchers back to the waters off the Kaikōura coast aboard *Tangaroa*.

"We were interested in understanding the physical process that had removed such a huge amount of sediment and rock from the canyon. It was also a chance to establish how the ecosystems were recovering after such a major event, and measure the amount of sediment re-entering the canyon," Mountjoy says.

"Although we had done surveys before, we now needed a way to capture the extent of the post-earthquake changes at a much higher resolution."

Technicians reprogramme *Rán* as the AUV prepares for its next mapping mission off the Kaikōura coast. (*Lana Young*)



“The data has given us unprecedented insight into how susbmarine canyons are created”

Dr Joshu Mountjoy

To get such a detailed picture of conditions almost two kilometres under the surface, Mountjoy recruited the help of the European marine research alliance, Eurofleets+. NIWA is the only southern hemisphere member of this 27-country alliance.

In October, *Rán*, a 6.5m autonomous underwater vehicle named after the Norse goddess of the sea, arrived in Wellington on loan from Sweden's Gothenburg University.

Fully equipped with its own suite of sensors for remotely scanning the seafloor and monitoring oceanographic conditions, *Rán* was also accompanied by two European technicians who both had to undergo full quarantine procedures prior to joining the voyage.

Pre-programmed and deployed from the stern of *Tangaroa*, *Rán* descended to the depths of the canyon floor, operating for up to 29 hours before needing to return to the research vessel.

It is the first time this type of technology has been used in New Zealand waters, and sweeping as low as 20m above the seabed, the AUV was able to map the entire canyon floor at resolutions 25 times higher than earlier surveys.

During *Tangaroa*'s research voyage, *Rán* completed a total of 14 dives, surveyed over 2,000km of seafloor at an average speed of 7km/h, and acquired a staggering 1.6 billion datapoints.

“The data has given us unprecedented insight into how submarine canyons are created,” says Mountjoy.

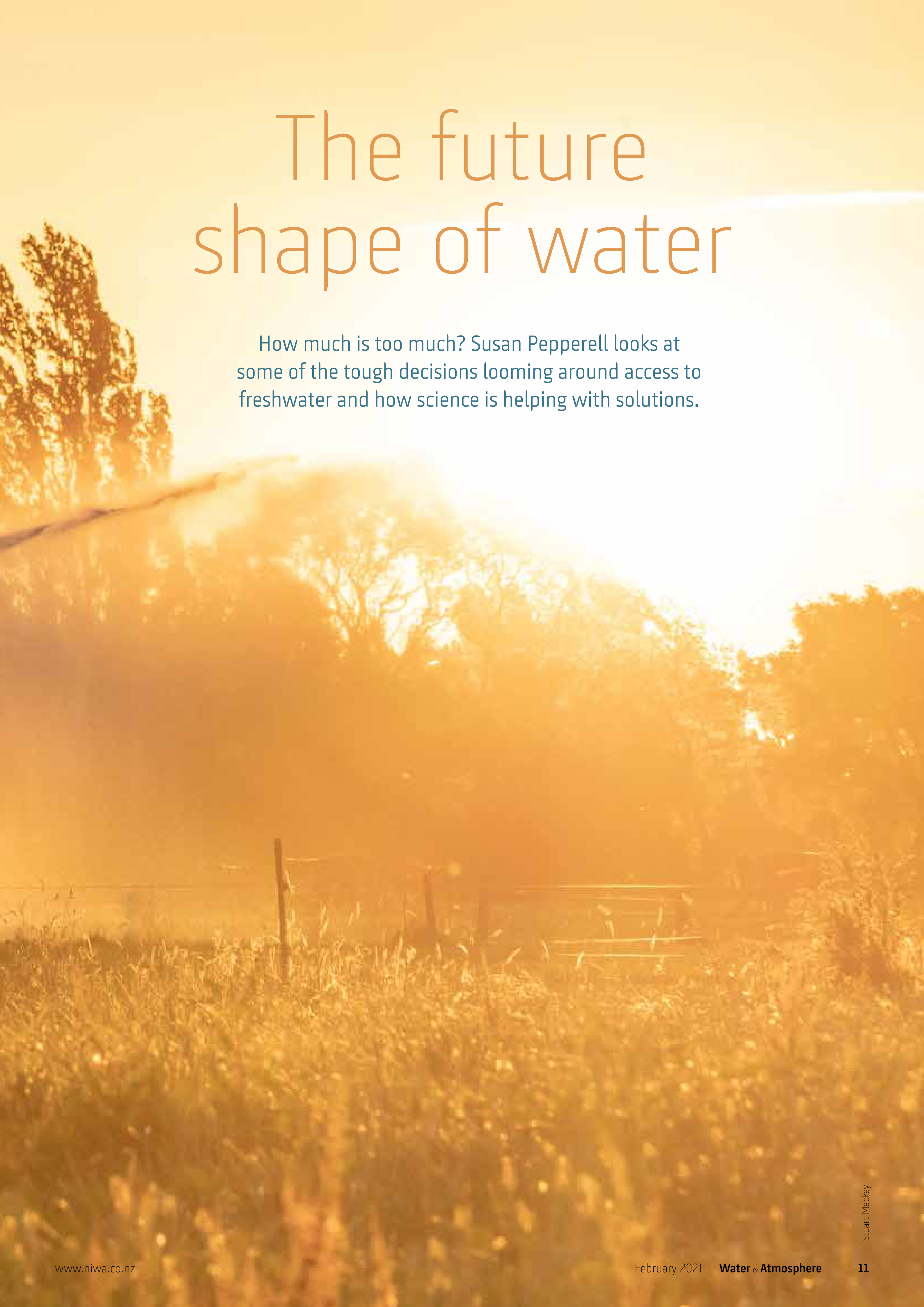
“The mid-lower canyon is dominated by giant gravel waves that are carving out the bedrock.

“We already knew that dunes 20m high and 200m across had shifted 500m down the canyon. But the data collected by the AUV now shows that these dunes are made of boulders up to 7m across.

“It is hard to imagine how much power is required to move rocks of that size, but that's exactly what has happened in that area.”

The research team are currently working their way through the detailed data files recovered during *Rán*'s successful mission – a high-resolution treasure trove which Mountjoy believes will lead to a clearer international understanding of post-earthquake continental shelf processes.

The AUV's high resolution mapping technology reveals huge boulder ridges running across the seafloor more than a kilometre below the surface. (*NIWA*)



The future shape of water

How much is too much? Susan Pepperell looks at some of the tough decisions looming around access to freshwater and how science is helping with solutions.

Stuart Mackay

> **“Water shortages will drive change”**
>
> Dr Scott Larned

Twenty-five metres above the Hurunui River, Hamish Sutton is leaning over the side of a metal cage hanging from a cable. Far below, bobbing on the swiftly flowing waterway is a small boat struggling to stay afloat.

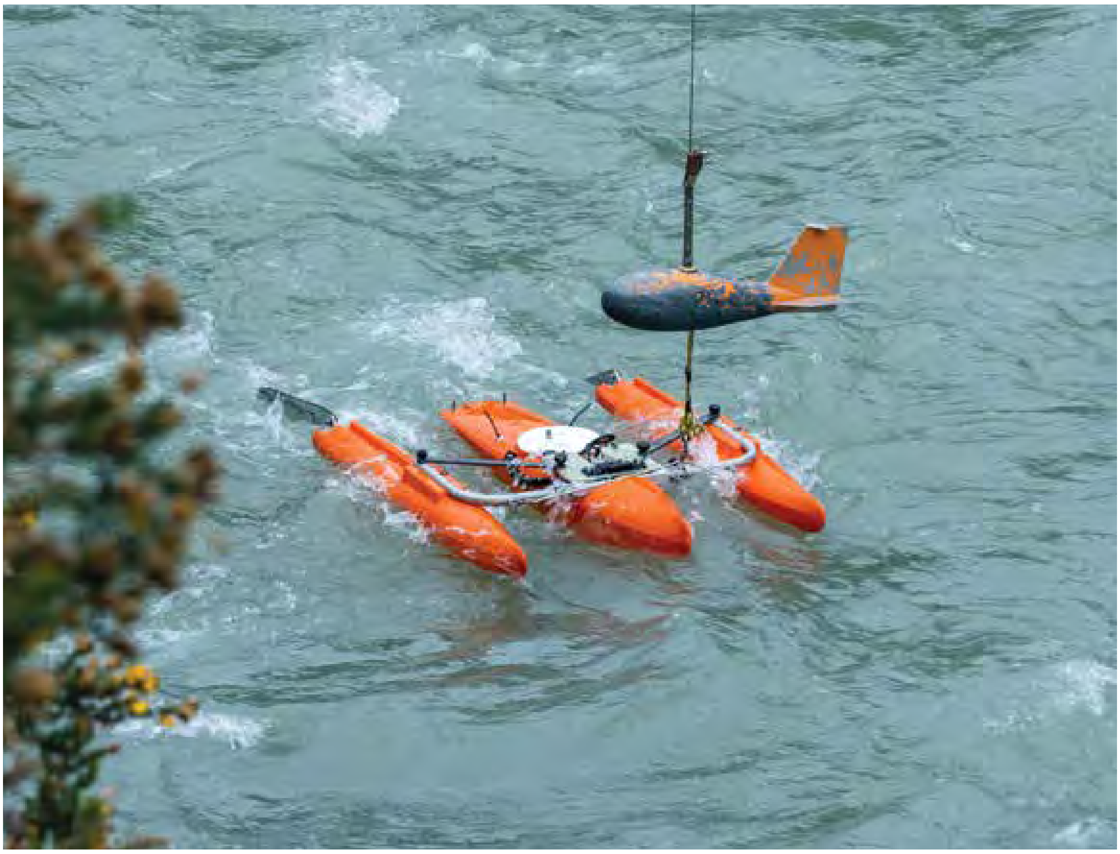
This scene in the north Canterbury hills may look a little precarious, but precise science is under way. Sutton is measuring the flow of the Hurunui River. In the corner of the metal cage a laptop is recording data gathered by an instrument on the boat below that shoots hundreds of acoustic pulses into the water to measure depth and velocity.

Sutton, a NIWA environmental monitoring technician, prides himself on the numbers coming into his laptop. “If you’re not collecting quality data, it’s pretty pointless – it’s easy to forget that out here.”

Sutton’s quality data will be used to build a “rating” of the level and related flow of the Hurunui that will be added to records that began at this spot in the mid-1950s.

These measurements – and others like it all over the region – span monumental change in land use in rural Canterbury. They began before large-scale conversion to dairy farming required vast irrigation schemes. The Amuri scheme, which takes water from the Hurunui, is one of the earlier projects and feeds the now grassy paddocks of the plains.

Knowing the volume of water in a river and how fast it travels to the coast, is a vital step in deciding how that water can be used to provide hydroelectricity or grow crops or grass – or support a plethora of other industries crucial to our economy. Irrigated agriculture alone contributes about $4.8 billion annually to GDP, and accounts for about two-thirds of all water used in New Zealand. However, the demand and supply balance is changing for agriculture, as it is for other industries. Notwithstanding that taking water out of a



Hydrologists gauge river flows using soundwaves fired into the water from the acoustic Doppler current profiler mounted on this small orange trimaran. (*Lana Young*)

river also alters its natural flow regime and can have unforeseen consequences elsewhere.

Or, as NIWA's Chief Scientist for freshwater Dr Scott Larned puts it, solutions can sometimes create problems.

"The conventional wisdom is that you harvest flood water in the winter and store it until it's needed in the summer. However, floods are required to carry gravels to the coastal zone and if there's not enough gravel, the waves get hungry and start eroding the land. Sure, it's a solution, but it's also creating a problem."

Larned and his team are preoccupied with one question: How much water should we leave in our rivers to maintain their ecological functions versus how much can be taken out for other uses?

It is a fundamental dilemma which has become more pressing as irrigation schemes and plans to dam or alter rivers have multiplied, at the same time as cultural, social and environmental issues demand more consideration.

Swirling around in the mix is climate change, and what that may mean for the future of the primary sector – and all of us.

To understand New Zealand's water issues, it is important to note that, comparatively speaking, our rivers are short and steep and have little capacity to store or manipulate flows.

Demand for water continues to grow, yet it is increasingly recognised that appropriate river flow regimes are fundamental to maintaining healthy river systems.

Larned says changes to the way freshwater is allocated to farmers, industry, groups and individuals are inevitable. New national policies for freshwater were announced by the Minister for the Environment in September and focus heavily on river health and water quality issues. The policies also signal major improvements in water allocation, but with minimal guidance about how this will happen.

"Carrying out the science needed to put the policies into action is one of NIWA's biggest responsibilities," he says.

Larned says the research community will need to play its part to help deliver meaningful change.
(*See* What next for environmental science? – page 17)

While freshwater reform will be fraught, he is also certain it will happen.

"Water shortages will drive change. I expect there will be substantial progress over the next decade."

Hanging high above the water, technician Hamish Sutton (right) and his ecohydraulics colleague Dr Hamish Biggs carefully position themselves to measure the flow of the Hurunui River below. (*Lana Young*)

QUICK FACTS

58%
of allocated water is used for irrigation

14%
of allocated water is used for drinking

73%
of New Zealand groundwater is located in Canterbury

One of the major issues is water consenting. New Zealand has an historical consenting system in which users are permitted to take certain amounts of water for long periods – up to 35 years in some cases. The system has little room for flexibility, and, as Larned points out, has become highly inequitable in places like Canterbury, where most of the available water is consented and there is little left for new applicants.

Treaty of Waitangi settlements have also granted some iwi rights to water and, notably, special status to the Whanganui River which recognises the river as having all the rights of a person. But, up until recently, water allocation rules have fundamentally been all about the economy, not kaitiakitanga. Reconciling the two is virtually unchartered territory.

Larned says NIWA possesses the bulk of hydrological science expertise in New Zealand and will need to provide the science that underpins water allocation reform. However, policy makers will be relying on community, iwi and other partners to identify their priorities and values.

"In one catchment the highest priority may be economic growth, for another it may be restoration of natural land. It is up to people to decide – we can then work out an allocation system to achieve that."

Hydro-ecological modeller Dr Doug Booker leads a NIWA programme focused on understanding the effects of human water use on surface and groundwater systems. The aim is to inform more sustainable water allocation decisions.

Booker's work includes carrying out the science behind options such as trading rights to access water, or permitting water to be used on a seasonal timeframe, rather than over decades.

Trading water is theoretically possible under the Resource Management Act, but it would be a radical change for New Zealand, and the infrastructure for it to be implemented doesn't currently exist.

Booker says that water trading is seen in some quarters as an effective management mechanism because it can deliver economic benefits within environmental limits. It can also recognise the environment as a water user, and transfer water rights to the environment to support ecological, cultural, aesthetic or recreational values.

How we ultimately change to a more dynamic consenting process will be up to central and local government.

Back at NIWA's Christchurch office, catchment hydrologist Dr MS Srinivasan adds another perspective to the views of his colleagues.

As we leave the city on a grey October day to meet North Canterbury farmer Bruce Baggott at Mandeville, Srinivasan is concerned about the potential lack of summer rain.

"We didn't get the winter rainfall we needed; irrigation has started earlier this year, so water supply will be an issue."

Srinivasan is the conduit between water efficiency science and its users. He has spent most of his

> “We want the best information to help make those decisions”
>
> Bruce Baggott

scientific career working directly with farmers – he knows when scientists talk about climate variability, farmers talk about rain.

“Science cannot always be done behind closed doors – we have to come out and work with people and listen to them.”

We find Baggott enjoying a beer at the Platform Bar after a local meeting about a controversial regional council proposal on nitrogen limits. He and his partner, Claire Mackay, moved to Canterbury from Northland in 2000 – when dairy farming was beginning to take off in the region.

They farm 235 hectares at Cust and run 850 cows. The couple is part of the Waimakariri Irrigation Scheme and work with NIWA on a Ministry of Business, Innovation and Employment-funded programme called Irrigation Insight.

Irrigation Insight is a five-year project involving a range of organisations across the sector looking to make better use of available water. The aim is to achieve a balanced irrigation approach that is economically sound and environmentally responsible.

For Baggott, that means starting each day on his tablet checking the high-resolution NIWA weather

Farmer Bruce Baggott (right) talks with NIWA environmental monitoring scientist Graham Elley about the best use of water on his Canterbury dairy property. (*Stuart Mackay*)

"Work with people and listen to them"

MS Srinivasan

Catchment hydrologist MS Srinivasan says scientists need to get out on the farm if they are to help develop irrigation solutions. (*Dave Allen*)

and soil moisture forecast tailored for his property, along with readings from his network of paddock soil moisture probes.

He has been working with NIWA for three years now, trialling the first tool of its kind developed to manage irrigation in a changing climate. Baggott is in awe of the technology available at his fingertips, but perhaps more appreciative of the partnership he has developed with Srinivasan and his colleague, environmental monitoring scientist Graham Elley.

"Farms are multi-million-dollar businesses and we are capable of making our own decisions, but we want the best information to help make those decisions," says Baggott.

Elley says Irrigation Insight works because it is based on communication and co-innovation.

"Every situation is unique – with its own set of controls, barriers, opportunities, people with different capacities, capabilities and aspirations, which can be in tension with each other. With all these things we are looking for an operating sweet spot, and that sweet spot is not the same for every farm."

Future-proofing irrigation practices is best summed up by the desire to achieve a change in mindset from irrigating "just in case" to irrigating "just in time", with science providing help around nutrient management, water supply and projected climate-change scenarios.

"We need to be looking beyond the biophysical solutions and work with people and listen to them," says Srinivasan. "Science will give an answer, but everyone holds knowledge, and if we don't listen, our solutions will not be complete and comprehensive."

Farmers, says Baggott, are very willing to change and want to be part of shaping the future. "We are trying to improve the land – if we stuff it up, it comes back to bite you."

This year MPI awarded $400,000 to a NIWA-led project that is examining future-proofing irrigation for climate change. It will develop an adaptation strategy tool to assess the irrigation supply and demand balance under a changing climate.

Further research is proposed that will look at transforming New Zealand's approach to building water resilience.

If the future looks like a mix of science and farming done differently, then people like ecohydraulics scientist Dr Hamish Biggs will be crucial to the transition.

Biggs was with Sutton high above the Hurunui River for the recent river flow measurements. Minutes earlier he had been flying a drone over the same section of river, programming it to take similar flow measurements to those from Sutton's small boat, so they can compare the drone for accuracy.

There is no internet coverage at the Hurunui site, but Sutton says it won't be long before it will have fixed cameras here and at every site water is measured, transmitting huge swathes of data in real time.

"You'll be able to get any kind of measurement any time you want and from anywhere you want. It will be a game changer for science and for the people who need that science."

Climate change and irrigation

Ask NIWA hydrologist Dr Christian Zammit how our future climate will impact irrigation and his first response is always: "It depends where you are."

Zammit is the co-author of a recent report prepared for the Ministry for Primary Industries that analysed the effects of climate change on irrigation supply and demand.

The report gently suggests water users should be exploring a transition to a drought-resilient future "before it becomes necessary". That's because the outlook, although uncertain, spells major changes in wind and rainfall patterns.

"There will be more climate extremes across all New Zealand," says Zammit.

The issue, he says, is that while New Zealand will still get plenty of water, it won't always get it in the right places.

In essence the North Island will get drier, Marlborough, Tasman and North Canterbury will also get drier, but South Canterbury and below will get wetter.

Zammit's report also found:

- Demand for irrigated water is projected to increase across most of New Zealand, with effects emerging by 2050 in the North Island and later in the South Island
- Irrigation restrictions will occur earlier in the year, mostly for the North Island
- The reliability of river water supply tends to decline during the century
- The decline in supply reliability and increase in irrigation demand point towards increasingly challenging conditions for irrigators.

Zammit says high-resolution modelling will help New Zealand adapt, but there will need to be some hard decisions made.

"We know temperatures are getting warmer and our precipitation is changing, but that gives us an opportunity to do things differently. It's really about being prepared and making it a successful story for us."

Opinion

What next for freshwater science?

Dr Scott Larned

Chief Scientist – Freshwater and estuaries

For most of the time humans have inhabited Aotearoa New Zealand, their impact on aquatic environments has been negligible.

Over the last century, things have changed. A five-fold increase in the human population, large-scale deforestation, intensive agriculture and urban development have all led to widespread water pollution and habitat loss. Many native aquatic species are now threatened with extinction.

There is still a realistic chance to reverse freshwater degradation in New Zealand, but only if we "go hard and go early".

Going hard entails some stringent regulation, and that's where the National Policy Statement for Freshwater Management (NPS-FM) comes in.

The NPS-FM came into effect in September 2020. Among other things, it requires councils to set objectives for rivers, lakes and estuaries, and specifies minimum allowable conditions for 18 different aspects of water quality and ecosystem health.

The NPS-FM also directs councils to use the Māori principles of Te Mana o te Wai as the policy framework – this is a profound change from previous legislation.

Full implementation of this wide-reaching policy statement could transform land and water management in New Zealand, and the environmental science community has a major role to play.

Much of the science carried out over the last decade to support the development of the NPS-FM concerned the ecological and human-health indicators that will be used to assess achievement of freshwater objectives.

The next big challenge for the science community is limit setting. This is the complex process of determining the amount of contaminant input (such as sediment and faecal bacteria) from land that is permitted before freshwater values deteriorate.

Limit setting requires scientific knowledge of the relationships between catchment land use and contaminant loss from land, and the impact of those contaminants on aquatic ecosystems and human health. This sounds deceptively simple. In practice, predicting contaminant losses and impacts in response to land use is difficult because of the complexities of catchments and aquatic ecosystems.

Direct observations alone are inadequate for predicting the effects of current land use, or forecasting effects in the future. The solution lies in combining observations with computer models that can link up the entire chain from land use to contaminant losses, to ecological and human health impacts, and finally to freshwater values.

Rapid progress is critical. New models will need to be built, and existing models will need renovation, but this is the most effective way to put the new freshwater policies into action.

Queen of the critters

Sadie Mills has come a long way from scaring the inhabitants of Scottish rock pools. Sarah Fraser explains.

What do a squat lobster, a sand hopper, a comma shrimp and a geodiid sponge have in common?

Uroptychus sadie, *Syrrhoe sadiae*, *Campylaspis millsae* and *Geodia sadiemillsae* are all named after Sadie Mills, who as a little girl played in rockpools on Scotland's Isle of Mull and dreamed of becoming a marine biologist.

Fast forward a couple of decades, and she's sharing her love of tiny ocean creatures with researchers from around the world in her role as manager of the NIWA Invertebrate Collection. The nationally significant collection is a veritable treasure trove of more than 300,000 specimens from New Zealand, Antarctic and southwest Pacific waters.

Having one species named after you is considered a great honour. Having four, is a clear testament to Sadie and the quality of her work.

She was in her teens when her family emigrated to Dunedin from the north of England in 1997 and she didn't want to come.

"I was most worried about the music. I was really into all the indie bands in Manchester, and the only music that I'd heard from New Zealand was OMC's "How Bizarre" and Kiri Te Kanawa," she laughs.

Sadie discovered the Dunedin sound and New Zealand reggae bands, and, still set on becoming a marine biologist, she took subjects through school and university that she hoped would send her down that path.

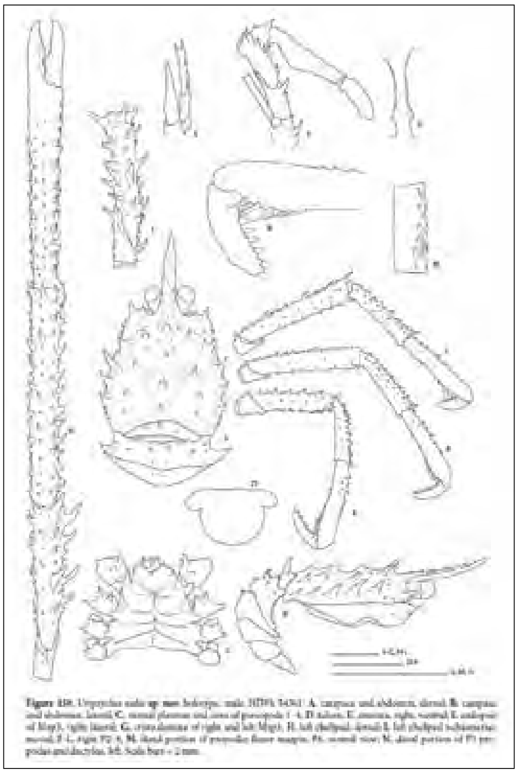
"I didn't know what job I would end up with. Even at Masters level I still wasn't sure, but I knew that NIWA was one of the places that was big in marine science.

"I saw an ad for a curatorial technician, and I thought that sounded really cool. While I was at Otago Uni, I worked at the Portobello Marine Lab on macrofauna, the little animals that live in the mud. I was really struck by what I was looking at down the microscope. For example, polychaete worms with massive jaws and amphipods – the little sand hoppers.

"That fascinated me, so I thought working in the collection would be cool because you'd get to see lots of crazy creatures from all over the place."

Sadie joined NIWA in 2006, and in 2014 was appointed Collections Manager, leading a team of three and responsible for more than 300,000 specimens. She has also been able to take her fascination with creatures in rockpools and mudflats out to the deep sea.

She has sailed on 17 voyages and spent 472 days at sea, mainly on NIWA's research vessel *Tangaroa*. This work has taken her all around New Zealand's waters and south to Antarctica. Her roles onboard include preserving and identifying marine invertebrates, live logging of fauna and seabed habitats, chemical safety and preparing biosecurity importation documents for samples.



“You get to see lots of crazy creatures from all over the place”

Sadie Mills

Lana Young

“Going to sea is really great because you get to see all of these deepsea animals. We lower a video camera to the seafloor, and you can see the amazing habitats the animals live in, ranging from seamounts – the undersea volcanoes – to sponge gardens, coral reefs and algal meadows.”

Her specialty is the taxonomy of New Zealand and Antarctic species of delicate starfish-like creatures called Ophiuroidea – brittle stars, snake stars and basket stars.

Asked what she’s proudest of, Sadie doesn’t hesitate. “The sheer number of collaborators we have in New Zealand and around the world.

“Our team is known to be friendly and really helpful. That’s important when we have people from overseas and around NZ coming to study our collection.

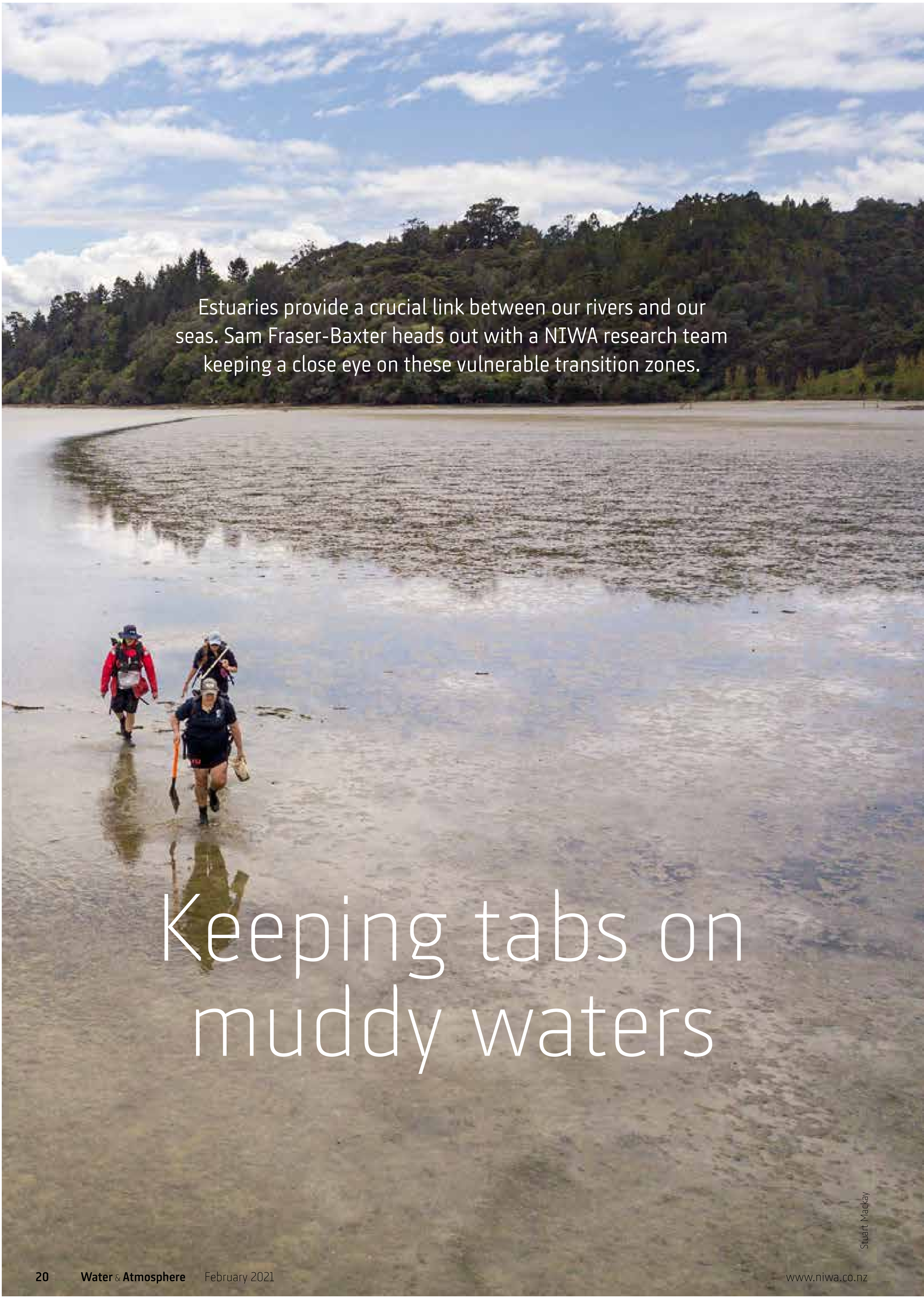
“The gains New Zealand makes are very high because we don’t have a lot of taxonomists here, and we have to rely on those international collaborators to get the biodiversity in our species described. And they give a lot back to us. The number of scientific publications we have every year is really high, because of our collaboration.”

In the last year alone, the NIC team hosted 21 visitors from nine different institutions. As well as hosting researchers, they also processed 148 loans and donations of NIC specimens to 43 researchers in 13 countries.

The team’s knowledge of biodiversity information informs NIWA research, client projects, government policies and international initiatives. They’re also in demand as ambassadors for NIWA, sharing their knowledge and specimens at public displays such as Te Taiao at Te Papa or last year’s Dive Deep with NIWA exhibition at Otago Museum.

“What gives me the greatest pleasure is seeing people’s reactions when they see something they’ve never seen before or learn something new.”

Sadie Mills at work amongst the busy shelves of the internationally recognised NIWA Invertebrate Collection. (*Lana Young*)



Estuaries provide a crucial link between our rivers and our seas. Sam Fraser-Baxter heads out with a NIWA research team keeping a close eye on these vulnerable transition zones.

Keeping tabs on muddy waters

Stuart Mackay

On a cloudy October morning, three people wade through the shallows of the Mahurangi Estuary, just north of Auckland.

They're up to their knees, sporting wetsuit booties and carting backpacks. Between them they carry a shovel, clipboards and a piece of PVC pipe. A small inflatable boat is anchored nearby.

NIWA researchers Kelly Carter and Sarah Hailes, and Auckland Council environmental specialist Martin Meyer are gathering samples to understand the long-term health of the Mahurangi Estuary.

They know – almost better than anyone – that like most of the country's estuaries, this one is far from pristine.

The biggest challenge for our estuaries can be summed up in one word: mud.

"We've gone from sandy estuaries to these muddy systems," says Dr Andrew Swales from his Hamilton office.

Swales, who leads NIWA's Catchments to Estuaries programme, is a scientist who studies human impacts on estuaries.

He says the largest decline in Aotearoa New Zealand's estuaries began in the mid-1800s when large tracts of land were deforested for farms and settlements.

"Unlike many countries where the human impacts have happened over many centuries, for us, some of the biggest impacts have happened in the last 170 years or so."

When trees are removed from the land, soils become loose and are easily eroded. Heavy rain transports that soil into rivers.

Swales says that while steep land, frequent rain events, earthquakes and geology make New Zealand particularly susceptible to erosion, land clearance is the primary driver of the huge amounts of soil entering waterways.

The Ministry for the Environment and Statistics NZ estimate that New Zealand loses about 190 million tonnes of soil each year.

Like tar choking the lungs of a smoker, the sediment travels down waterways and settles in estuaries as mud.

Mud smothers bottom-dwelling animals. It makes the water cloudy and changes the landscape, ultimately impacting the estuarine habitats and the organisms that live in them.

Swales points to the Firth of Thames in Waikato as a classic example of a New Zealand estuary badly suffering from sedimentation.

"There was a sand flat in the southern Firth that is now buried under two metres of mud. Millions of tonnes of mud has accumulated over that sand flat in the last 50 years.

"People don't realise how places have changed. I was talking to a retired farmer a few years ago. He told me that in the 1950s he used to go land-yachting on the sand flats in the southern Firth."

"Many people just don't appreciate what we've lost and what we continue to lose"

Dr Andrew Swales

Sarah Hailes (left) and Kelly Carter taking biodiversity samples in the Mahurangi Estuary. More than 100 different species of worms have been found in the estuary mud. (*Sam Fraser-Baxter*)

Where a land-yacht might have once sailed across a firm, sand-bottomed Firth of Thames, the wheels would now sink into sticky muck, between mangroves.

Sedimentation isn't the only challenge our estuaries are facing. Swales says that estuaries also trap a huge range of contaminants that enter rivers from human activities.

Urban contaminants include heavy metals such as zinc and copper, while farming contaminants are mostly pesticides and fertilisers such as nitrogen and phosphates.

From algal blooms to long-lasting chemical cocktails, the effects can be devastating.

There are more than 400 estuaries across the country. As transitional zones where freshwater flows into and mixes with saltwater, estuaries are unique environments.

They're a place where people live, gather food and play. They are a nursery for our fisheries, protect low-lying coastal lands from storms and provide a home for hundreds of endemic species.

Swales says estuaries have too long played second fiddle to more visible features such as beaches and rivers. Considering their environmental importance, they don't get the profile they deserve, he says.

As a child growing up on the North Shore, he remembers visiting the Barry's Point Road rubbish dump. The tip wasn't a hole in the ground. It was an estuary. People would just pull up to the water's edge and throw their rubbish into the mangroves.

Swales says there has been an historic lack of integrated estuary management at a national scale.

"What activities are being undertaken in catchments? What are the impacts on the estuary? Estuaries have been forgotten. They fall through the gap between freshwater and the sea.

"Many people just don't appreciate what we've lost and what we continue to lose."

Back on the Mahurangi, the researchers are sampling their first site. It is part science, part resistance training.

They follow a small laminated map with random sample locations. The corer, a simple piece of PVC pipe, is pushed into the mud and lifted out with a spade.

The sediment sample is transferred into a bag which is tied shut and dropped into one of the researchers' backpacks.

They will repeat this process 12 times at each site. All up, there are five sample locations dotted around the estuary – sites that have been visited four times each year since 1997 and which together tell the story of the Mahurangi estuary.

Kelly Carter says that the mud gets harder and harder to walk through as the sampling goes on.

"Our backpacks can weigh between 25 and 30kg with the samples. As soon as you have the cores in your backpack it feels like you can't unstick yourself. Your calves really start to burn."

Back at the boat, they organise the samples into storage bins for detailed analysis back in the lab.

Carter says the negative effects of sediment have been increasingly detected in the Mahurangi Estuary since monitoring began.

"It is interesting – coming so frequently for such a long time, you can actually start seeing the trends and notice quickly when things start changing. Currently, the data shows upward trends in five species that are known to increase with mud."

However, compared with many estuaries, Carter says overall, the Mahurangi is in "moderate health".

She points to tiny shellfish barely visible under the water.

"You can tell that this site is still healthy because cockles are still here. If your estuary lost all of its cockles, that would be a bad sign."

Every sediment sample is meticulously sieved, to identify what is living in the estuarine sediments, and organisms such as cockles are exactly what researchers are looking for.

Dr Drew Lohrer is a marine ecologist who specialises in estuarine invertebrate communities and how they function.

He says invertebrates like worms, crabs and shellfish can provide many of the answers to changes in estuaries.

"We've developed indices of estuarine health that are based on the composition of these invertebrate communities. For example, if all the species that are sensitive to mud are disappearing, we might have a strong indication that too much fine sediment is being added to the estuary.

"In a single core of sediment you can get 30 to 40 species and up to 300 individuals.

"It requires a lot of understanding of these species, but when you know a little about their sensitivities and how they respond to these different types of stressors, you can get good information on what's happening in the environment and what's driving it."

He says the invertebrates that live in estuarine sediments are perfect for this research: they're long-lived and they don't move around too much.

As well as studying the invertebrates, researchers also analyse the samples to assess what kinds of sediments and contaminants are entering the estuary.

Lohrer says, together, these methods give researchers a clear understanding of what is changing.

NIWA has worked closely alongside the Auckland Council for more than three decades to monitor estuaries in the region.

Lohrer says that the collaborative nature of the partnership has been key to research success and, ultimately, better estuary management.

"If they trust in the science and can incorporate it into policy that protects the marine environment, for a variety of users and uses, that's the most beneficial thing.

"That, to me, is real success."

QUICK FACTS

190

million tonnes of soil lost each year from New Zealand

>400

estuaries across the country

After a productive morning on the Mahurangi Estuary, the researchers take a quick look at some of their samples before heading out to the remaining sites.

If carrying the backpacks through the mud was resistance training for the legs, the sieving is a full-on workout for the arms.

After a minute of vigorous shaking, the sediment clears through the mesh, leaving an array of crabs, worms and shellfish.

The researchers funnel the invertebrates into labelled containers filled with an alcohol solution that preserves the samples for laboratory analysis.

Hailes and Carter work like clockwork. It's almost intuitive for them.

With an encyclopaedia-like knowledge of the invertebrates, they marvel at the tiny specimens emerging from the sediment, firing off both their common and scientific names.

Hailes holds up a carnivorous worm that wriggles across her hand.

"*Aglaophamus macroura*. It's a predator, a polychaete worm. It eats smaller worms. They throw out their jaws, grab the prey and then suck it back in. It's really cool."

There are more than 100 species of worms that live in the Mahurangi Estuary. Hailes' on-the-spot identification of the tiny worm belies the detailed work ahead carefully analysing their haul.

"There are 60 samples from this one trip, so that's a week and a half of sorting and a week of IDs. It will take more than two weeks of processing."

The Parliamentary Commissioner for the Environment, Simon Upton, recently released a 200-page report titled '*Managing our Estuaries*.'

It makes two main recommendations. The first is a management approach that treats estuaries and the waterways that feed into them as a single entity.

Lohrer agrees.

"We need to have an integrated plan to manage estuaries that starts up in the hilltops and runs out through to the coast. You can't really manage estuaries if you can't control what's coming into them from up above.

"Estuaries are potentially one of the most sensitive parts of the freshwater to marine continuum, so until we manage for the most sensitive part of the system, we could be making mistakes."

Estuaries exist in a zone that is managed by a confusing cluster of authorities and organisations, working under a mishmash of overlapping plans, legislation and policy statements.

One infographic in the Commissioner's report attempts to visualise the maze of legislation and entities that needs to be considered when managing a single estuary. It is chaotic.

Upton describes it as "the sort of intimidating image that defies a summary," and calls for a concise estuaries management framework to cut through the "complicated jigsaw."

The second recommendation made by the report is for more, improved and nationally consistent monitoring.

Lohrer unequivocally agrees.

"Without monitoring, you have no idea about why things are changing, and you have difficulty disentangling what is natural variability from what is being driven by human-caused stressors."

"I think that's the most important thing about monitoring. You need to monitor over time to understand the natural variability, including things that are happening on greater than annual cycles."

Lohrer says that his team's methods have proven successful over decades and could be used throughout the country to gain insights into how estuaries are being impacted in different regions and why.

Birdsong echoes across the estuary as the field team climb back into their boat, heading out again to collect more samples.

For Hailes and Carter, the work always feels fresh. They say the incredible variety of life in estuaries brings something new every visit.

"I love it because it looks like nothing, but in Whangarei Harbour we collected 120-odd species in just one sample site. It's just so diverse," says Hailes.

"Estuaries are such vulnerable areas, and I don't think they really get enough press. People don't really understand how important they are."

"You can tell this site is still healthy because cockles are still here"

Kelly Carter

Sam Fraser-Baxter

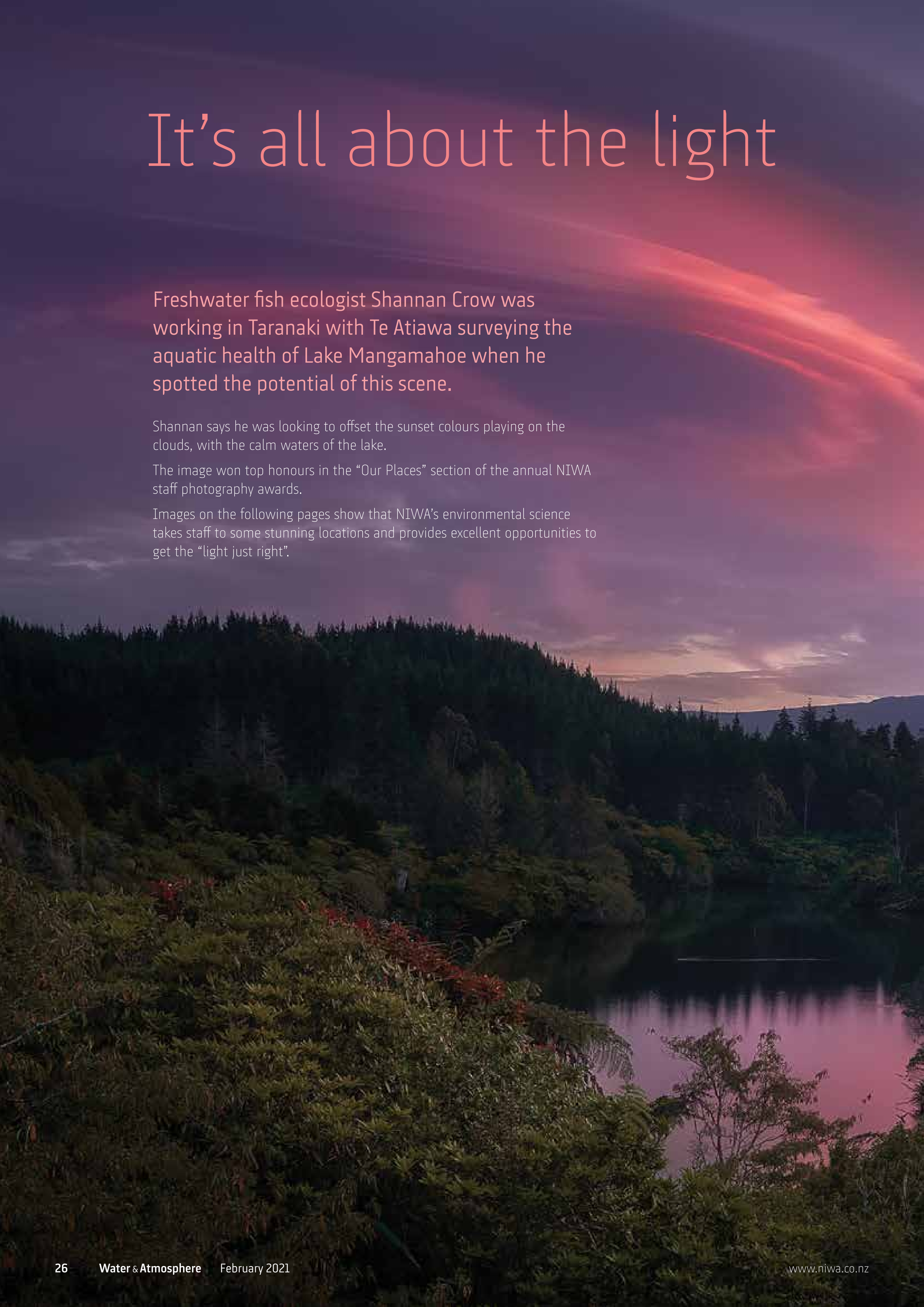
It's all about the light

Freshwater fish ecologist Shannan Crow was working in Taranaki with Te Atiawa surveying the aquatic health of Lake Mangamahoe when he spotted the potential of this scene.

Shannan says he was looking to offset the sunset colours playing on the clouds, with the calm waters of the lake.

The image won top honours in the "Our Places" section of the annual NIWA staff photography awards.

Images on the following pages show that NIWA's environmental science takes staff to some stunning locations and provides excellent opportunities to get the "light just right".



NIWA staff photos

NIWA PHOTOGRAPHY AWARDS
Our Places Winner

Water weasel

A hard-paddling mustelid snapped in the middle of Lake Coleridge while staff were surveying aquatic plants. (*Susie Elcock*)

Secret Falls

An unnamed Bay of Plenty waterfall enjoyed by the few locals who take the time to find it. (*Dan Hayward*)

The longest cave

Two-spot demoiselle and blue maomao swimming in Long Cave, Poor Knights Marine Reserve. (*Richie Hughes*)

NIWA PHOTOGRAPHY AWARDS
People's Choice Winner

Time for lunch
An oystercatcher dines on a juicy cockle in Tasman Bay. (*Rosemary Hurst*)

A sticky trap
Glow worm strings hanging in the Mangapohue limestone gorge near Waitomo. (*Margaret McMonagle*)

Rivers in the sand
A freshwater stream flows through the beach at Te Waewae Bay, Southland. (*Jo Hoyle*)

NIWA PHOTOGRAPHY AWARDS
Freshwater Winner

Kōura resting

Half in, half out. A kōura rests on a palm frond in a Northland stream. (*Crispin Middleton*)

Underwater garden

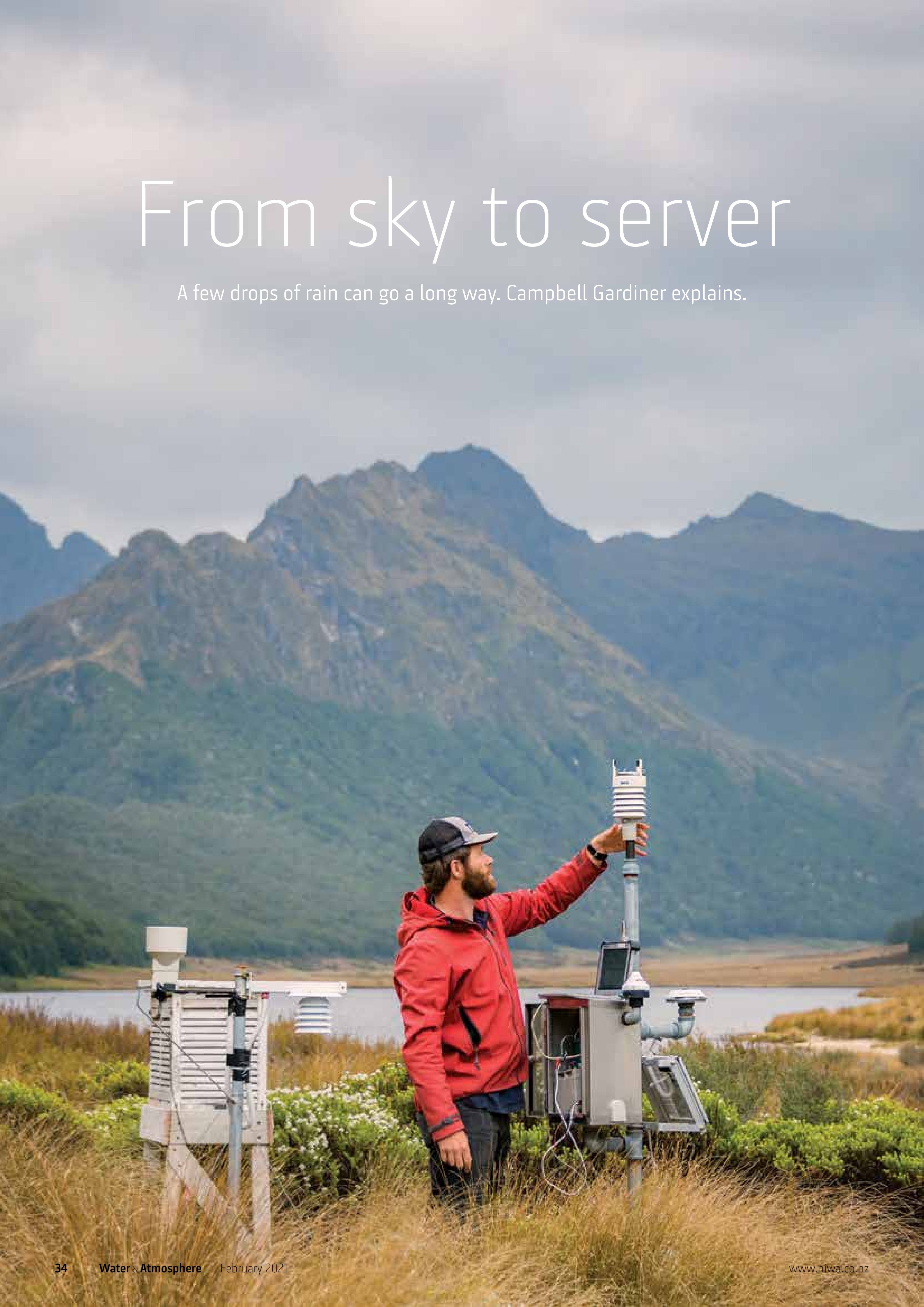
Two-spot demoiselle shelter under kelp (*Ecklonia radiata*) in the Poor Knights Marine Reserve. (*Leigh Tait*)

Tide marks

The outgoing tide leaves channels in the mudflats at Whanganui Inlet northwest of Nelson. The remote inlet is one of the country's best preserved. (*Rob Murdoch*)

From sky to server

A few drops of rain can go a long way. Campbell Gardiner explains.



The Mueller Hut weather station, 1800m above sea level. One of 11 stations NIWA manages to gather high-elevation meteorological data such as snow density. (*Jeremy Rutherford*)

Ominously large and bloated with moisture, angry clouds sweep across the Fiordland coast.

Winds drive the storm system higher and torrential rain begins thudding into the earth below. It doesn't take long before heavy drops start falling plumb into the mouth of the Takahe Valley rain gauge, in the Murchison Mountains just west of Lake Te Anau.

The raindrops are about to make their mark at a national scale.

In a matter of seconds, they will trigger a response from the automated gauge and be registered in an ever-growing climate database that plays a key role in decision making across the country.

Environmental technician Eric Stevens carries out routine maintenance on the remote Takahe Valley weather station in Fiordland. Readings are transmitted by satellite to the network. (*Dave Allen*)

The raindrops falling at NIWA's Takahe Valley weather station collect in a small, seesaw-like receptacle called a tipping bucket. Bit by bit, the water level inches upward. The bucket over balances, dumps its load and resets for another take.

A datalogger records the tip and pings the information to a server at NIWA's Christchurch office. From there it travels along a high-speed network to NIWA's Wellington office, where it is automatically entered into long-term storage in New Zealand's national Climate Database – more commonly known as CliDB.

For a meteorologist, CliDB is the motherlode. It stores weather data from all over New Zealand, Antarctica and the Pacific Islands. The earliest recordings are from the mid-1800s, with the latest information flowing in from a network of hundreds of stations like that in Takahe Valley.

The database is growing fast. If it is raining hard in the Murchison Mountains, the automated rain gauge generates a measurement every six seconds. Ten minute and hourly readings are also taken – rain, hail or shine. Weather stations, of course, measure far more than just rainfall. Sensors put together by NIWA's Instrument Systems division simultaneously record temperature, wind speed, air pressure and humidity. Some specialist stations measure solar radiation, and every instrument is busy feeding its own stream of data into the network.

With stations dotting the country and weather fronts hitting all points of the compass, the numbers quickly add up. In January alone, more than 1.5 million new rainfall data points flooded into CliDB.

In total, CliDB is connected to more than 600 weather stations – a network that stretches out across New Zealand, north into the Pacific and as far south as Antarctica. Many of the facilities are maintained by other agencies, such as MetService, the Department of Conservation and regional councils.

The database also incorporates a host of additional weather information provided by sources ranging from drifting ocean buoys and shipping vessels to historic observations gathered from lighthouses or aircraft.

Readings from seven key sites – Auckland, Masterton, Wellington, Nelson, Hokitika, Lincoln and Dunedin – are particularly important. Stations at these locations have been benchmarking New Zealand's average annual temperature since 1909. NIWA's seven station temperature series has confirmed NZ's average annual temperature has increased by about 1ºC over the past 100 years.

NIWA is the custodian and the curator of all the information flooding into CliDB. The data is rigorously quality controlled and audited to international standards, with machine learning playing an increasingly significant role as computers are programmed to hunt for gaps and flag anomalies in the dataset.

Once checked and curated, the data is made available to end users through a range of software. Much of the information is freely available through a web app called CliFlo – developed by NIWA's principal climate technician Errol Lewthwaite.

With more than 50,000 registered users, CliFlo is accessed hundreds of times an hour by individuals and organisations. MetService is a major user, along with commercial entities in the primary, engineering, energy, insurance and consulting sectors. CliFlo data is also used by criminal investigators and even competitive pigeon racers.

New Zealand's national Climate Database helps Fire and Emergency NZ fight fires like the 2019 blaze in Nelson's Pigeon Valley. (*Stuff*)

> **“The more data we have, the better our understanding”**
>
> Dr Trevor Carey-Smith

The volume, and range, of real-time data feeding into CliDB is pivotal in letting meteorologists such as NIWA principal forecaster Chris Brandolino more accurately analyse and forecast weather conditions and trends.

Brandolino and his team use innovative visual software to transform the raw details into user-friendly forecasts for both public and commercial clients.

The team is currently working with Emirates Team New Zealand using observations pulled from CliDB to forecast race day wind shifts on the Hauraki Gulf at unprecedented scale.

Data from CliDB is used to produce a host of other targeted climate products, including national soil moisture maps, drought indicator maps and NIWA's three-month seasonal climate outlooks.

The historic records stored in CliDB also let climate researchers understand trends over much broader time frames. NIWA climate scientist Dr Trevor Carey-Smith says weather observations are vital for understanding New Zealand's long-term climate.

“The amount of rainfall falling in a typical year can vary quite a bit. The more data we have, the better our understanding of that normal variability. And, unless we know about variability, it's hard to determine trends.”

Every six hours, observations from CliDB are pulled into a weather model called NZLAM that predicts the future state of the atmosphere. This gives researchers information to run forecast models down to scales of 300 metres.

Using the computational power of NIWA's supercomputers, weather observations are assimilated into sophisticated numerical models that capture the current state of the atmosphere with as much detail as possible.

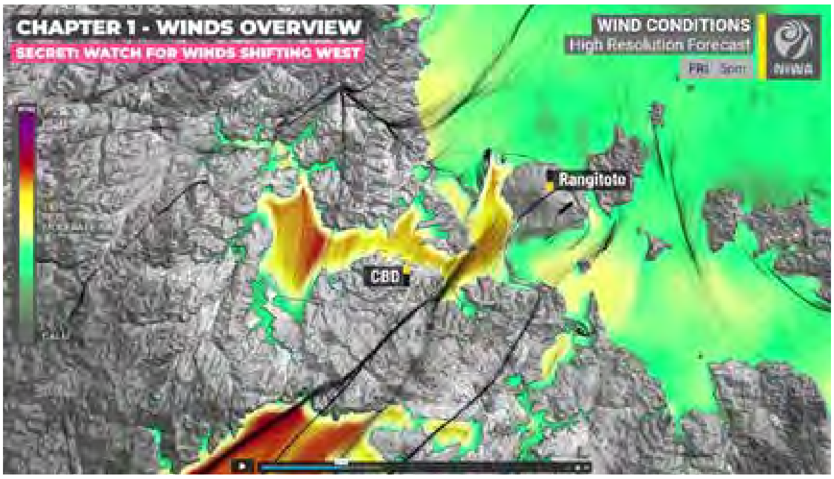
NIWA researchers are constantly comparing observations and forecasts from the past – using the difference between the two to improve their models.

Capable of processing more than 2000 trillion calculations per second, the Cray supercomputers can run atmospheric models to forecast the weather and generate climate scenarios decades into the future.

NIWA uses the national climate database to help communities and industries inform and improve decision making across New Zealand. CliDB is a fundamental part of that decision-making infrastructure.

The database helps fire crews on the ground read conditions to battle forest flames. It means farmers and power companies can plan months ahead for drought or low water flows, and it is critical to modelling the projections communities and businesses need to prepare for climate scenarios decades into the future.

Given all this, it is about time this vital national database – and its humble rain gauges – got their moment in the sun.



Meteorologists use CliDB to produce high-resolution race day forecasts of the Hauraki Gulf for Emirates Team New Zealand. (*NIWA*)

A job for the buoys

Susan Pepperell looks at NIWA's role in a new multi-agency tsunami warning network.

New Zealanders and Pacific Island communities are on their way to having the most advanced tsunami monitoring system in the world, thanks to a huge project that has required equal measures of collaboration and technical expertise.

The project is led by the National Emergency Management Agency and involves a range of organisations, including the Ministry of Foreign Affairs and Trade, GNS Science and NIWA.

To date, NIWA has assembled and deployed 8 out of an eventual network of 12 purpose-built tsunami detection buoys in the waters off New Zealand and north into the Pacific.

The remote ocean buoys provide high-speed early warning of tsunami activity in our region, triggering alert systems for vulnerable coastal communities.

Called DART (Deep-ocean Assessment and Reporting of Tsunami) buoys, the network marks a significant boost to New Zealand's systems for monitoring, detecting and issuing warnings about tsunami threats.

"This will be the first time that we have a network of DART buoys close enough to New Zealand to give us advanced warning as to whether a tsunami is an hour away or many hours away," says Sarah Stuart-Black, director of Civil Defence and Emergency Management.

But it's not just a matter of buying some buoys and dropping them into the ocean. Ensuring they are assembled correctly, working faultlessly and go in exactly the right place has been the responsibility of a NIWA team led by oceanographic engineer Mike Brewer.

The DART buoys are fourth generation technology, manufactured in the US, and they arrive at NIWA in pieces. Brewer describes the assembly as "much like a giant Lego set".

"You put everything together and then put the units through some rigorous testing, so that when they're deployed, we have complete faith in the system."

Each buoy comprises two main components – a Bottom Pressure Recorder (BPR) that sits on the sea floor, and a large, yellow float on the surface above.

Deploying both components requires a sophisticated mix of precision positioning on the high seas, sophisticated marine mapping below and a deep understanding of ocean currents. NIWA's flagship research vessel *Tangaroa* and Brewer's deployment team onboard are fully equipped to deliver.

A bathymetric survey of the seafloor using multibeam echosounders checks to ensure the gradient is less than 5 degrees, with no obstructions to interfere with signals travelling through the ocean.

The detection buoys will ensure early warning of tsunami generated along the Kermadec Trench or north west of New Zealand. (*NIWA*)

Current and wave conditions are also assessed. Once the site has been cleared, the two components are lifted off the ship, and their separate moorings are carefully positioned hundreds of metres below.

The BPR and the float communicate with each other through the water column. Every 15 seconds the BPR records the height of the ocean above and sends that information to the surface buoy once an hour. From there the data goes via satellite to the server based at GNS Science's National Geohazards Monitoring Centre back in Wellington.

"Tsunami are very long period waves, with some having wave lengths of up to an hour," says Brewer.

"Wind and swell waves are short period waves, so by measuring every 15 seconds we are cutting out those short waves and concentrating on the big differences."

If the BPR records a measurement it thinks is outside normal parameters, it will send a special signal to the surface float.

This is when the system flicks into "event mode" – a trigger that means it will update the GNS server every few minutes rather than once an hour. Event mode can also be triggered remotely if it is suspected that a tsunami may be headed towards the buoy.

The GNS server registers every incoming report, and if a tsunami threat is detected, NEMA steps in to alert communities nationwide using its Emergency Mobile Alert system. Alerts are also sent to our Pacific neighbours through the Pacific Tsunami Warning Centre.

Tangaroa has already successfully carried out two of three deployment trips. The first, in late 2019, stayed closest to New Zealand. The second, last May, ventured north to Tonga and Niue, and later this year *Tangaroa* heads back towards New Caledonia to deploy the remaining four buoys. NIWA will also maintain the network in the years ahead.

Brewer says the "New Zealand Inc." approach to establishing the network has been one of the project's strengths.

"This has been a massive project with one approach which has really helped make it work."

Engineer Dan Renfroe completes final data tests as the first detection buoys are readied for deployment in the waters above the Kermadec trench. (*Sarah Searson*)

Back cover photo:

NIWA researchers Hamish Biggs and Hamish Sutton check readings from acoustic monitoring equipment mounted on the small trimaran below to gauge the flow of North Canterbury's Hurunui River. (*Lana Young*)