OCTOBER 2018

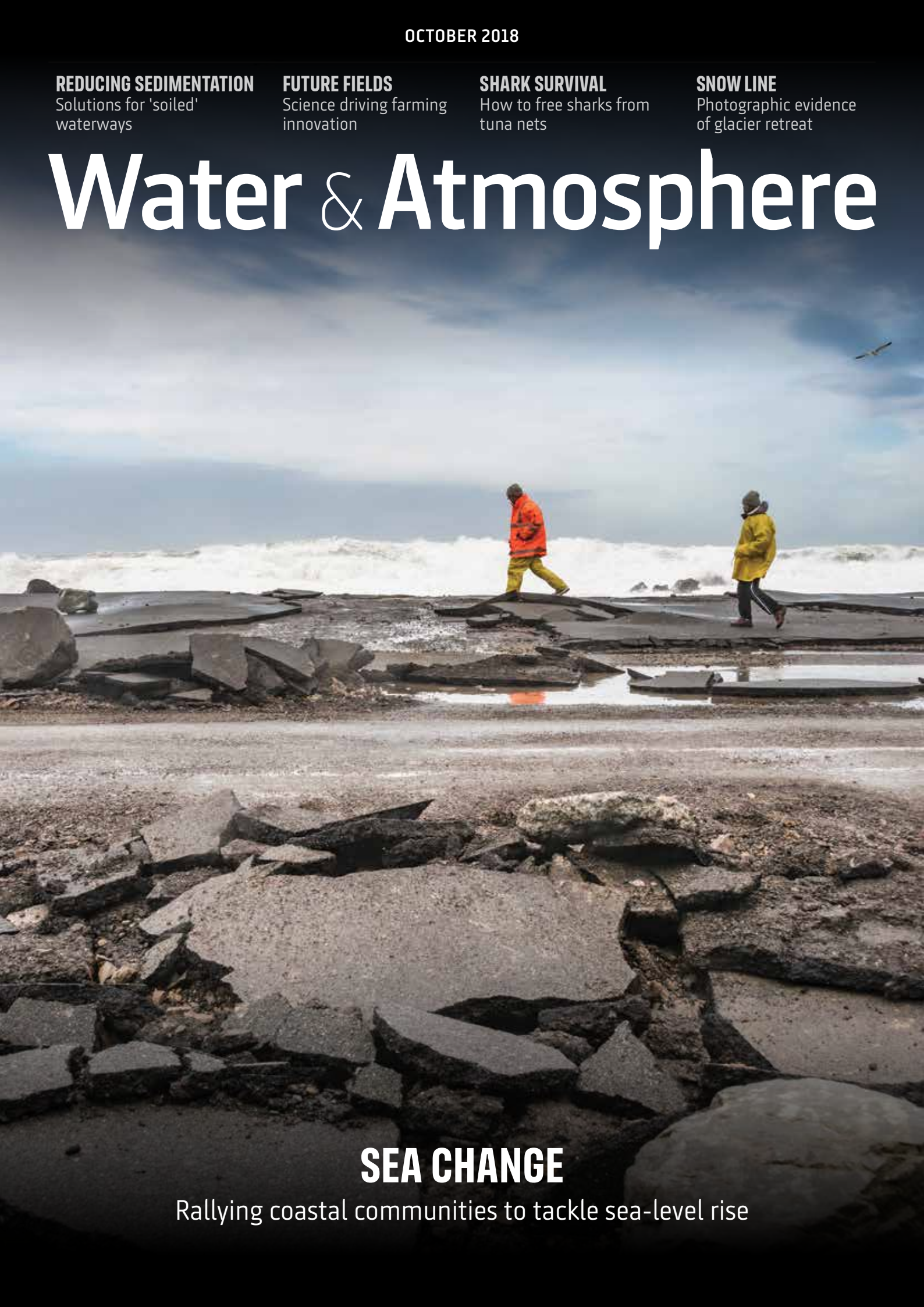
REDUCING SEDIMENTATION
Solutions for 'soiled' waterways

FUTURE FIELDS
Science driving farming innovation

SHARK SURVIVAL
How to free sharks from tuna nets

SNOW LINE
Photographic evidence of glacier retreat

Water & Atmosphere



SEA CHANGE

Rallying coastal communities to tackle sea-level rise

Water & Atmosphere

October 2018

Cover: Storm damage along the Esplanade, Owhiro Bay, Wellington in 2013. (*Dave Allen*)

Water & Atmosphere is published by NIWA.
It is available online at www.niwa.co.nz/pubs/wa

Enquiries to:

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

email: wa-editor@niwa.co.nz

ISSN 1172-1014

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Water & Atmosphere is produced using vegetable-based inks on paper made from FSC certifed mixed-source fibres under the ISO 14001 environmental management system.

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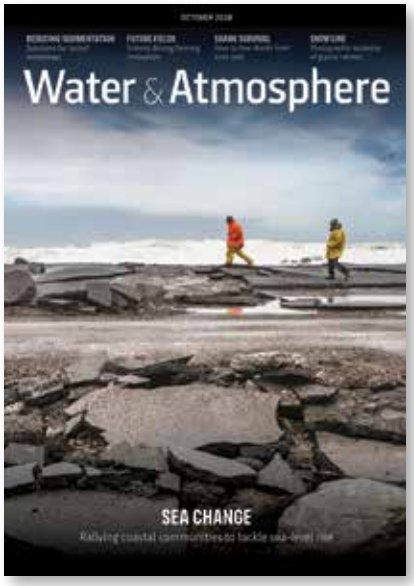

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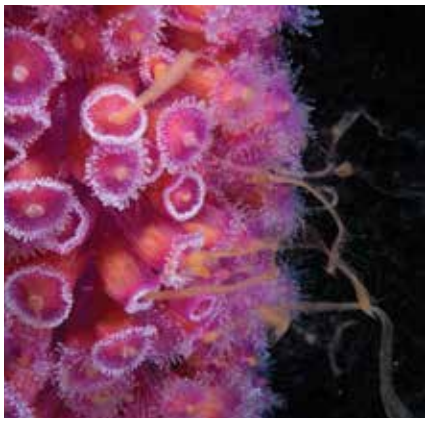

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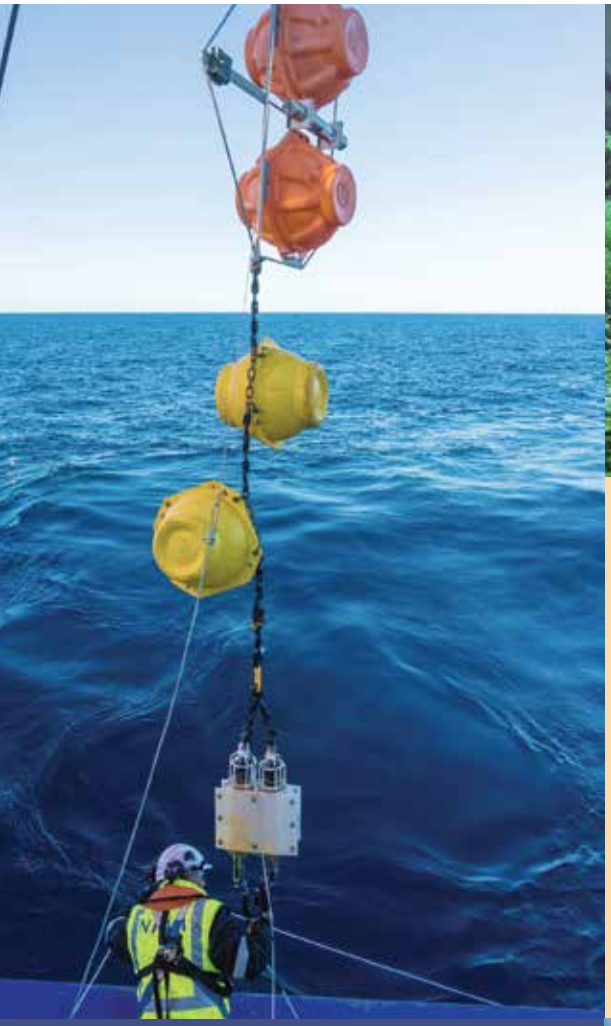


Passive acoustic moorings, deployed from RV *Tangaroa*. (*Hamish McCormick*)

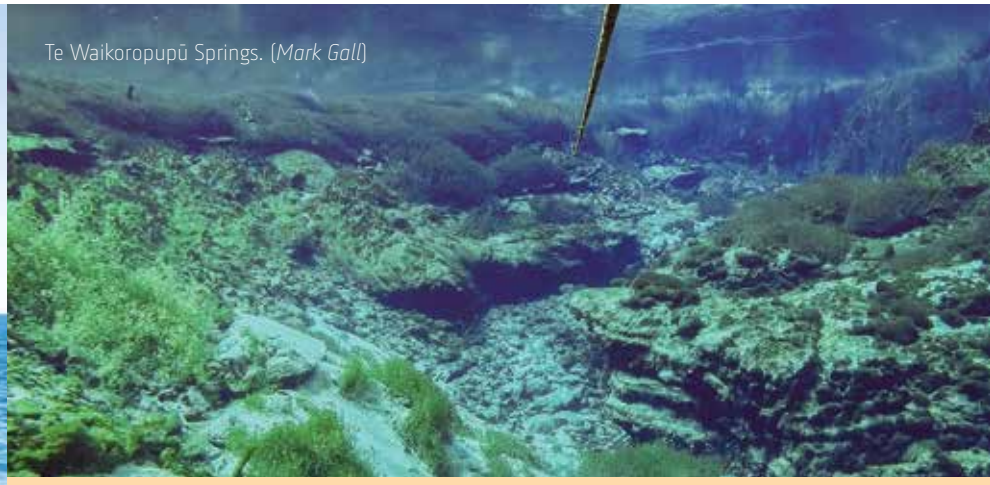
Unidentified sounds in Cook Strait

A NIWA-led research team has detected two yet-to-be identified species of beaked whale in a recent project conducted in the Cook Strait region.

Their presence was confirmed after the analysis of underwater acoustic data, which was collected during two, six-month deployments of passive acoustic moorings. The data revealed three distinct beaked whale signals. However, two did not match any previous recordings of the species.

Little is known about the beaked whale species, which makes this an important find in understanding the population of the marine mammal in New Zealand waters.

The next step for the researchers is to examine the rest of the collected data for similar signals to determine how often the sounds from the unidentified species were recorded.



Te Waikoropupū Springs. (*Mark Gall*)

Exceptional clarity at Te Waikoropupū Springs

A three-month monitoring project recently finished by NIWA for the Tasman District Council has confirmed that Te Waikoropupū Springs in Golden Bay has some of the clearest water ever measured. Researchers found that visual water clarity at the springs in Golden Bay is about 76m – although at times has approached 81m – which is just short of the theoretical maximum of pure water at about 83m.

NIWA used measuring instruments hung from a submerged line near one of the main vents, as well as a GoPro camera to film the deployment.

"The Te Waikoropupū Springs have exceptional visual clarity, at times close to that of pure water." said NIWA Marine Ecosystems and Aquaculture Scientist Mark Gall.

The springs are also the largest cold water springs in the Southern Hemisphere.

NIWA research vessel *Rukuwai* on Lake Tekapo. (*Susanne Woelz*)

Tsunamis happen in lakes too

A pilot project led by NIWA marine geologist Dr Joshu Mountjoy has provided the most advanced mapping of a New Zealand lake ever, after using multibeam sonar equipment to map the floor of Lake Tekapo, which subsequently revealed the hazard to lakeside towns of tsunamis caused by landslides.

Dr Mountjoy said they had modelled tsunami from slope failures within and into the lake, based on the evidence for the size and location of past landslides. The results show that waves could exceed 5m at many of the lake's shoreline locations.

"Most people think of tsunamis as ocean-based, but they are just as capable of happening in lakes, although little work has been done on this worldwide," he says.

Researchers are hopeful that the Lake Tekapo study can be used as a basis for research on tsunami hazard in other large New Zealand lakes, such as Wakatipu, Wanaka and Taupo.

Dr Wendy Nelson. (*Dave Allen*)

NIWA scientist tackles climate change with seaweed

A paper co-written by NIWA marine biologist Dr Wendy Nelson has been named one of the 250 ground-breaking findings to help tackle climate change by Springer, a US-based academic publisher.

The paper explores the potential of commercial seaweed farming in mitigating global carbon dioxide levels, a key greenhouse gas responsible for man-made climate change.

Dr Nelson said the paper tackled the possibility of developing more seaweed aquaculture to mitigate the impacts of ocean acidification and the potential for converting their biomass to biofuel, which could reduce the use of fossil fuels and provide renewable alternative fuels.

"We need to consider the fate of carbon being absorbed by marine systems. How we protect the marine environment to maintain these ecosystems is an exciting area of research," she said.

Southern right whales may be returning to the capital

The southern right whale which spent over a week in Wellington Harbour may indicate the species returning to their historic habitat, according to University of Auckland marine science PhD student Victoria Warren who helped analyse data recorded by NIWA scientists.

Increasing numbers of southern right whales have been congregating in New Zealand waters. The species takes annual migrations, swimming north from Antarctica, and is known to breed around the Auckland Islands each year.

"It may be a sign of a recovering population following the decimating impacts of commercial and illegal whaling during the 19th and 20th centuries," she said.

Southern right whale with NIWA researchers in Wellington Harbour. (*Karl Halvorsen*)

NIWA staff at Seabed 2030, Wellington, June 2018. Left to right Dr Rob Murdoch; Tilmann Steinmetz; Dr Geoffroy Lamarche; Arne Pallentin; Dr Helen Neil; Patrick Hayes; Kevin Mackay. (*Dave Allen*)

NZ scientists to help map the world seafloor

Scientists from NIWA, GNS Science and Land Information New Zealand have opened the new South and West Pacific Ocean Regional Data Assembly and Coordination Centre at NIWA Wellington, which is a part of the Seabed 2030 project to create a definitive map of the entire ocean floor in less than 12 years.

The centre, led by NIWA marine geologist Dr Geoffroy Lamarche, will map out an area equivalent to a quarter of the world's ocean which covers the Pacific Ocean from South America to Australia, north of latitude 50°S to 10° north of the Equator, and the western part of the Northern Pacific Ocean to Japan.

The task requires close collaboration and involvement of all coastal states coordinated by the centre.

"Such information is critical to enable coastal states to properly manage and protect benthic (at and near the seafloor) environment from the coast to the greatest depths of the ocean," said Dr Lamarche.

Kaikōura earthquake provides world-first insight into submarine canyons

Research conducted after the 2016, 7.8 magnitude Kaikōura earthquake has provided scientists with an extremely rare opportunity to understand the processes that shape submarine canyons.

Pre and post-earthquake seafloor video, bathymetry, and sediment core samples collected from NIWA's research vessel *Tangaroa* has shown that strong ground-shaking during the earthquake triggered widespread landslides in the Kaikōura Canyon, causing a powerful "canyon-flushing". Canyon-flushing describes the process where high-energy currents transport sediment in the undersea canyon to the deep ocean.

Evidence showed the earthquake stripped over 850 million metric tonnes of sediment from the Kaikōura Canyon. It travelled more than 680km northeast along one of the world's longest deepsea channels – the Hikurangi Channel. It's the first time, globally, that the impact of a full canyon flushing event has been documented in such detail, providing scientists with an incredible benchmark to understand how the process works, and how the undersea environment and ecosystem recovers over time.

Flushing of submarine canyons can be triggered by a range of events, including earthquakes, typhoons and extreme river discharges.

"This study unequivocally demonstrates that earthquake-triggered canyon flushing is the primary process that carves out submarine canyons and delivers coastal sediment to the deep ocean," says NIWA marine geologist Dr Joshu Mountjoy.

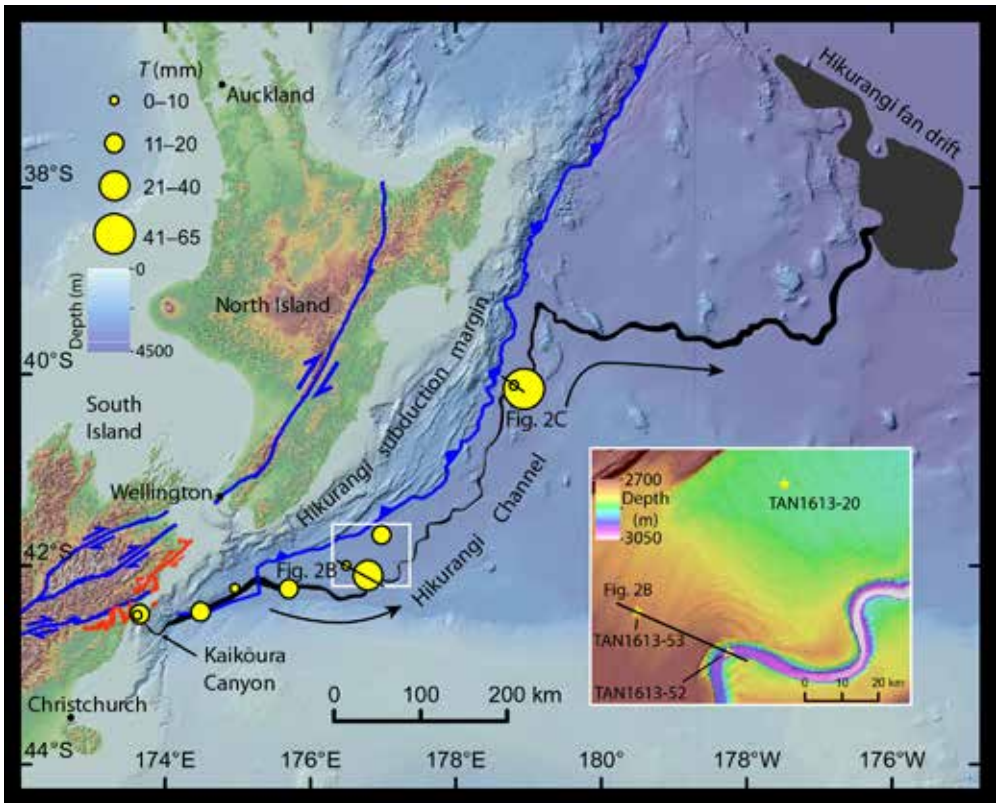
"The impact has been extreme, delivering 850 million metric tonnes of sediment to the deep ocean in one go – twice the annual sediment delivery of all New Zealand rivers.

"These results have proven long-standing scientific hypotheses about how submarine canyons are shaped. For the first time we'll be able to quantify the scale, timing and seafloor impacts of a canyon-flushing event, giving us unique insight into this important global process," says Dr Mountjoy.

Results also indicate canyons may form at a much faster rate than previously thought – as little as a hundred thousand years. Sediment flow generated by the quake carved into the rock underneath the canyon – deepening two main reaches of the Kaikōura Canyon by up to 50m, and the middle-canyon region by 20–30m.

Despite devastating the ecosystem, subsequent NIWA surveys have confirmed the former biodiversity hotspot is slowly recovering, with evidence of juvenile animals that once dominated the head of the canyon beginning to re-colonise the seafloor.

This study was part of a collaboration between NIWA, Victoria University of Wellington, GNS Science and international colleagues, funded by the Natural Hazards Research Platform and NWIA SSIF.



The NIWA study reveals how earthquakes trigger landslides in seabed canyons, 'flushing' sediment into the deeper ocean. (*NIWA*)

A silky shark. (*Alex Chernikh*)

(Top) Warrick Lyon, NIWA fisheries technician. (Dave Allen)

A mako shark is tagged and released. (*Matt Saunders*)

Shark survival tale

As part of a Pacific-wide study, NIWA is measuring the survival rate of sharks returned to the sea by commercial tuna fishers.

The Western and Central Pacific Fisheries Commission (WCPFC) is trying to determine whether the way sharks are caught and released makes a difference to their survival.

The study began in New Zealand waters in 2017–18, then spread to Fiji, and is about to expand further into the Pacific. Mako and silky sharks are the two species selected for the study.

The first stage in New Zealand found that only one of 34 mako sharks released from tuna longlines by commercial fishers died, indicating that they are relatively hardy. Fishers bring sharks smaller than 1m long onto their boats to remove the hooks. Larger sharks are brought alongside the boat and the hook is removed or the trace is cut while it is still in the water.

Warrick Lyon, a NIWA fisheries technician, says the study is heading to the Pacific to test survival rates for sharks treated differently – such as those where hooks are not removed and where long pieces of monofilament fishing line are left attached.

"We want to assess whether the manner of catching and releasing sharks, in addition to age and sex, makes a difference to their chances of survival," Lyon says.

"The fishers will bring the sharks to the side of their boat to measure, sex and tag. Other than that, they will handle and release the sharks as they usually do."

The tag measures the animal's depth over the following two months. A steel attachment pin corrodes after 60 days, allowing the tag to float to the surface. Once there it starts broadcasting its data to the Argos satellite system.

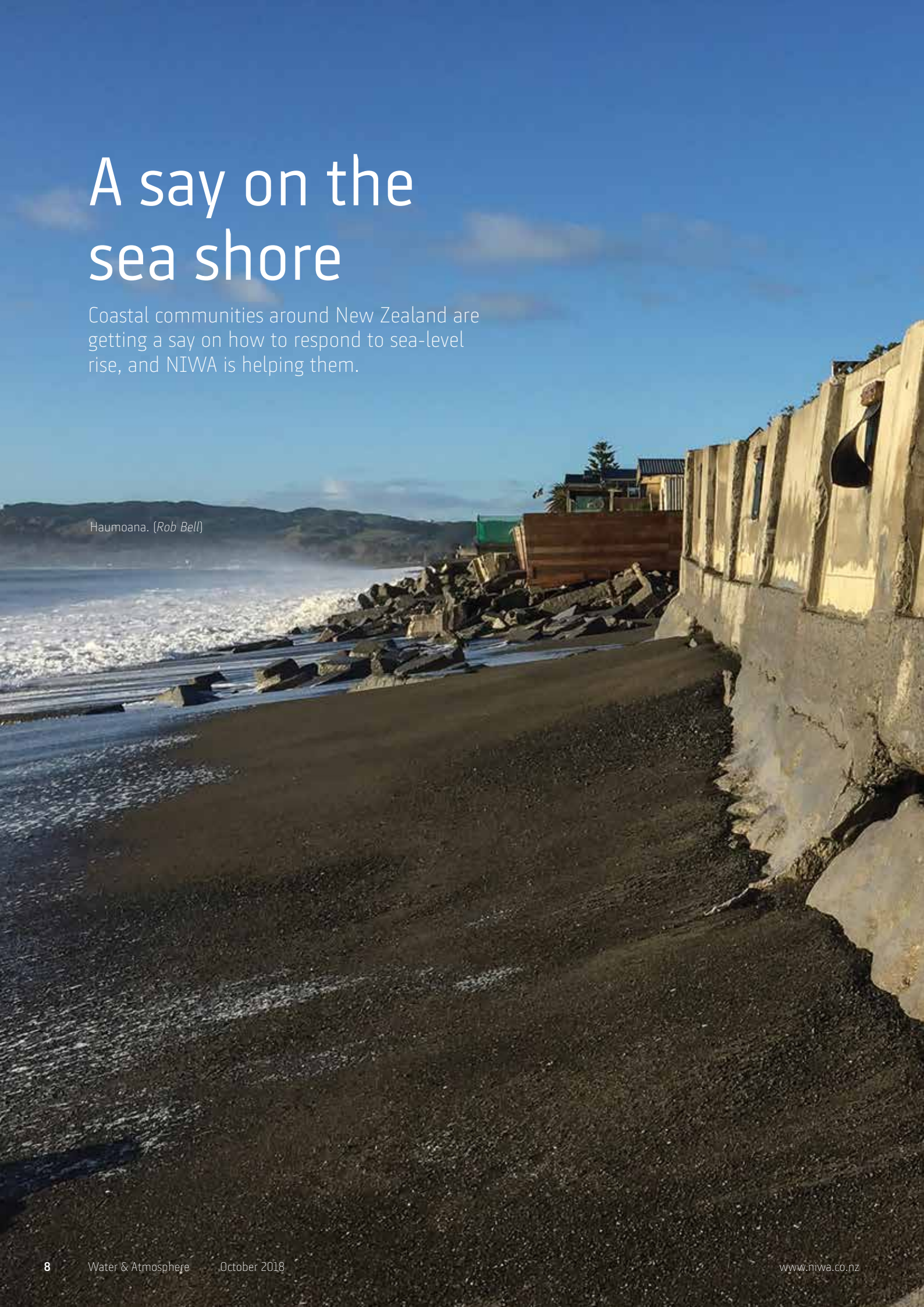
Mako and silky sharks usually move actively up and down in the water column. If the depth of the tag is constant for several days, the shark is almost certainly dead on the seabed.

NIWA scientists, in association with scientists from the South Pacific Commission (SPC), are training fishery observers in New Caledonia and the Marshall Islands to deploy tags on an initial 30 mako sharks and 30 silky sharks caught by tuna longliners.

The aim is to eventually tag 100 each of mako sharks and silky sharks. The data transmitted back by the tags will be collated and the analysis will be completed early in 2019.

A say on the sea shore

Coastal communities around New Zealand are getting a say on how to respond to sea-level rise, and NIWA is helping them.



Haumoana. (*Rob Bell*)

Discussions about the impact of sea-level rise on our coast have revealed the deep difficulties in communities agreeing on whether, and how, to respond to changes.

There has been intense community resistance to local authorities identifying, labelling and controlling homes at risk of flooding from rising sea levels.

Now though, moods are changing as new approaches are taken to discuss the threats forecast from climate change.

This shift was marked in December last year by the release of the Ministry for the Environment's (MfE) 'Coastal Hazards and Climate Change – Guidance for Local Government in New Zealand' in December 2017.

The guidance recommended a "dynamic adaptive" approach to planning. The approach is less severe and top-down, and more consultative and consensus-based. This is less threatening to those who face the bulk of adaptations, and more accommodating of small, regular adjustments over a longer period.

A benefit of the approach is the decisions and investments made now can accommodate future changes required by the still uncertain rate and scale of impacts from climate change.

Scenario planning

The Guidance provides four sea-level rise scenarios out to the year 2150 which can be used to plan for fast, slow, or intermediate rates of sea-level rise.

At its heart is a 10-step decision-making approach, to plan and adapt to rising seas. It addresses "What is happening?", "What matters most?", "What can we do about it?", "How can we implement the strategy?" and "How is it working?"

Dr Scott Stephens is a Coastal and Estuarine Physical Processes Scientist at NIWA, and one of the Guidance authors. He says the Guidance combines a step-by-step approach to assessing, planning and managing the increasing risks, with updated information, tools and techniques.

"The approach improves on previous guidance and current coastal hazard management practice in its treatment of uncertainty and the central role of community engagement in the decision-making process.

"The new guidance is a major revision of the 2008 version. It includes updated sea-level rise projections, advances in hazard, risk and vulnerability assessments, collaborative approaches to community engagement and changes to statutory frameworks."

A king tide and large waves wreak havoc along Auckland's Tamaki Drive on 5 January 2018. (*Stuart Mackay*)

Haumoana, a coastal town just south of the Tukituki River in Hawke's Bay, is prone to coastal erosion. The shoreline is retreating at a rate between 0.3 and 0.7 metres per year. (*Paula Blackett*)

> **"The approach improves on previous guidance and current coastal hazard management practice in its treatment of uncertainty and the central role of community engagement in the decision-making process"**

Essentially this reflects an appreciation that sea levels are rising, but the seriousness of impacts is still unknown.

"The Guidance provides methods that can be used for decision making under deeply uncertain conditions about the future, such as how fast sea level will rise, or how community coping capacity and vulnerability will change," says Dr Stephens.

The local word

Hawke's Bay is one of the first regions to apply the 10-step decision cycle in the MfE Guidance. The region has had its share of historical controversy and conflict as residents have grappled with the implications of sea-level rise.

The latest efforts, focused on the development of the Clifton to Tangoio Coastal Strategy, have been more successful. This has been facilitated by the combined councils of Hawke's Bay and a team from consultants Mitchell-Daysh.

Dr Paula Blackett is a NIWA Environmental Social Scientist and one of several social scientists on the interdisciplinary team working on what Hawke's Bay has dubbed the 'Living at the Edge' project.

She says the format has enabled a decision cycle that was "specially designed to work in situations of conflict where contested values and uncertainty dominate conversations".

To support the Clifton to Tangoio Coastal Strategy development, Blackett is acting as a 'critical friend' which she describes in this case as "essentially an independent research team providing supporting knowledge, ideas and thinking, and constructively highlighting problems and dilemmas to be resolved."

A king tide combines with a nor-west wind in Wellington Harbour to create havoc along the only road in and out of Eastbourne. (*Dave Allen*)

She says the contribution of social scientists has been essential.

"The purpose was to provide timely feedback that illustrated how the community participants perceived the process and progress at each event or workshop, and to identify any potential issues and challenges before they became more substantial issues."

Chair of the strategy development process, Hawke's Bay Regional Council Councillor Peter Bevan says that the bottom-up approach was essential.

"Those who find themselves threatened by coastal hazards need to be closely involved in any response strategy. That is why we adopted a bottom-up strategy in Hawke's Bay.

"Any local body that adopts solutions that have not been extensively consulted will risk prolonged conflict and argument."

Dr Blackett says that early engagement of the community is both possible and fundamental to developing climate change adaptation strategies.

"This work has shown how the Guidance can succeed in practice through a combination of well-thought-out processes, technical science support and attention to the social and economic aspects of coastal adaptation."

She notes that overall, the stepped process created time and the space for people to talk through the issues and conflicts, to consider all the options and to think in a long-term, strategic and dynamic way about the challenges ahead.

"In short, it empowered them in a way which has not been attempted previously."

Informed decisions

The Deep South National Science Challenge is another initiative delivering valuable scientific knowledge communities can use in their decision making. Part of the NIWA research funded by the challenge is to estimate storm-tide levels around the New Zealand coast based on a one percent annual chance of these levels being reached or exceeded.

Ryan Paulik, NIWA Hazards Analyst, explains that these levels are projected onto land to create individual storm-tide hazard exposure maps for the present-day hazard, and future sea-level rise scenarios, using increments of 0.1m up to 3m above mean high water springs.

"This work extends an earlier project for the Parliamentary Commissioner for the Environment in 2015 by including storm-tide hazards in sea-level rise inundation maps," he says.

The floating Sea Scout hall

Based on the coastline of Wellington's Evans Bay, the Britannia Sea Scouts are currently considering solutions for their hall, which has frequently flooded during king tides and storms over the past six years.

The club's chairperson Inger Deighton says the hall has sometimes been saturated by up to 30cm of sea water, which enters through the floor boards.

"The latest casualty has been our gas oven after its pipes rusted from the frequent flooding. Other items we have lost have been our water blaster and vacuum, as well as really anything that has been on the floor of the hall.

"One storm the hall was actually lifted off its pilings, which parents attempted to fix by strapping the piles to the floor boards as a temporary solution," she said.

The initial solution was to raise the hall by 30cm, however consultations with NIWA have indicated that this will only solve the issue temporarily as sea levels continue to rise.

According to NIWA Principal Scientist Dr Rob Bell, the frequency at which low-lying coastal areas are flooded is increasing as sea levels rise, which have already risen by 23cm over the last 100 years in Wellington.

"I've noticed over the years I have been visiting NIWA's Wellington campus at Greta Point that the tide reaches the boatshed floor level more often.

"The sea level is also rising faster in Wellington as the lower North Island is subsiding by 2–3mm per year due to seismic slow-slip of plates."

NIWA have also found that the already risen sea level has resulted in a change in frequency of 100-year storm-tides.

"For Wellington, it will only take a modest sea-level rise of 30cm for this rare storm-tide level to be reached once a year on average."

"This also means spring tides and smaller storm tides will be higher and more often – as observed at the boat sheds," said Dr Bell.

As the battle with Mother Nature continues, the Sea Scouts are feeling under pressure to decide the fate of their hall. The irony of one option has not escaped them; that the Sea Scouts will need to build a new hall further away from the sea.

Built before sea-level rise was common knowledge – the Britannia Sea Scout' hall in Wellington's Evans Bay frequently floods during king tides and storms. (*Hamish McCormick*)

> **"Universities and Crown Research Institutes like NIWA provide the capacity to develop new and innovative modelling techniques to estimate New Zealand's exposure and vulnerability to future impacts from natural hazards"**

"The incremental sea-level rise scenarios enable these maps to be matched to future sea-level rise projections. This provides both spatial and temporal estimates for asset exposure to inundation from sea level rise and storm-tide hazards in New Zealand."

Paulik considers that the relationships between research institutes, such as NIWA, and academic and government organisations are critical to delivering robust science.

"Universities and Crown Research Institutes like NIWA provide the capacity to develop new and innovative modelling techniques to estimate New Zealand's exposure and vulnerability to future impacts from natural hazards."

Knowledge shared

Over the next few months MfE will hold workshops around the country with regional and local authority staff to help them understand how to use the guidelines.

Dr Scott Stephens is part of the team facilitating the workshops.

He says they will help "familiarise users with the Guidance, explaining context, key features, how it interacts with the statutory (legal) framework, advice on conducting sea-level rise, hazard, risk and vulnerability assessments, and advice on community engagement processes".

"The workshops will demonstrate the application of dynamic adaptive pathway planning methods, step-by-step and with exercises."

The workshops are another example of a shift in approach that will help coastal communities become better prepared for rising sea levels, and provide them knowledge they can use to make practical adaptations.

Roads turn to rivers in South Dunedin as flood waters have nowhere to drain after a significant rainfall event in 2015. (*Otago Daily Times*)

Digital maps show flooding caused by rising groundwater combined with rainstorms and elevated storm-tide levels.

Mapping floods

Digital mapping of flood prone areas is enabling local communities to gain a clearer picture of vulnerabilities to flooding caused by a changing climate, and what to do about it.

One fascinating study is mapping where flooded roads could lead to floating cars.

Ryan Paulik, NIWA Hazards Analyst, was part of a NIWA team reviewing international literature on vehicle stability in flood flows.

"Laboratory studies have demonstrated that hatchback or sedan models can float in water depths as little as 0.3m, compared with 0.45m for SUVs."

"With this information, we are able to use high resolution flood maps to identify roads and locations inundated by flood waters that are dangerous for vehicle traffic."

The open access software RiskScape, developed by NIWA and GNS Science, provides a framework to estimate impacts and material losses, from floating cars to saturated houses. The team used the data from the Christchurch City flood event in March 2014 to identify a prevention method that could reduce losses by 70% in future events.

In South Dunedin, a new multi-layered database is producing digital maps showing how forecast sea-level rise will cause flooding in the area from rising groundwater combined with rainstorms and elevated storm-tide levels.

The maps are a collaborative effort by the University of Otago's Centre for Sustainability, the Dunedin City Council and the Otago Regional Council.

The maps allow better demonstration of the impact because they combine details held by different agencies, such as demographics and house ages.

Auckland Transport has used NIWA-developed inundation maps to identify the replacement value of roads that could be exposed to coastal flood events under future sea-level rise scenarios.

Auckland Council is working with Auckland Transport to identify the most vulnerable assets and hot spots where future planning and adaptation work can be targeted. The information has been made publicly available through the Auckland Council's GeoMaps online mapping service.

2018 NIWA Photography Awards

This year's NIWA staff photographic competition is a testament to the extraordinary landscapes our staff work in.

Crispin Middleton

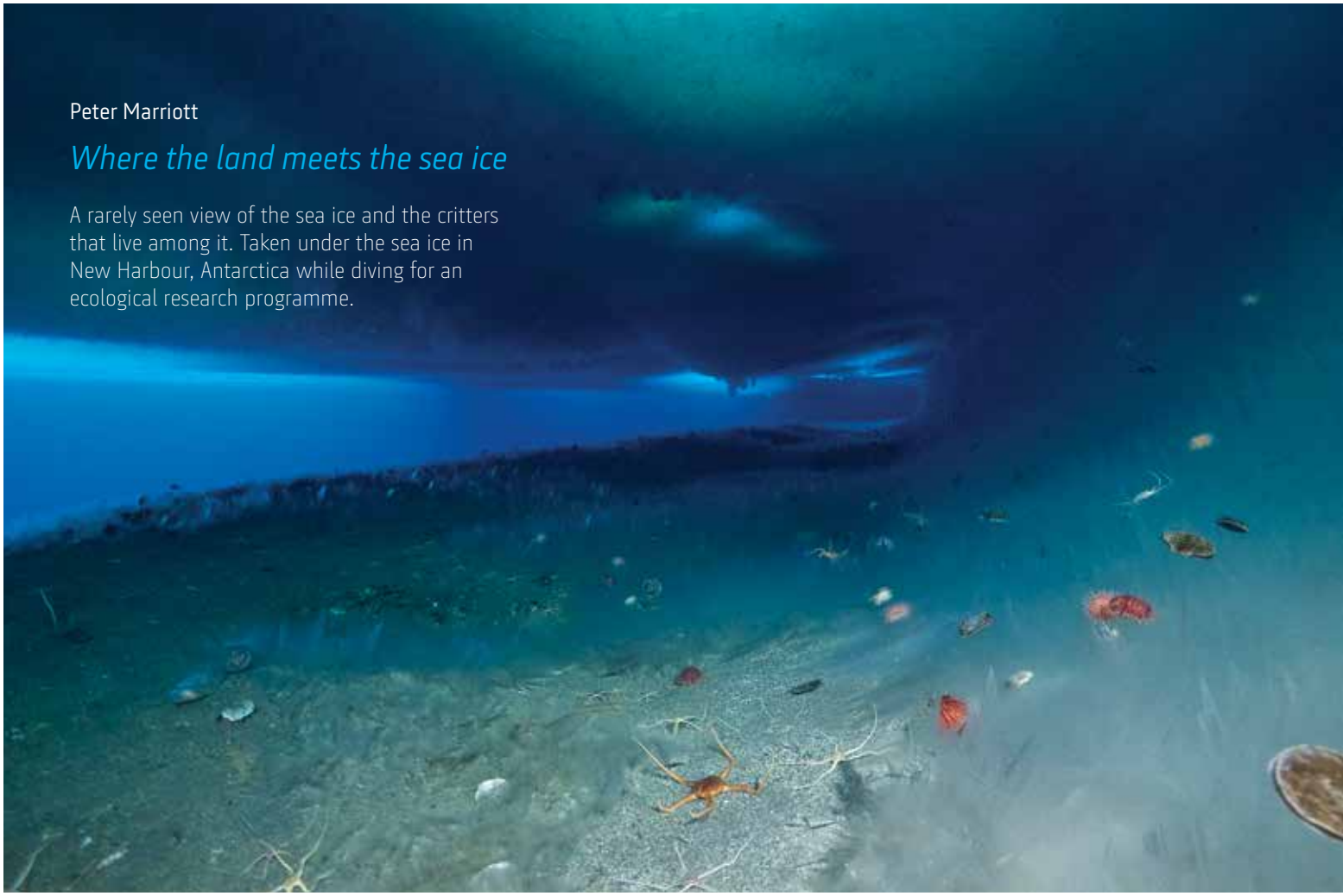
Spawning jewel anenome

Jewel anenomes spawn once a year, and the event only lasts between 10 and 20 minutes. It is carefully coordinated with the tide and the cycle of the moon.

Peter Marriott

Where the land meets the sea ice

A rarely seen view of the sea ice and the critters that live among it. Taken under the sea ice in New Harbour, Antarctica while diving for an ecological research programme.



Peter Marriott

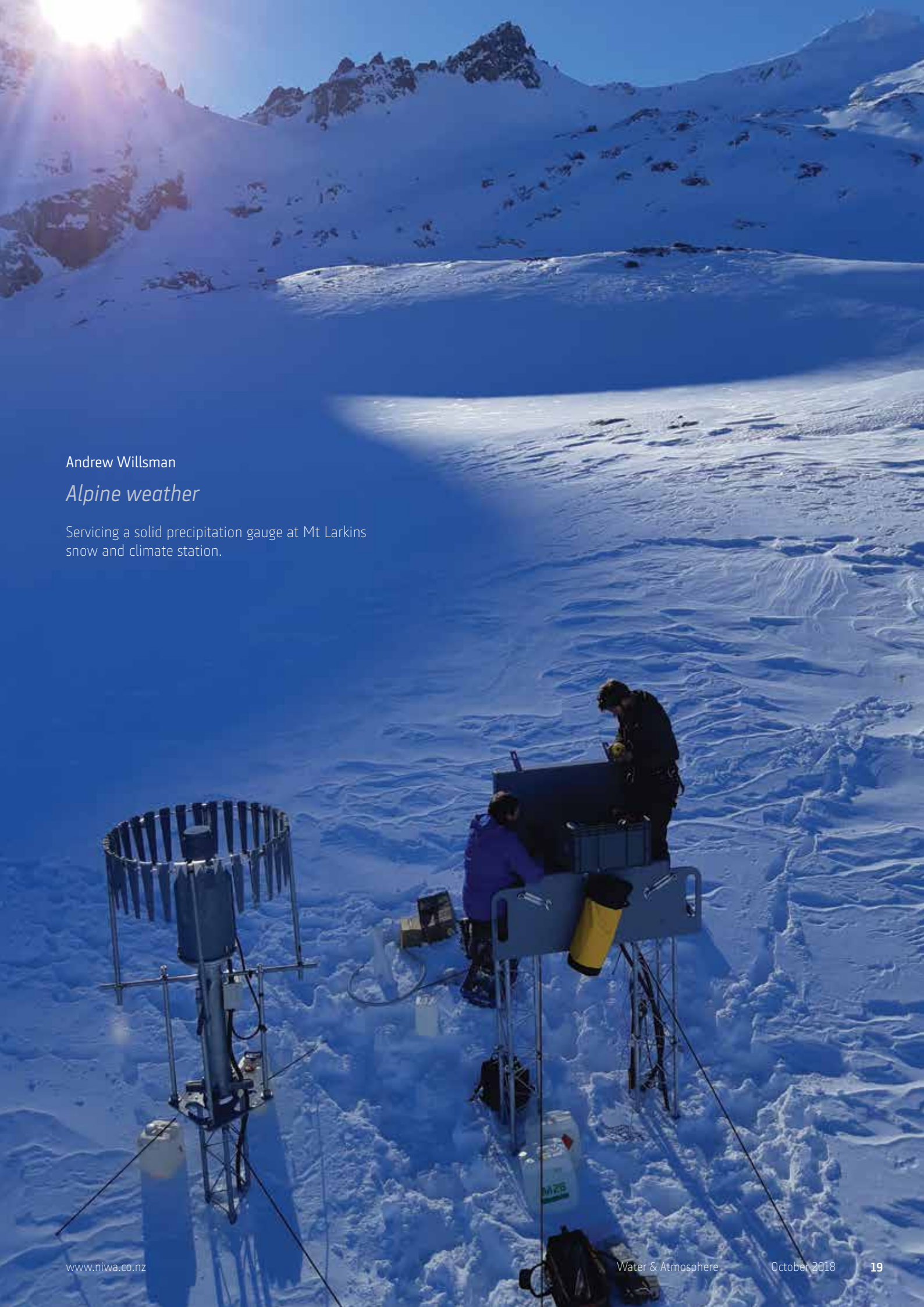
Biosecurity surveying

NIWA diver Lily Prior Rodgers surveying wharf piles in Bluff for invasive species.

Lily Prior Rodgers

Te Wheke

Taken under Tiwai Wharf in Bluff during the summer Marine High Risk Site Surveillance, massive and frequently encountered octopuses are a highlight of this port.



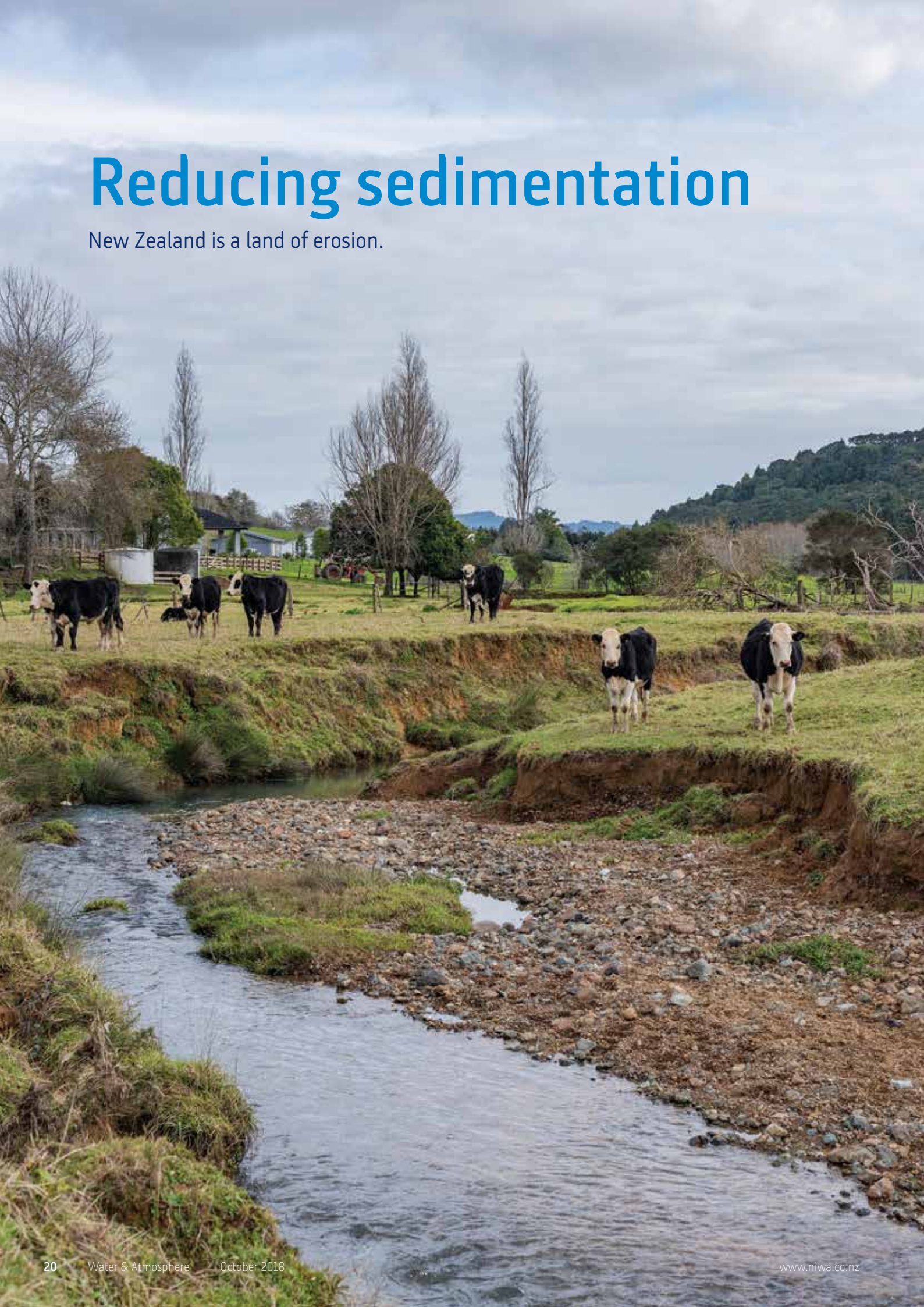
Andrew Willsman

Alpine weather

Servicing a solid precipitation gauge at Mt Larkins snow and climate station.

Reducing sedimentation

New Zealand is a land of erosion.



We're losing about 192 million tonnes of soil a year, according to the latest report *Our Land 2018*, from the Ministry for the Environment and Statistics NZ. It says New Zealand is contributing about 1.7% percent of the sediment delivered to the world's oceans annually due to soil erosion, even though the country accounts for just 0.2% of global land area.

A lot of this lost soil comes from natural erosion. However, over 40% of the soil entering our rivers comes from pasture.

According to Dr Andrew Swales, an estuarine physical processes scientist who leads NIWA's Catchments to Estuaries programme, New Zealand is particularly susceptible to erosion due to the country's steep lands. They have more erosion potential due to their slope, their geology, high intensity rainfall and earthquakes.

It's a potent mix: many places have highly erodible sedimentary rocks, earthquakes destabilise hillslopes, and rain triggers slope failure and landslides.

While soil erosion and sedimentation are entirely natural processes, the rates increased markedly due to loss of forest landcover with the arrival of people in New Zealand, says Dr Swales. Deforestation and present-day land-use practices have increased New Zealand's existing susceptibility to erosion.

Prior to human arrival, sedimentation rates in our estuaries were typically much less than 1mm per year on average. As catchments were deforested, the average sedimentation rates increased 10-fold.

"Typical rates in upper North Island estuaries over the last century are in the order of 2–5mm per annum," says Dr Swales.

The result of this accelerated sedimentation has been the formation of intertidal mudflats in place of the sandflats that characterised many estuaries prior to catchment deforestation.

In upper North Island estuaries, these rapidly accreting mudflats have been colonised by mangroves, where shellfish previously lived.

"It's a double whammy," he says. "We're losing productive soils from the land, and these eroded soils are having adverse effects in estuaries."

Known as the "universal contaminant", some of the most damaging effects of fine sediments accumulating in our

NIWA staff working with representatives from Manaaki Whenua, Auckland Council, Ngai Tai Ki Tamaki and the local residents association in the Aroaro valley catchment near Clevedon. The catchment is useful to study because the land has a variety of purposes, such as livestock, orchards and forestry, in a relatively small area. Water samples are gathered and processed using a mass spectrometer, and the sample's isotopic signature is then used to trace the source of fine sediment in the water. (*Dave Allen*)

New Zealand is a land of erosion. We're losing about 192 million tonnes of soil a year. (*Hamish McCormick*)

estuaries are related to clays that are less than 4 microns in diameter.

"They're the most effective at decreasing sunlight … they reduce the visual clarity of the water. Many predatory species, including fish and birds, are visual predators, using their eyes to find their prey," says Dr Swales.

Fine sediments carry other contaminants with them, including heavy metals, organic contamination from stormwater runoff, and microbes which are harmful to human health.

"A fraction of that contamination is conveyed by fine sediments and deposited in estuaries," says Swales. "In rural settings the fine sediments carry phosphorus with them as well."

Erosion can be reduced by changing the type or scale of land use or adopting practices to mitigate losses. But before we can do that, we need to work out which land use is responsible for the sediment.

Tracing sediment

Dr Swales says one way to trace the sources of fine sediments is by using stable isotopes. These are non-radioactive forms of atoms found in almost all of the first 80 elements in the periodic table. They have been used as a kind of natural ecological recorder, to trace things like sources of water, sources of various foods, and even tracking counterfeit money.

Dr Swales's colleague, emeritus scientist Dr Max Gibbs, was the first person to identify that compound-specific stable isotopes (CSSI) and their isotopic signatures could be applied to tracing the sources of fine sediments. He published his work on the CSSI sediment tracing method in 2008.

All organic life has fatty acids. All plants secrete their fatty acids into the surrounding soil. The fatty acids of plants like native trees, forestry pine, grass and food crops typically have different ratios of the two main isotopes of carbon, 12C and the slightly heavier 13C.

These isotopic signatures can still be found in sediment, which means you can label sediment by the land use from which it originated.

"When you collect sediment from an estuary, lake or river, it's going to come from a mixture of various sources," says Dr Swales. "We analyse samples for their stable isotopic signature, and use a model to unmix that mixture. That allows us to apportion the average contribution of different plant communities, which gives an outline of the contribution of different land uses."

> **"We're losing about 192 million tonnes of soil a year ... about 1.7 percent of the sediment delivered to the world's oceans annually"**

Stable isotopes provide information on the sources of sedimentation. When combined with measurements from radioisotopes, the rate of sedimentation can be determined.

The CSSI method can analyse a dated sediment core taken from an estuary or a lake and provide information about how sources have changed over time.

Other studies

NIWA is participating in a study with the International Atomic Energy Agency (IAEA) and the Food and Agricultural Organization (FAO).

NIWA is bringing together the CSSI and radioisotope methods to capture persistence information from sediment cores as well as determining how land-use change influences the isotopic signatures of soils. NIWA's contribution to this international study includes a case study that has measured rates of change in soil isotopic signatures associated with a pine-to-dairy land-use change near Taupo that has occurred since the 1980s.

In New Zealand, the Ministry for the Environment has been commissioning research into sediments, primarily the effects of sediments in rivers. Dr Swales says it is likely that in the future there will be more focus on estuaries, as well as setting limits for different contaminants, including fine sediments.

Separately, NIWA's Managing Mud programme is providing new knowledge and tools to underpin better management of fine sediments and their effects.

More sediment likely

Dr Swales warns that climate change will have a further impact on sedimentation. It is likely that New Zealand will be subject to more of the high intensity and frequent rainfall events that have massive erosion potential.

"There might be a need to modify the pattern of our land use. Potentially, that's both in space and timing of what we

Planting along waterways lower in the catchment can reduce sedimentation and pollution as well as provide shade for the stream. (*Dave Allen*)

grow, and where we do things to mitigate the effects," he says.

The solution is not necessarily as obvious or easy as planting trees. Dr Swales notes that landslides from high intensity rainfall events can even occur in regenerating native forests.

"It's taken us 150 years to get to this point. Trying to change the trajectory we're on, or mitigate the effect, is going to take some time and quite a lot of effort."

How much can fish handle?

Based on seven years of research, NIWA has established turbidity limits to protect fish in New Zealand rivers.

Turbidity is the measure of cloudiness in water. It is caused by tiny particles in the water, including fine sediments.

The application of turbidity limits to protect fish depends on knowledge of both the distributions and life history patterns of sensitive species. To help water managers apply turbidity limits, NIWA has developed a decision support system (DSS).

The DSS has two parts: one for peak-flow (that is, floods) and one for base-flow. In floods and other peak-flow conditions, extreme turbidity may kill fish. Whereas in base-flow conditions, long-term exposure to sublethal toxicities can reduce populations and affect fish behaviour.

The DSS can be used for planning purposes, monitoring, and restoration, but only covers direct effects of increased turbidity on common riverine fish. It does not address the potentially more insidious, indirect effects of settled solids on river or steam habitats. Current NIWA-led work for the Ministry for the Environment is addressing both direct and indirect effects.

Some freshwater fish species such as eels can tolerate a relatively high level of turbidity, while others such as inanga and smelt tend to struggle in murky water. (*Stuart Mackay*)

Are trees the answer?

Planting trees is one solution to the problem of sedimentation.

Trees change several processes in a catchment, according to NIWA hydrologist Dr Christian Zammit.

Firstly, the soil is anchored both by the tree roots and organic matter generated under the tree. "Tree roots grab the soil, which avoids soil being moved further downstream", says Dr Zammit, who is the Programme Leader – Water Resources at NIWA.

Trees can also slow water running off land surfaces during high rainfall events. "This will impact the velocity at which the soil is moved," he says.

Trees also intercept much more precipitation than grass. "This means there is less water received by the soil. Less water means a bigger proportion infiltrates through the soil instead of creating direct runoff."

In addition, trees provide a path for water to go directly to the root system, and deeper into the soil. "Basically, reducing the amount of surface flooding that could generate sediment runoff," says Dr Zammit.

He cautions that all that water-redirection and retention can have consequences when using trees for erosion control, as it typically reduces the amount of water available for uses such as water catchment.

Acknowledging that trees have many benefits (including an impact on soil erosion), the Government has committed to planting one billion trees over the next ten years.

"Planting trees reduces erosion by helping to keep the soil on the land and improving pasture productivity and water quality," Julie Collins, Head of Forestry, Ministry for Primary Industries told *Stuff* in April.

The programme "will see us go from [planting] 55 million trees this year, to 70 million a year in 2020, to 90 million in 2021. From there we will be aiming for 110 million a year over the next seven years," said Forestry Minister Shane Jones in a media release in February.

A billion trees over ten years doubles the current number of trees being planted in New Zealand. At the moment, there are 50 million trees planted each year, or 500 million over ten years.

At present it is unclear exactly how the one billion tree programme will work. "I suspect sometime next financial year, one of the funded projects will start looking at what needs to be done, what type of trees need to be planted, where, and at which density," says Dr Zammit.

Ms Collins echoes this. "An important focus is about

Planting the right trees in the right locations can reduce erosion by helping to keep the soil on the land. (*Paul Sutherland*)

planting the right tree, in the right place, for the right purpose."

According to Minister Jones, planting will include exotics and natives and will focus on commercial crops as well as environmental and regional gains. "We want to enable planting of a mix of permanent and harvestable forestry, using both exotic and native tree species on private, public and Māori-owned land. Species include radiata pine, redwood, tōtara, eucalyptus, Douglas fir and mānuka," he said in a statement.

Dr Zammit believes the programme is a "great opportunity to redesign the New Zealand landscape to be sustainable under climate change."

To mitigate sedimentation, forest planting is usually conducted at the top of a catchment where precipitation falls the most. However, one of the ideas that could be explored would be to "redesign land management at a catchment scale by planting some forest further downstream at a lower density," he says. Planting along waterways lower in the catchment would reduce the amount of soil lost to streams, but at the same time provide an ecological corridor and refuge under climate change. It would also "provide shading for the stream, so maintaining fish populations at a longer time span," says Dr Zammit.

The Government is currently considering a proposed research strategy for the one billion tree programme, including whether a model should be established to indicate the best position and density for the trees. Minister Jones has said that he expects to make more announcements about where trees will be planted in coming months.

(*Dave Allen*)

Fieldays – farming for the future

Farmers visiting Fieldays at Mystery Creek in June could not have missed the take-home message: *that science and innovation are key to their continued success.*


Hill Laboratories
Hill Laboratories
FIRE EXIT
OSPRI
OSPRI
NIWA
Taihoro Nukurangi
Look into the future with NIWA

Science featured strongly among displays, stalls and talks: from introducing dung beetles or growing plantain to reduce nitrogen leaching, to deer milking, take-home kits for laboratory soil testing, and robots that autonomously navigate kiwifruit orchards to capture fruit data.

From a humble start in 1968 at the Te Rapa racecourse, Fieldays is now the largest agribusiness event in the Southern Hemisphere. It attracts more than 130,000 visitors from all over the world. In celebration of its 50th anniversary, this year's theme was the "future of farming" – focusing on agricultural innovations and ideas. The organisers kicked off a discussion on what New Zealand's farming's future will look like.

Understanding future farming scenarios is the focus of NIWA's work on climate change adaptation for rural communities. NIWA's Fieldays site showcased a range of climate-based services that help farmers and growers make confident and informed operational decisions, such as when and where to irrigate, fertilise, spray, harvest and move stock.

NIWA's Chief Scientist, Climate, Atmosphere and Hazards, Dr Sam Dean says that by making sound choices now, and in the future, farmers can adapt, increase resilience, and reduce risks and costs for themselves and future owners of their farms.

What climate change will mean for farming:

Some future scenarios predicted by NIWA's current climate modelling include:

- A mean temperature increase throughout New Zealand
- Fewer frosts, meaning pests that cannot survive in cooler regions, may spread
- Increasing hot days, particularly in the north and east, when temperatures will be higher than 25°C
- Changing rainfall patterns, with increased rainfall in the west and south, and less in the east and north
- Increased droughts, putting stress on water resources and animal feed
- More extreme rainfall events, resulting in flooding, slips, landslides and damage to infrastructure.

Ari, Kalarni and Nikau Henman from Awakeri playing the Climate Adaptation Challenge at NIWA Fieldays 2018. (*Sarah Fraser*)

"If we are to build a more resilient, better-prepared agricultural sector, we need to make decisions informed by good knowledge and science," he says.

Dean says while farmers are known for their resilience and adaptability, climate change will go beyond any previous experience they've had. It will increase the likelihood of extreme weather events that cause flooding, drought, and erosion. These will affect almost all on-farm activities, including harvest times, crop choice, productivity, irrigation, groundwater recharge, and pasture growth.

"Climate change effects are accelerating. Farmers understand significant change is coming, and some of it is now inevitable – so planning how to adapt and thrive is a priority.

"Optimising current farming practices, informed by good science, is one of the most effective adaptation strategies," Dean says.

Computer games

Farmers visiting the NIWA site were able to find out what climate change might look like on their own farm, using highly detailed computer graphics.

An inventive table top board game helped them explore different climate scenarios and pathways they could take to mitigate or realise potential opportunities from a changing climate on their own farms.

The 'Climate Adaptation Challenge' game works a bit like Monopoly. One version of the game was created for dairy farming and the other representing a dry stock farm. Using 3D-printed pieces and specially-designed NIWA play money, players were encouraged to make decisions about their own farming practices, in response to expected increases in extreme rainfall brought on by climate change.

Each player rolled a 12-sided dice to simulate 10 years on the farm. Three sides of the dice represent 'severe flood', four

Climate Change Minister James Shaw plays the Climate Adaptation Challenge with NIWA's Rob Bell, Paula Blackett, Susie Elcock, Stephen FitzHerbert and Stu Mackay looking on. (*Sarah Fraser*)

'high flood' and five 'no event'. Players used the 'pathways approach' to explore, develop and implement strategies to address climate impacts, without compromising or shutting off other options.

'Pathways thinking' is a strategic planning approach, giving farmers a framework to consider many different options, how long these might be effective for, and when it might be time to change tack.

"Serious gaming is now a well-regarded social science tool, which enables conversations with scientists and between partners, that they might otherwise be reluctant to have," says NIWA Senior Communications Advisor, Alex Fear.

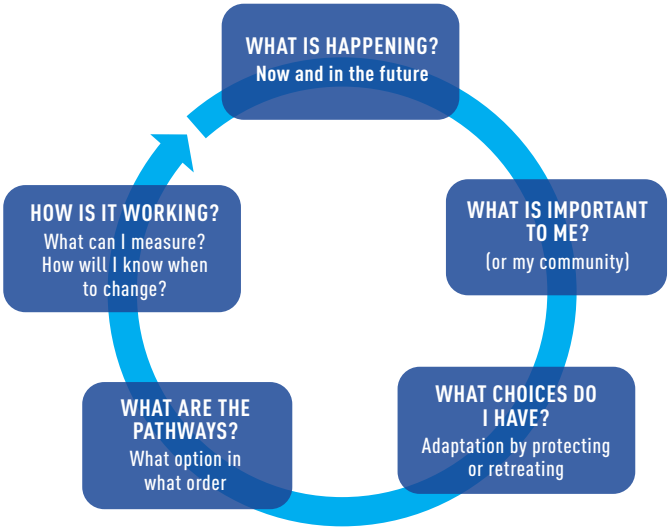
"It's been really interesting to see the conversations it has kick-started between husbands and wives about what they would do on their own farm. There's been some rigorous debate about what future actions or steps they might take."

Climate Change Minister James Shaw also visited the NIWA site and was impressed with how the game demonstrated that responding to climate change is about choices.

"If we're educated about what the risks are and what the choices are, and how much money you've got available to make those choices, I found that quite empowering."

Dean says he wants those in the agribusiness sector to make decisions based on good science, because although climate change brings risks, it also offers new opportunities, such as diversification and development of new crops.

"If we understand the climate projections, we are better informed about what our choices might be. We can feel a real sense of opportunity about the future – what role science can play, and how people can contribute."



Farmers visiting the NIWA Fieldays site could pick up a 16-page workbook, showing them how to use pathways thinking to develop their own farm business climate change strategy.

NIWA 2018 glacier survey

Melt water flows swiftly down the Tasman River towards Lake Pukaki. Water from this river is used for hydroelectric power generation, irrigation and recreation. What happens when the contribution from seasonal snow and ice melt changes in a warmer world? (*Dave Allen*)

2018 glacier survey

Aoraki/Mt Cook with Lake Pukaki in the distance. (*Dave Allen*)

The end of summer snowline survey team from NIWA, Victoria University, Alpine and Polar Processes Consultancy, and Milford Sound Flights. Left to right – Dr Huw Horgan, Dr Brian Anderson, Lauren Vargo, Dr Andrew Lorrey, Andy Woods and Dr Trevor Chinn. (*Dave Allen*)

High above one of New Zealand's most famous glaciers - the Tasman. Since 1990 the ice has retreated an average of 180 metres per year. Tasman Lake at the terminus of the glacier is a result of the glacier's decline – before 1973 it did not exist. (*Dave Allen*)

Safely harnessed into position, NIWA's Dr Andrew Lorrey points an FLIR T640 infrared camera out of the open cabin door towards the Tasman Glacier to gather thermal data on the glacier ice, meltwater and the debris cover. (*Dave Allen*)

Q&A

Burning wood – not as cosy as it seems

As temperatures drop over winter months, many Kiwis turn to their fireplaces to heat their homes. However, most of us are not fully aware of the immense impact that wood burning can have on people and the environment.

Dr Ian Longley, a NIWA Air Quality Scientist, discusses wood burning, smog and its impact on air quality.

What are the rules for burning wood in winter?

There are rules at a national level, but also more stringent rules in certain regions and towns which have a worse air quality record.

At a national level, all new wood burners installed after 1 September 2005 on properties of less than two hectares, must have a particle emission of less than 1.5 grams per kilogram of dry wood burnt. They must also have a thermal efficiency of greater than 65%, and the burning of treated timber is forbidden. Open fires are outside the national rules; however, a number of regional councils have rules about open fires in their regional plan.

The Ministry for the Environment provides a national list of authorised wood burners that meet this standard. Whether wood burners not meeting this standard are permitted depends upon local and regional rules.

How does burning wood affect air quality?

Although wood is a very convenient source of fuel, it is not a very pure or efficient one. Unlike fuel oil, or especially gas, much of the fuel isn't burned properly and creates a tremendous amount of smoke.

Smoke from a single agricultural fire can fill a whole valley. Smoke from home fires in winter can be smelt across our towns, causing irritation and annoyance to some, reducing visibility, and frequently causing air quality to exceed the National Environmental Standard.

What is the main source of 'smog' in New Zealand?

'Smog' is a term describing the combination of smoke and fog. Although we don't monitor smog directly, the levels of smoke are indicated by networks of air quality monitors operated by regional councils. The monitors measure levels of 'PM10', or 'particulate matter smaller than 10 microns (one hundredth of a millimetre).

Extensive monitoring and research over the last two decades have shown that smoke from home heating (mainly wood, but also coal) is the largest single contributor to PM10 levels across the country. In some smaller towns home heating contributes more than all other sources combined.

What weather conditions contribute to smog?

The weather conditions that lead to high levels of smoke are broadly the same as those that lead to fog – low temperatures, calm winds and clear skies. These conditions provide a combination of high demand for heating (which may lead to people lighting fires early, or keeping them burning for longer, or using fires to supplement regular heating) and poor dispersion of the smoke that is emitted.

Clear skies allow heat to rapidly radiate away from the earth's surface, causing an 'inversion' (where the normal gradient of temperatures reducing with height is 'inverted') which suppresses the ventilation of damp or polluted air, keeping it trapped near the surface, leading to fog or a thick layer of smoke. In valleys and basins this can be worsened by extra sheltering from the wind, preventing the build-up from being released, and cool breezes flowing off the cold hills strengthening the inversion, further preventing the escape of pollutants.

What are the unhealthy compounds in smog?

Smoke generated from the burning of wood contains a complex cocktail of soot and organic compounds, some of which are toxic or carcinogenic. It also contains the odourless gas carbon monoxide, which (at high levels) can cause headaches and nausea.

However, in addition to these specific compounds, many people can have an adverse reaction to the particles themselves, regardless of their chemical composition. Particles present in wood smoke have been known to trigger asthmatic reactions, enter the bloodstream and worsen cardiovascular disease.

Alexandra. (*Stuart Mackay*)

When wood isn't burned properly it creates particle-filled smoke. (*Gregory Dubus*)

PROFILE

A different point of view

As a child growing up in Dunedin, Juliet Milne was always a sporty, "outdoorsy" type.

Summers were spent in the tiny Central Otago town of Naseby, a small settlement 10 minutes up the road from Ranfurly.

"I'd swim in the dam, go for walks with my family and play tennis with my brother until the sun set. I'd also spend hours exploring the Naseby forest and the tracks in it. I'd build dams in the Hogburn (a tributary of the Taieri River).

"I just loved being outside, and when I was younger I always had that curiosity – where do these walking tracks go? Is there another view just around that next bend?"

Sitting in her office at NIWA's Greta Point campus, one gets the impression that Juliet would love to be outside, working in the field. But the truth is that the resource management scientist enjoys the balance of mostly inside work and outdoor pursuits.

"I don't get to do a lot of field work these days," she says. "I call myself the 'so what?' person – part of my role as a resource management scientist is looking at how our science and research can be applied to improve the management of our fresh and coastal waters. I have input into a wide range of interesting projects, and a lot of the time I find myself connecting dots between staff, projects and outside organisations. I look to understand and draw on different perspectives.

"So most of time is spent here in the office, or in meetings. But it's a privilege to work here at NIWA with some of the most talented and passionate scientists in New Zealand, contributing to the research that will help improve the management of our natural water resources."

Juliet's interest in the environment as a potential career began at high school, but not before she'd assessed all her options.

"I was the kid who wanted to study everything, and I had trouble narrowing my subjects down. I somehow put science, design and the environment together and came up with landscape architecture, so at the end of seventh form I took myself off to Lincoln, which at the time was the only university that offered a landscape architecture degree.

"By the end of my first year I'd discovered ecology and been exposed to a range of other disciplines, including engineering, social science and environmental economics. I had the opportunity to take a few environmental monitoring papers, which introduced me to fresh water. From there, I knew I wanted to assist with the management of fresh water and especially in an applied science role.

Graduating with a Masters of Applied Science in Resource Management, Juliet might have gone on to complete a doctorate if not for a summer spent in Christchurch.

"My first summer job was racing around in a little car with a fellow student surveying the ecological health of streams across Christchurch. At that time, and this is the late 90s, the Christchurch City Council was the leading the way with its Waterway Enhancement Programme – re-examining the traditional approach of 'engineering' urban streams, taking out boxed culverts and reinstating more natural meandering stream channels.

"My supervisor wanted me to go on and do a PhD. But that one summer, working as a stream ecologist on that waterway enhancement project in Christchurch, being out there gathering information that was going to improve how those streams were managed, confirmed for me that I wanted to be in an applied role. I was impatient, wanting to get out into the 'real' world.

"My Masters focused on the Avon–Heathcote Estuary. At the time it was receiving treated wastewater from Christchurch city. The city council needed to renew its resource consent and wanted a study done on the effects of heavy metals in the discharge on sediment quality and mudflat snails in the estuary.

"I also had contact with Environment Canterbury at that point, which sparked my interest and connection not only with issues around the management of resources, but also the authorities responsible for resource management.

"Working as a student in Christchurch also gave me my first connection with NIWA, because our stream survey was developed by scientists in the Christchurch office. It was called USHA (urban stream habitat assessment). That's now essentially SHMAK (Stream Health Monitoring and Assessment Kit), which is widely used by communities to monitor the ecological health of streams across the country.

"I would never have guessed back then that, 20 years on, I would be working at NIWA."

During those two decades, Juliet worked with the Canterbury, Otago and Wellington regional councils in scientific and regulatory roles. There was also a short stint of work for the Environment Agency in the United Kingdom, which gave her a base for exploring some of the outdoors on offer in the UK and Europe.

"I mainly went on my OE to experience the history and culture of Europe, but day walks in the mountains in places like Scotland and Switzerland remain a highlight."

Juliet Milne en route to the summit of Mt Arthur (Wharepapa) as part of the Tableland circuit in Kahurangi National Park. (*Kirsty van Reenen*)

Back in New Zealand, Juliet opted for a new career perspective in 2016 and joined NIWA.

"I'd worked across several regions in a bunch of roles. But I was very interested in experiencing another side or perspective in environmental management. I'd regularly interacted with NIWA in their capacity as a research provider, so when this applied role came up I jumped at it.

"I've always wanted to keep thinking, keep growing. It was an exciting opportunity because my role integrates science and policy. And it was great to still be able continue to work with the regional sector, while also experiencing what a Crown Research Institute has to offer."

Wellington might be home now, but Juliet still considers herself a Mainlander.

"I've been here since 2005 where I live with my partner. But I'm still a proud southern girl at heart. I regularly head down to Central Otago, that's where I relax. I love the big skies and the big space that is the Maniototo. I especially love being up in the hills, walking or running.

"I've always been an active relaxer. I love sport and the outdoors – I used to play tennis, cricket and hockey. I'm a bit older now, so a lot of my sport is watched on TV, but I take time out for walking, tramping with friends and, more recently, trail running.

"I used to run around the streets and do the odd event, but trail running has opened up a whole new world to me, and Wellington sets you up for hills and stunning views.

"I regularly run up Mt Kaukau and that was a great training ground for my friends and I leading up to February's 30km Moonlight-Shotover Trail mountain run in Queenstown.

"That event was fantastic. There were parts you couldn't run because it was too steep and there were about 20 river crossings. You get a lot of perspective when you're out in the natural environment. I love the views, the mountains and the bush. I enjoy taking photographs, too – tramping is better for that."

Is there anything this sporty, trail-running scientist can't do? Well, it turns out Juliet's violin skills could use some brushing up.

"I was lucky enough that my father was musical. I was the youngest of three and we each were given the opportunity to learn an instrument. I chose the violin. I don't play now, but I'm thinking about getting back into it."

A real all-rounder?

"Well while I work hard, I'm interested in a lot of things and I enjoy learning. Life is full of so many opportunities, so enjoy them while you can."

Early warning of PNG floods

Monitoring provides early warning; training builds local capability

Environmental Monitoring Technician Alec Dempster and villagers install a water level gauge alongside Yalu River on the outskirts of Lae City. (*Jeremy Rutherford*)

At about 30km long, the Bumbu catchment may be short by New Zealand standards, but it cuts through the country's second biggest city of Lae, which has more than 5,000 people living on its banks – many of whom have migrated to the city and are living in informal settlements.

The river is prone to erosion and flooding in the rainy season and the damage can be catastrophic.

This year, NIWA completed a project that aims to help build community resilience against flooding in the Bumbu River and contribute to improving Papua New Guinea's disaster preparedness in the face of increasing climate-related disasters.

NIWA and PNG staff installed a hydro-meteorological monitoring network and early warning system for floods, in a pilot scheme for the river. Throughout the installations on-the-job training and capacity building of PNG personnel was conducted with staff from the key national and provincial government agencies. The network comprises three river water-level stations and five automatic rain gauges in the Bumbu catchment, as well as automatic weather stations in five surrounding provinces.

It was a challenging project for NIWA's technical team. Sites had to be selected according to security and ease of access, while some of the main river channels changed too often for them to be reliably monitored. "We made our decisions on monitoring locations after engaging with relevant technical agencies and the local community. You have to think about the future – these sites won't exist for long if they can't be easily maintained, so they can't be too difficult to get to," NIWA Principal Scientist – Environmental Monitoring Graham Elley said.

"One remote weather station was installed at an ex-provincial governor's family house, and one that was even more remote was placed in a village where responsibility for its continued operation was assumed by the head of the village."

Once the monitoring and data collection systems were installed, standard operating procedures were developed and tested during a flood simulation exercise held for about

30 stakeholders from the key agencies involved in flood warning and disaster response, to ensure they understood what to do when a flood warning is issued. Mr Elley said the simulation was considered by most participants to be an outstanding success and led to positive refinements being made to the monitoring and flood warning system.

The Papua New Guinea government sees the pilot flood early warning system as a major milestone for the country that will hopefully be replicated in other major rivers.

The data produced by the river monitoring sites will also be invaluable for other development planning in the Morobe

> **"on-the-job training and capacity building of PNG personnel [and] high levels of commonality across the Pacific ... help refine development needs and resolve problems"**

Province because it has been many years since the last significant hydrological monitoring data was collected.

Mr Elley said the challenge now is to sustain the monitoring system. "There is no use in having monitoring sites if there is no way of maintaining them".

"Advances in monitoring and telemetry technology are enabling us to do more for Pacific hydro-meteorological agencies than we have previously, because we can now more easily provide remote technical support."

This partnership with PNG has also seen several people from the Papua New Guinea National Weather Service and Conservation and Environment Protection Authority travel to NIWA for further specialised training, under support provided by the NZ Ministry of Foreign Affairs and Trade Short Term Training Scholarship scheme.

Mr Elley said NIWA was trying to maintain high levels of commonality in its work across the Pacific region so nations facing similar issues can begin to support each other.

"Countries across the Pacific all have similar challenges and shared experiences, meaning that communication with each other can help to refine development needs and resolve problems."

The data produced by the river monitoring sites will also be invaluable for other development planning for Morobe Province because it has been 22 years since since the last hydrological data was collected.

NIWA was contracted by the United Nations Development Programme (UNDP) with funding from the Adaptation Fund, and in collaboration with the Papua New Guinea National Weather Service, Conservation and Environment Protection Authority, Climate Change Development Authority, National Disaster Centre and Morobe Provincial Disaster Centre.

NIWA

Climate, Freshwater & Ocean Science

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 680 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.

Back cover:

The confluence, where the Gorilla Stream meets the Tasman River meets the Hooker River. (*David Allen*)

NIWA
Taihoro Nukurangi