MAN OF MANY PATHWAYS
Searching for solutions to sea-level rise

MARINE MYSTERY
Spotlight on the secret lives of eels

SNOW TIME
Using past weather to predict future climate

FROZEN MENAGERIE
A scientific goldmine

Water & Atmosphere

FEBRUARY 2020

GONE FISHIN'
Science on the high seas

Water & Atmosphere

February 2020

Jim Tannock

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NIWA
Taihoro Nukurangi

Cover: John Yanko brings in the trawl net during a recent fisheries survey on NIWA's research vessel *Kaharoa*. Scientists have been surveying Cook Strait's hoki fishery for more than three decades. (*Rebekah Parsons-King*)

Stuff

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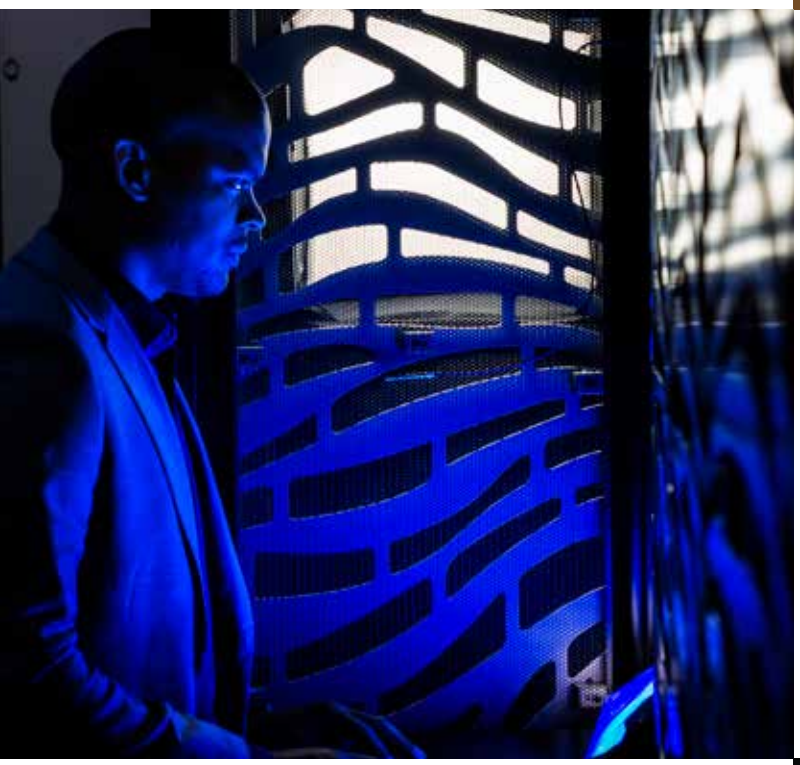
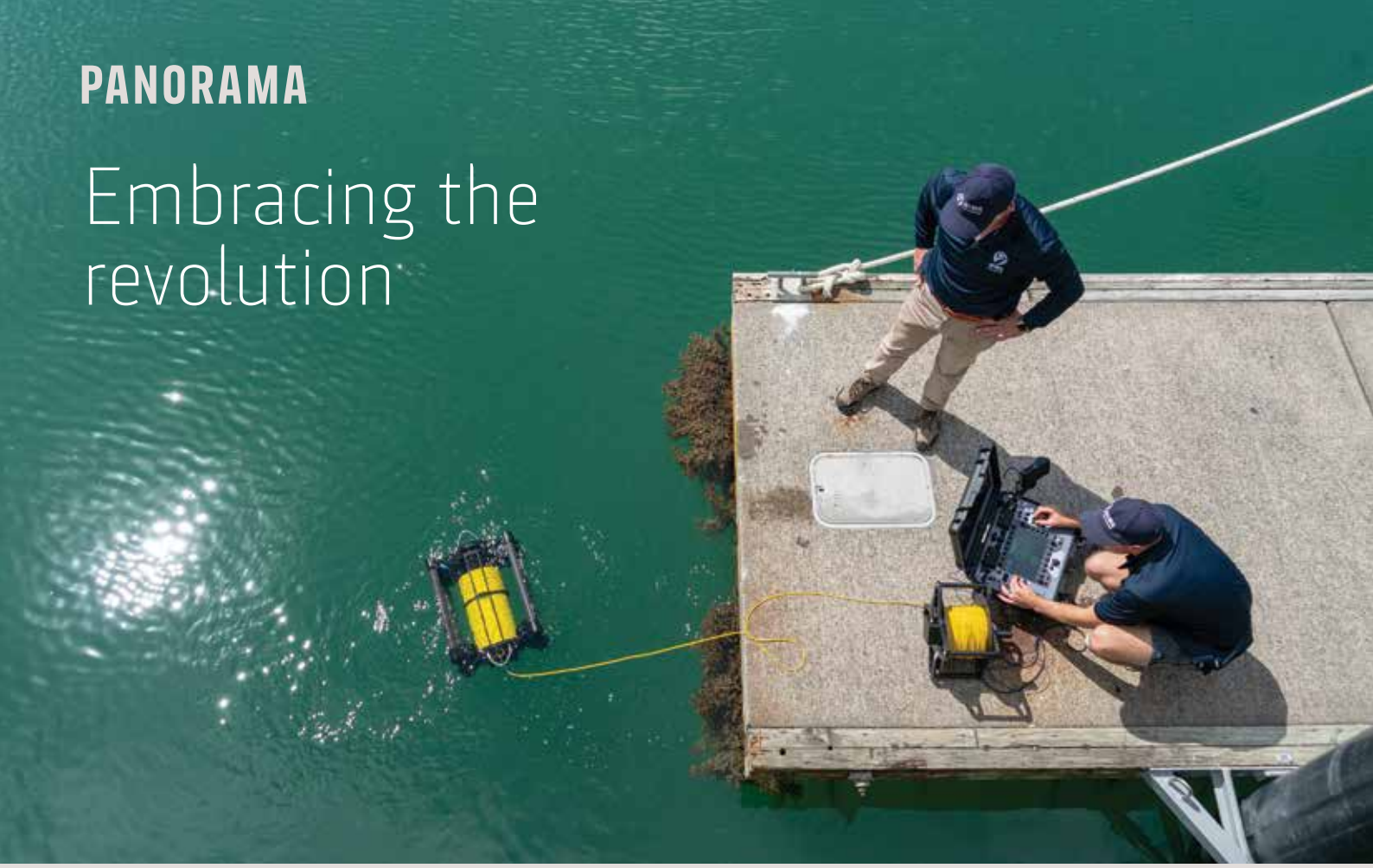


Embracing the revolution



NIWA's remotely operated underwater Boxfish drone on marine biosecurity duty in Auckland's Viaduct Basin. (*Stuart Mackay*)

Technology and Innovation General Manager, Dr Barry Biggs, looks at the impact of the fast-moving world of "tech" on NIWA's science.

> **"Emerging technologies have brought big changes to the world of science"**

Technology is evolving all around us and just keeping pace is daunting.

On a personal front, your cellphone is about to move to 5G and many of the apps that are likely to dominate your life in five years' time aren't even on the market.

Life is equally challenging for organisations. The business landscape is littered with the graves of companies that have failed to embrace new technology.

Over the past two decades, more than half the Fortune 500 companies have either been acquired, merged, or declared bankrupt as a result of digital disruption.

But technology also brings opportunity, and for every corporate failure there has been a profusion of innovative and often hugely successful companies with new techno-based DNA.

Emerging technologies have equally brought big changes for the world of science, particularly in our ability to significantly advance understanding of our environment and the processes that shape it. Data can now be collected on a much finer scale – both in time and space. This in turn provides significantly deeper insights into system structures and dynamics. New analytics, visualisation and virtual reality technologies also provide opportunities to abstract new information from that data and to present it more simply to the wider world.

NIWA works at the frontline of this world of developing technology and we are an eager early adopter. High-performance computing, remote sensing, real-time data collection, intelligent control systems, remotely operated vehicles, environmental isotope analysis – the list goes on. It is an exciting but challenging frontier. Not only do existing technologies continue to advance, but new ones appear – both at an accelerating rate.

In response, NIWA has developed a strategic agenda to drive technology uptake and innovation within the organisation, and with our collaborators. The action points include:

- Increased capital investment in new technology
- Virtual technology research centres spread across NIWA
- Targeted skill transfer in digital technology, data analytics, and artificial intelligence
- Expanding our remote sensing, environmental forecasting and high-performance computing networks
- Bringing environmental data technologies and business together to improve performance, lower environmental footprint and increase resilience to environmental risks.

NIWA will continue to take bold decisions around the adoption of new technology because innovation will deliver the cutting-edge environmental science New Zealand needs in an ever-changing world.

IN BRIEF

Rebekah Parsons-King

Tsunami buoys on watch

NIWA's research vessel *Tangaroa* has successfully deployed four new tsunami detection buoys off the east coast of the North Island.

The buoys are the first instalment of what will be a 15-strong network to provide New Zealand with early warning of potential tsunami generated from the Kermadec and Hikurangi trenches.

The DART (Deep-ocean Assessment and Reporting of Tsunami) network will stretch along the east coast of the North Island up through the Kermadec Trench and across towards New Caledonia.

The network is part of a government emergency response programme overseen by the new National Emergency Management Agency (NEMA). NIWA is working with NEMA and GNS Science to deploy and commission the ocean-based network.

Sizing up our climate risks

NIWA is partnering with the international infrastructure consultancy AECOM, and others, to help the Government understand the full impacts of climate change for New Zealand.

The partnership will deliver the country's first National Climate Change Risk Assessment later this year.

NIWA's researchers are engaged across the project which will provide a baseline overview of how New Zealand's natural, financial and infrastructure assets may be affected by our future climate.

The final report will help the Government to prioritise actions under the up-coming National Climate Adaptation Plan.

Dave Allen


Tiny toothfish embryos can grow into adult fish, up to 2m long. (*Steve Parker*)

Caught on camera

Scientists have achieved a world-first by collecting and photographing the embryos of Antarctic toothfish.

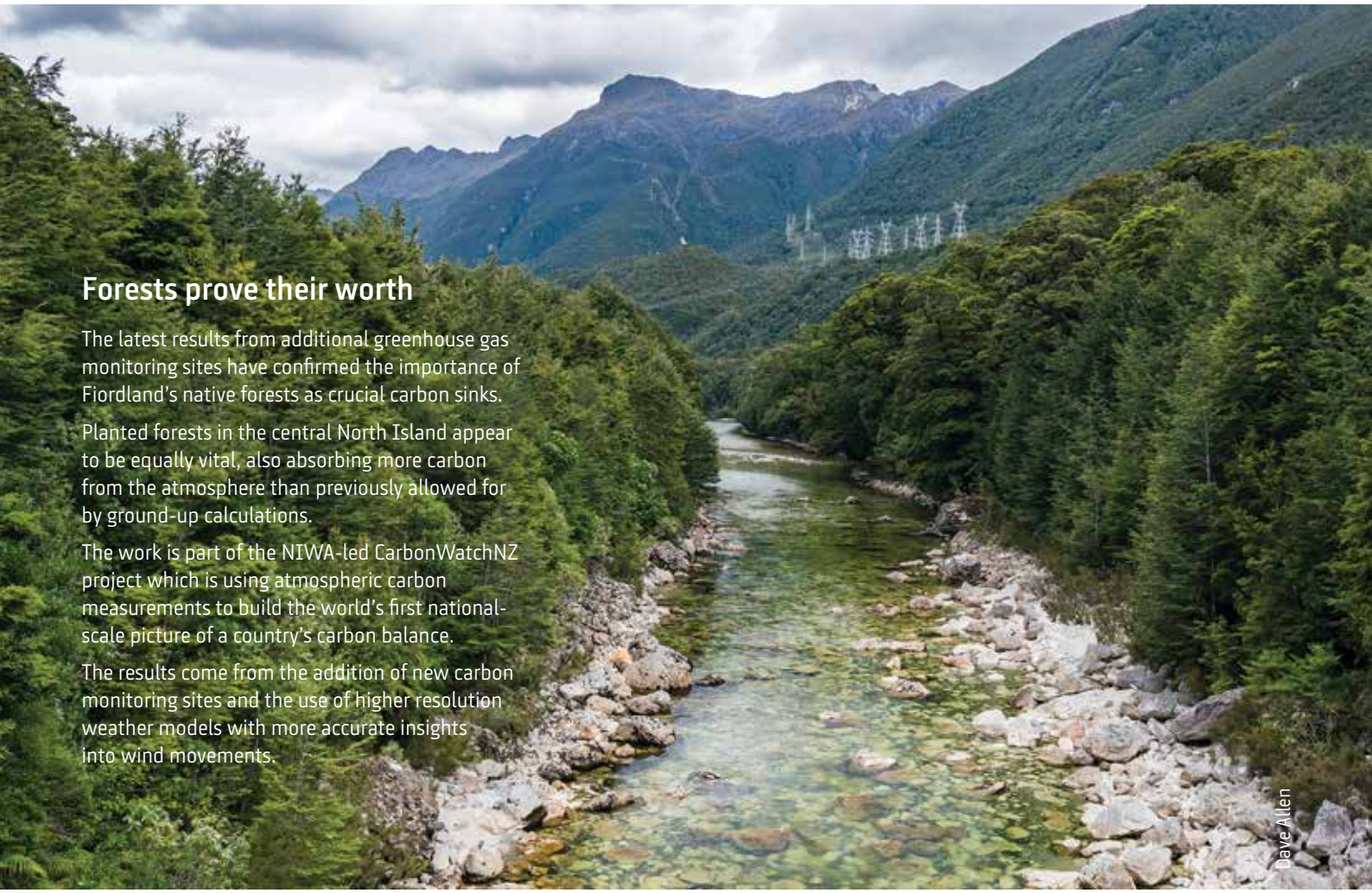
Adult toothfish grow up to 2m long and the embryo breakthrough came aboard the Talley's owned vessel *Janas*, carrying researchers on a six-week voyage to study toothfish ecology in the Ross Sea.

Initial results suggest spawning likely occurs in August. Eggs appear to catch currents heading eastwards towards the sea ice which may act as a nursery.

These observations shed fresh light on the life cycle of the fish and will help inform management of the Ross Sea fishery.

The survey was co-designed by NIWA and the Ministry for Primary Industries through the Antarctic Working Group.

IN BRIEF



Forests prove their worth

The latest results from additional greenhouse gas monitoring sites have confirmed the importance of Fiordland's native forests as crucial carbon sinks.

Planted forests in the central North Island appear to be equally vital, also absorbing more carbon from the atmosphere than previously allowed for by ground-up calculations.

The work is part of the NIWA-led CarbonWatchNZ project which is using atmospheric carbon measurements to build the world's first national-scale picture of a country's carbon balance.

The results come from the addition of new carbon monitoring sites and the use of higher resolution weather models with more accurate insights into wind movements.

Dave Allen

Fish snack on microplastics

Microplastics are being fed to snapper to find out how the world's most pervasive pollutant affects fish.

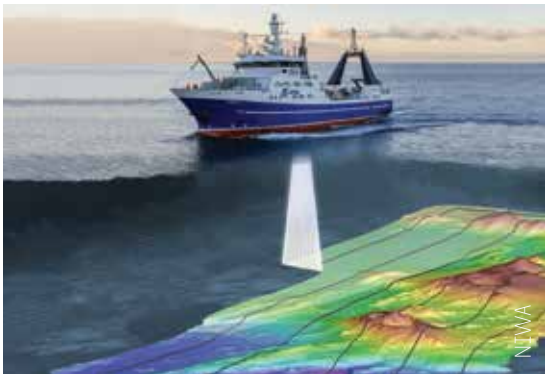
The microplastics are given to the fish in controlled amounts at NIWA's Northland Marine Research Centre over a 10-week period.

The fish are then dissected to determine whether the plastics have impacted on their physiology or their reproductive development.

Auckland University masters student Veronica Rotman, working under the supervision of NIWA fisheries scientist Dr Darren Parsons, is also looking to see whether the plastics have moved into the fishes' flesh.

A second phase of the experiment will focus on the impacts of microplastics on hoki.

Malcolm Francis



NIWA

Slip, sliding away

New information about landslides on the seafloor off New Zealand's east coast will help scientists better understand the threat they pose.

NIWA marine geophysicist Dr Sally Watson has compiled a new database that brings together information gathered from many scientific voyages.

The database maps where underwater landslides occur, how big they are and where they are most common. It covers Bluff to the East Cape and indicates that landslides cluster in submarine canyons.

Underwater landslides have the potential to cause tsunami, but can also damage marine infrastructure and seafloor habitats.

Seen any crays?

NIWA is calling on recreational fishers in the Hauraki Gulf and Bay of Plenty to help assess how local crayfish are faring.

Researchers are stationed at boat ramps in the region through summer asking divers, snorkellers and crayfish pot owners to participate in a survey about their success.

Commercial catch limits for crayfish, officially known as rock lobster, have been lowered to attempt to rebuild populations after low stocks were identified.

The voluntary survey will run over the next five summers and will help to determine whether the population is recovering and to monitor changes in fishing trends.

Mucking in for mangrove research

NIWA researchers are joining their overseas colleagues and heading once more, deep into New Caledonia's muddy mangrove forests.

It is part of an on-going project supported by National Geographic and the French Pacific Fund studying the impact of sea-level rise on these important ecosystems.

Mangroves cover about 75% of tropical coastlines worldwide, and many developing coastal populations depend on them for food, material and protection.

The research aims to understand their resilience to climate change and how sediment-poor Pacific atolls fare in the face of rising sea levels.

A range of studies is underway on the UNESCO World Heritage site of Ouvéa Atoll, measuring sea-level and sediment changes along with plant growth and historic forest changes.

Lamprey spend much of their life at sea, feeding by burrowing into the flesh of other fish, before they return to freshwater to spawn. (*Catriona Paterson*)

Spreading the love

Lamprey "love lofts" are enabling freshwater scientists to learn more about the spawning behaviour of these elusive eel-like creatures.

Lampreys are a taonga species for Māori and were once prolific nationwide. However, numbers are dropping, and they are now formally classified as threatened.

The fish typically spawn under rocks and in cavities in streambanks, but specially built structures with underwater cameras have been placed in Southland's Waikawa River to allow researchers to observe their breeding behaviour.

It is hoped the artificial love nests may boost spawning habitat in modified waterways.

The work is part of a five-year project with local iwi studying lamprey behaviour.

Scientists recreate the week it snowed everywhere

NIWA has teamed up with Microsoft for a new project using artificial intelligence to combine historic weather records with breakthrough handwriting recognition tools.

Left: Dunedin's Kaikorai Valley cable car struggles through the "Great Snow" of 1939. (*Otago Daily Times*)

Centre: Climate scientists Petra Pearce and Drew Lorrey with historic weather records. (*Dave Allen*)

Right: Clearing snow from Dunedin's streets. (*Otago Daily Times*)

In July 1939, pictures of trams struggling through snowdrifts made front pages across the country, as many Kiwis experienced the first white winter of their lives. In Clevedon, Auckland, locals threw snowballs, while the summit of Mt Eden lay five centimetres deep. Masterton's town clock froze under the weight of snow clinging to its hands, and there were flurries at the Cape Reinga lighthouse.

NIWA's archives are full of such fascinating glimpses into our past. Now, in a world-first project with Microsoft, NIWA is pioneering use of artificial intelligence to scan old weather observations and turn it into data to evaluate climate change and extreme events in a long-term context.

Principal climate scientist Dr Andrew Lorrey says the more we know about past weather, the better we can accurately predict climate patterns today and into the future.

"Was 1939 the last gasp of conditions that were more common during the "Little Ice Age", which ended in the 1800s? Or the first glimpse of the extremes of climate change thanks to the Industrial Revolution?

"We had snow in Northland in 2011, but having more detail from the past helps us characterise these extreme weather events better within the long-term trends. Are they a one-in-80-year event, do they just occur at random, can we expect to see these happening with more frequency – and why, in a warming climate, did we get snow in Northland?"

This trial project will use data from winter of 1939 to train machine learning tools to accurately transcribe the handwriting in old logbooks. The project has been awarded an AI for Earth grant by Microsoft to support local climate scientists in their quest.

The aim is to scan 3000 handwritten documents per day, upload them to the cloud, and generate searchable insights through Microsoft's Cognitive Search application.

Patrick Quesnel, Senior Cloud and AI Business Group Lead at Microsoft New Zealand, says old data is the new data. "That's what excites me about this. We're finding better ways to preserve and digitise old data reaching back centuries, which in turn can help us with the future. This is data which is basically forgotten unless you can find a way to scan, store, sort and search."

> **"Having more detail from the past helps us characterise these extreme weather events"**
>
> Dr Andrew Lorrey

The problem for scientists like Dr Lorrey is the sheer volume of data lying unassessed and vulnerable in warehouses and archives. Weather records – some dating back to the mid-1800s – were meticulously kept in logbooks by sailors, whalers and land-based observers, with entries made several times a day. They recorded information such as temperature, barometric pressure, wind direction and comments about cloud cover, snow drifts or rainfall.

NIWA has previously relied on citizen scientists to key the handwritten data into a computer database for analysis. The scale of the project is enormous, involving more than a million photographed weather observations from old logbooks being painstakingly reviewed and loaded by hand into the Southern Weather Discovery website (southernweatherdiscovery.org).

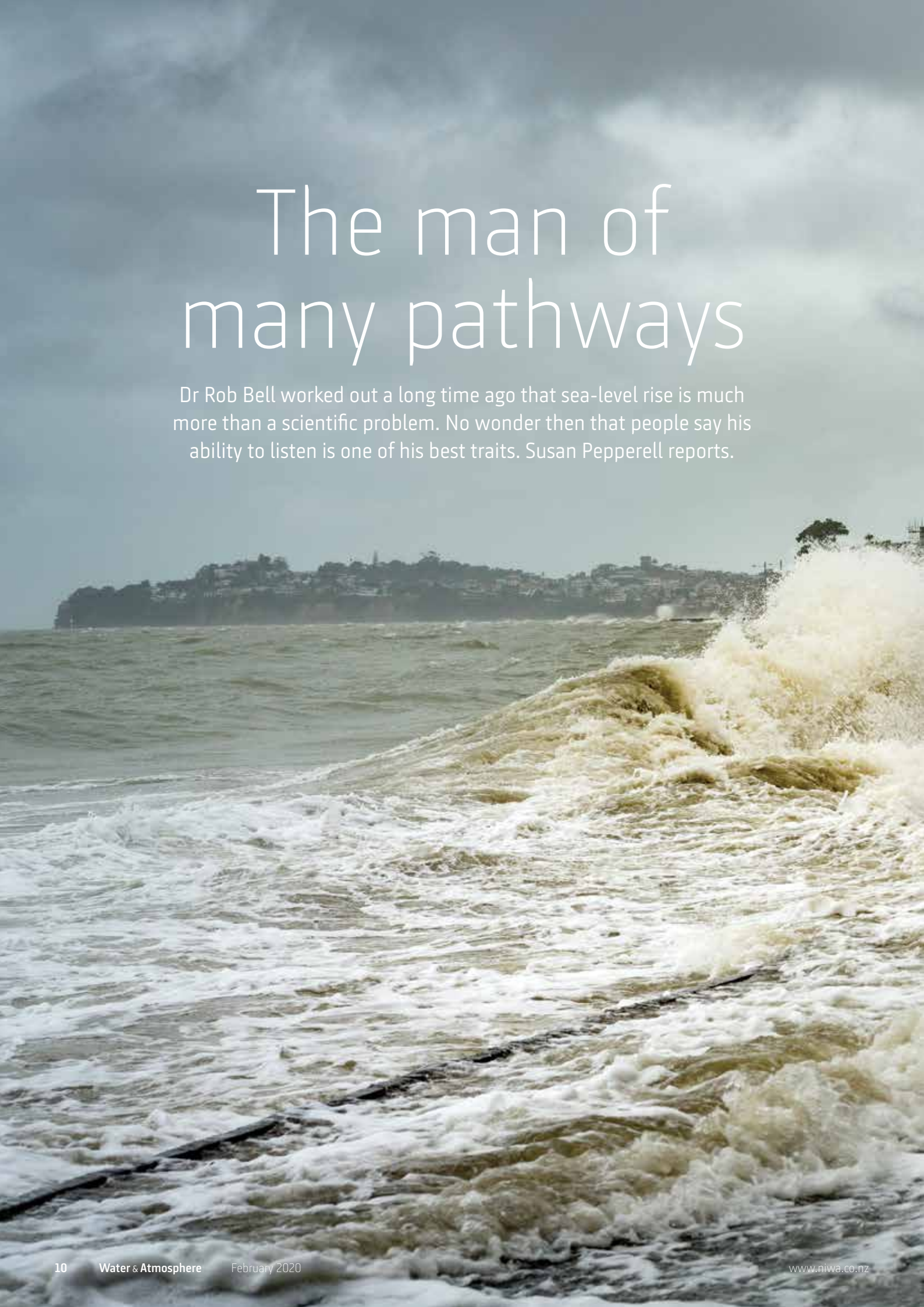
NIWA collaborates with scientists at NOAA in the US, the UK Met Office, and at universities across the globe who all have huge piles of old archived data ready to be recovered and analysed. Speeding up the data inputting and analysis with smart machine learning technology would enable the group – who band together under the Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative – to produce better daily global weather animations and a longer-term perspective of past weather.

"Automated handwriting recognition is not a solved problem," says Dr Lorrey. "The algorithms used to determine what a symbol is – is that a 7 or a 1? – need to be accurate, and of course for that there needs to be sufficient training data of a high standard."

A car in the 'Great Snow' of July 1939, which brought 100mm of snow to Dunedin, and the first recorded snowfall to Auckland. (*The Evening Star*)

The man of many pathways

Dr Rob Bell worked out a long time ago that sea-level rise is much more than a scientific problem. No wonder then that people say his ability to listen is one of his best traits. Susan Pepperell reports.



Flooding along Auckland's Tamaki Drive on 5 January 2018, as storm and king tides meet. (*Stuart Mackay*)

> "It was the beginning of the stark reality that seas were rising"
>
> Dr Rob Bell

Rob Bell stood on the stage at NIWA's annual awards ceremony in September for a few stunned seconds and declared: "I'm shocked."

You could tell he really was by the tremor in his voice and his suddenly-bright eyes, but he would have been the only person in the room the least bit surprised.

Bell had just been presented with a NIWA Lifetime Achievement Award by Climate Change Minister James Shaw, who used his speech not only to acknowledge Bell's phenomenal contribution to New Zealand, but also to implore him to stay put.

"Please keep it up," said Shaw. "Don't stop."

At 64 Bell is thinking ahead to retirement – not yet, but soon enough to make plans. Under that scenario there will be less travel, more time with his six grandsons, and maybe he'll finally get around to answering the emails that have lingered in his inbox for way too long.

Bell is a civil engineer by training, guided into his career by an astute teacher who encouraged him to enrol at the University of Canterbury. Bell liked science, but he also wanted to see impacts for his efforts – engineering offered the opportunity to produce practical solutions.

That morphed into coastal engineering, working out ways to clean up wastewater outfall discharges, which in turn evolved into understanding coastal oceanography – tides, currents and erosion – and then being involved in developing a coastal hazard zone for the main subdivision at Coromandel town Pauanui, long before sea-level rise was really a thing.

Bell knew though; the team he worked with at the Ministry of Works included an allowance for it in their final recommendations.

It was the 1980s, and at the end of the decade the Intergovernmental Panel on Climate Change would be established to provide policymakers with regular scientific assessments on the current state of knowledge about climate change.

"I got really interested in the sea-level component of that – it was the beginning of the stark reality that seas were rising and it was going to be a big issue."

In 2001, he co-authored the first report for the Ministry for the Environment (MfE) on how sea-level rise would affect New Zealand, along with some adaptation options.

"It was very plain and inauspicious, but it was the start of the journey." Today Bell is one of New Zealand's leading sea-level rise experts.

He remains at heart, and in practice, an engineer dedicated to making a practical difference, and while at times he has taken a "deep dive" into science

Ex-Cyclone Gita sent sea swells smashing into Pukerua Bay, north of Wellington, in February 2018. The storm surge cut State Highway One and caused widespread damage. (*Dave Allen*)

Dr Rob Bell – Climate Change Power Lister and self-described "dot joiner". (*Hamish McCormick*)

research it's always been with the end goal of solving a problem.

"I think engineers are taught to be innovative and think outside the box. There is a drive to come up with something concrete that is going to work. Science can be more theoretical at times and you don't necessarily have to come up with a tangible solution – you might just want to improve the knowledge of something."

Bell describes himself as a member of a loose group of people he likes to call the "dot joiners".

They are among the planners, engineers, scientists, academics, council staff, iwi representatives and others working to find a way forward for coastal communities grappling with the complex issues forced on them by impending sea-level rise.

Being a dot joiner means being able to see connections, to look beyond your field of expertise and consider the whole system, to ask questions when nobody else is and motivate others to work in a similar fashion.

Bell gives an example of an engineer designing a bridge.

"A good engineer would consider the concept that this is not just a bridge, but something that serves a community. And perhaps there's something that could be included in the design, such as flood control works, that might benefit the community in other ways."

Bell may be a natural dot joiner, but the trait is fuelled by a realisation he came to some time ago that issues caused by sea-level rise could not be solved by science alone.

"In the early days I did a lot of technical work, but much later it dawned on me that this is about people, funding, economics and equity – far more than it is about technical science."

At the end of 2017 MfE released its latest Coastal Hazards and Climate Change Guidance report, again with Bell at the helm along with Victoria University researcher and long-term colleague, Dr Judy Lawrence.

The pair toured the country after the report was released to lead a series of workshops for council staff, engineers, planners and infrastructure managers to help convey what was essentially a blueprint for how councils should be planning for climate change.

The guidance report included a method of using a process known as Dynamic Adaptive Pathways Planning. It's a concept pioneered in the Netherlands and introduced to New Zealand by Lawrence. At its core, Dynamic Pathways Planning embraces the uncertainty that surrounds climate change.

It encourages communities to consider many different options, how long they might be effective for and to understand when it's time to change tack. Bell calls it the "most versatile tool in the box".

> "I see so many places where people are not getting it"
>
> Dr Rob Bell

"Each coastal situation is different – some issues are imminent, and some are down the track, so councils and communities need to work out when they have to adapt and what short- and long-term options are available to them. When they near a threshold they can then decide which of the options they want to implement."

It was trialled in Hawke's Bay, where councils and communities were locked in a cycle of finger-pointing and blame over coming to terms with continuing coastal erosion. Dynamic Pathways Planning helped break that paralysis. (*see Consensus in Hawke's Bay page 16*).

Part of its success is due to the way members of the community were included in the process. "We started with a grass roots, bottom-up approach and asked 'it's your process, it's your coast, what would you like to see in the long term?"

It is a lesson that has been hard learnt. Planning for sea-level rise on the Kapiti Coast turned to custard, says Bell with characteristic understatement.

To cut a very long story short, it all ended in court.

"That's why it's essential to take a multi-disciplinary approach and include social scientists who understand the dynamics of communities and in particular their strong attachment to place. People want to live at the coast, they want to stay at all costs – that's what you're up against."

Bell says it's slightly different for iwi and hapū who have been connected to the coast for eons. "You have to understand the whole kaupapa of a particular hapū before you get into any technical stuff."

If you ask Bell whether New Zealand is where it needs to be to deal with sea-level rise, he is optimistic – with provisos.

"There is some criticism that scientists and the IPCC haven't made it patently obvious that we've got a major issue. But what I've found is that councils – until recently – haven't had the tools or the wherewithal to go out to communities to talk about how they're going to adapt. They've been sitting on the side asking for national and central government guidance which they now have – to some degree.

"So now they're in a phase where they're trying to get their heads around it and need a lot of help just to put a plan together so it doesn't end up turning toxic. It takes time, but momentum is building."

He is also aware that some huge transformational changes will be required – particularly around accepting that there will be a need to retreat from low-lying coasts and harbours.

"There are ways it can be tackled, different ways of doing things, land-use change; a whole raft of creative thinking we can do rather than the traditional approach of just building a house on land at the coast."

In September, MfE, issued the framework for the first national climate change risk assessment for New Zealand, which will provide an overview of how the country may be affected by climate change. The assessment will be used to prioritise actions to reduce risks or take advantage of opportunities. Bell was on the expert panel for the framework and is now part of the team doing the risk assessment.

That's just one commitment. The territory occupied by a dot joiner means being on expert panels, working groups, technical committees and at the beck and call of ministers and their officials. Bell admits he's probably too responsive, but he sees opportunities and can't help himself. At the moment he is involved with three business cases going to Cabinet for funding, although he did say he turned down a fourth.

Sea-level fast facts

1m

potential sea-level rise by 2100 if little action is taken over climate change

$38billion

Value of New Zealand property at risk of 1m sea-level rise

188,000

Number of New Zealanders exposed to coastal flooding if sea level rises by 1m

"The first thing I do if I get given a policy document is do a word search for climate change and adaptation. If they're not in there, I ask why. I'm not naturally provocative, and I often sound like a broken record because I see so many places where people are not getting it."

There is one place, however, where they are getting it – the University of Canterbury School of Engineering.

Funny how time flies. Last year Bell was invited back to his old university to deliver a lecture series to engineering students as part of a new course entitled Sustainability and Climate Change for Engineering. Now compulsory for second-year professional engineering students, it's a course about adaptive planning principles and infrastructure.

Bell developed the lectures from scratch and he loved it. "I really enjoyed the interaction. Here we have 180 young engineers who will be going out armed with how to do Dynamic Adaptive Pathways Planning and adaptive design for our infrastructure.

"To me that was a real buzz, to pass on my knowledge, skills and enthusiasm, because there is a bright future if they can come up with some really creative solutions."

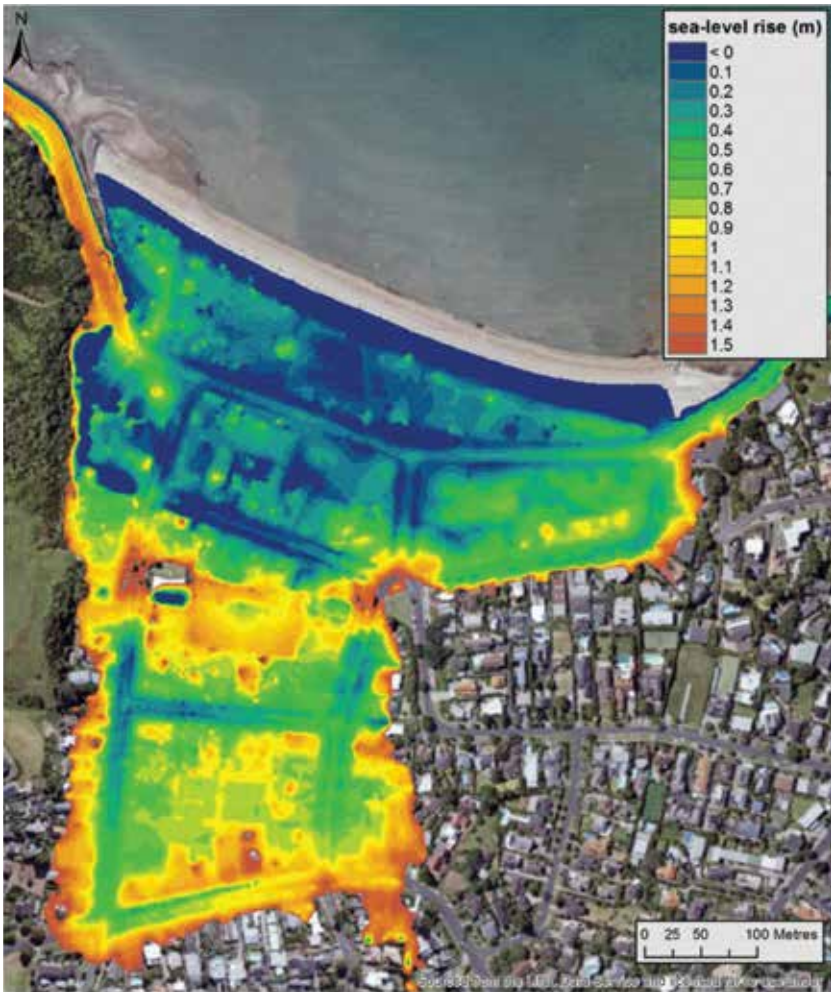
Bell, along with Lawrence, was named on Stuff's Climate Change Power List in September that identified a group of New Zealanders with the greatest influence over climate change issues in this country. And as well as receiving NIWA's Lifetime Achievement Award, he was the joint winner of the NIWA Science Communication Award. Then in November Science New Zealand awarded him a Lifetime Achievement Award.

Colleagues, contemporaries, and workmates speak of Bell with one voice. They value his mentoring skills and willingness to make time to review others' work and provide quality feedback. He is, they say unanimously, inclusive, humble, always positive and respectful.

Perhaps the greatest accolade comes from a younger scientist who chose his career path because Bell helped him out as a student.

"He is just a genuinely lovely person who wants to help."

Bell would like a lighter workload, but is torn by the knowledge that there is still much to do.



The projected impact of coastal storm flooding on Mission Bay in Auckland from sea-level rise of up to 1.5m. (*NIWA*)

"I've never been very protective of my knowledge and skills and I like sharing them because that's how change is going to happen."

At NIWA's Excellence Awards ceremony in September, after first thanking the team of people he works with, he had one final comment: "May the young ones go for it."

On climate change deniers:

"There's a very small minority of hard core deniers out there, and they've become more aggressive of late. I've had a few emails from them – it's like a last ditch stand and it gets a bit disheartening at times."

On media:

"There's so much more media interest in sea level now.

"I don't naturally shine to media, but climate change is all about communication, and if we can't do it and we don't do it, we're dead in the water."

On the future:

"There are ways we can tackle sea-level rise, but it will require some huge transformational changes. There's a whole raft of creative thinking we need to do."

"I think there is going to be upheaval for a lot of communities, and we haven't yet solved the big questions around equity and who pays."

Consensus in Hawke's Bay

Hawke's Bay is no stranger to problems at the coast.

The sea has been eroding property and infrastructure from Tangoio to Clifton for decades; some homes have been abandoned and some protected by sea walls and concrete – hoping against hope, and science, that they will hold on.

Hastings District Council principal advisor district development Mark Clews says the finger-pointing and blame over what to do has been as relentless as the tides – or at least it was until 2014.

That's when the Hawke's Bay Regional Council, the Hastings District Council and the Napier City Council realised there needed to be less "us and them" and more "we're all in this together". So they committed to working with residents on a strategy that would last for the next century.

It required a fresh start and a leap of faith – and a new way of looking an old problem: Dynamic Adaptive Pathways Planning provided the answer. Developed in the Netherlands and introduced to New Zealand by Victoria University researcher Dr Judy Lawrence, Dynamic Pathways allows for a planning approach that includes uncertainty.

This is particularly useful when considering what to do about the consequences of climate change which brings with it the uncertainty of knowing what might be done to slow its progress.

Clews says Dynamic Pathways allowed everyone to start thinking that there were multiple solutions and that not every decision had to be made now. "It opened our minds to different ways of doing things."

Panels comprising ratepayers, residents and council staff developed weightings and criteria for ideas and recommendations for their preferred pathways. Clews says they quickly realised that Hawke's Bay residents who didn't live at the coast also had a huge vested interest in what was happening, so additional members were added to the panels to represent that perspective.

Eventually the panels will help identify trigger points, the time at which something happens that requires the community to get together again and consider staying on the same pathway or choosing a new one.

"While we know that managed retreat is ultimately the only viable option long term and will eventually happen, the pathways allow us to buy time. We still have quite a long way to go, but at least we have agreed on the preferred pathways to go forward."

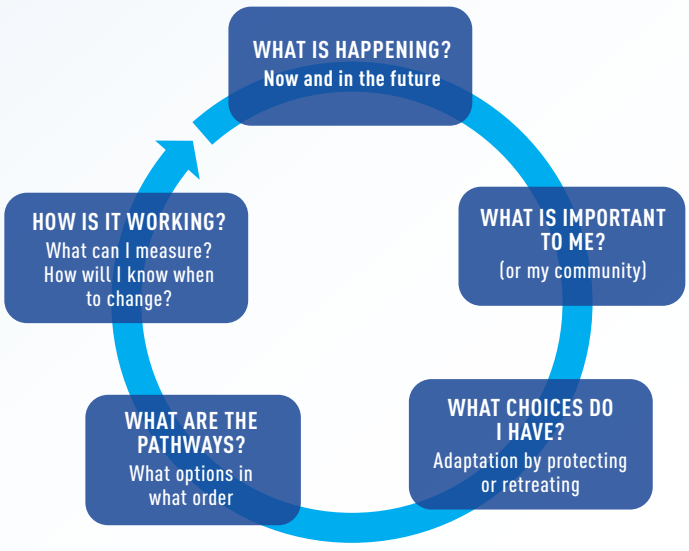
Lawrence and other experts observed the process in action, given the status of "critical friend". According to Clews they also provided reassurance to the community panels that there were respected academics watching on.

But key issues remain, particularly around the design, the evaluation and implementation and who pays. There is also the need for some immediate work to shore up parts of the coast until the long-term plan is decided.

Clews admits there is some impatience creeping in, which is worrying.

"We are finding that robust debate takes time. Who is responsible for undertaking and maintaining works? Where is the government in this? How do we work out the private/public funding split? How does a managed retreat actually work in practice, and what does it look like for the homeowners and agencies involved?

"We are not at the end by any stretch of the imagination."



Dynamic Adaptive Pathways Planning

> “At least we have agreed on the preferred pathways to go forward”
>
> Mark Clews

Alan Blacklock

Hitting the high notes

Dr Kameron Christopher plays a mean sax. Campbell Gardiner checks in with NIWA's new Chief Scientist for High Performance Computing and Data Science.

Dr Kameron Christopher working in NIWA's High Perfomance Computing Facility. (*Rebekah Parsons-King*)

When Kameron Christopher rates American saxophonist and composer Wayne Shorter as the greatest living exponent of the instrument – he is talking from first-hand experience.

Los Angeles born and bred, Christopher has played professionally with some big names. Along with Shorter, he's turned out with Herbie Hancock, Horace Silver, Stevie Wonder, George Clinton and Macy Gray – to name just a few.

Christopher is NIWA's first Chief Scientist for High Performance Computing and Data Science and, in addition to his sax, he brings an impressive array of data analytics credentials to the table.

Notes, numbers, fractions, frequencies – music, mathematics and science have a lot in common.

"They're all about patterns," says Christopher.

It's a space he is deeply familiar with. Among an alphabet soup of qualifications gained in the USA and New Zealand, Christopher has post-graduate letters in music signal processing and the development of artificial intelligence (AI), including from Berklee College of Music, CalArts and Victoria University of Wellington.

Since coming to New Zealand seven years ago he's plied his computing and data trade with AI start-ups and big corporates – notably at Westpac New Zealand where he led the development of a wholesale data and analytics transformation strategy.

Machine learning is a subset of AI where computers automatically learn and improve from experience without having to be programmed.

Sounds like something from an Isaac Asimov novel. But far from it. Machine learning is increasingly common across many disciplines, including NIWA's environmental sciences. Coupled with the processing power of NIWA's High Performance Computing Facility, it is used to analyse bigger, more complex data, and deliver faster, more accurate insights.

However, don't worry, the robots aren't taking over. For all the number crunching and data processing, Christopher is adamant that humans remain the key to the equation.

The computer is looking for a specific kind of pattern, he explains. "It does one thing. People have a more holistic, intuitive view and they are pivotal to interpreting how it all fits together."

With a nine-word job title, Christopher's new position reflects the multidisciplinary nature of NIWA's science and the fact that high speed computing and big data are now essential tools.

Each year, NIWA researchers collect terabytes of spatial and temporal data, spanning climate, marine and freshwater disciplines. He sees his challenge as maximising the value of that data and promoting the opportunities advanced AI and data technologies can bring.

"Machine learning and AI, combined with the capabilities of high-performance computing, let researchers recognise patterns in data that weren't always so apparent in analysis.

"There's lots of creativity and innovative ideas here at NIWA. We want to help with that and accelerate the adoption of new research capability," he says.

"It's about enabling our researchers to gain more actionable insights from information so they can drive more innovation. High-performance computing and data science can help with that."

Christopher is upbeat about the potential of AI and machine learning technology. "Good, reliable data gets produced, fast. Data that augments and assists human-driven processes and skills, and, ultimately, helps us solve real-world problems."

He says New Zealand has a history of producing top notch AI and research. Some of the tools that have come out of this country are now used as industry standard around the world. He believes it's a domain we're good at and have an opportunity to explore. Plus, we have the capabilities.

Put it all together and, for Christopher and NIWA, data science and high-performance computing is a tune worth playing.

"Music, mathematics and science have a lot in common – they are all about patterns"

Dr Kameron Christopher

Rebekah Parsons-King

Unlocking the mysterious marine life of eels

Tiny, translucent eels may hold the answers to one of the fish world's great mysteries. Zen Gregor investigates.

> **"The layers act as a daily diary of an eel's life"**
>
> Dr Eimear Egan

Tuna, or freshwater eels, hold a very special place for iwi. Widely valued as both a food source and a taonga, they are a culturally significant mahinga kai species.

Their survival, and the protection of the waters they live in, is paramount to many.

Toby Salmon, mana whenua from Ngāti Awa, is in no doubt about the importance of tuna habitat in the Bay of Plenty's Rangitāiki River.

"This is our cupboard, this river, and if we don't look after it, if we don't nurture it, we're going to lose it," says Salmon.

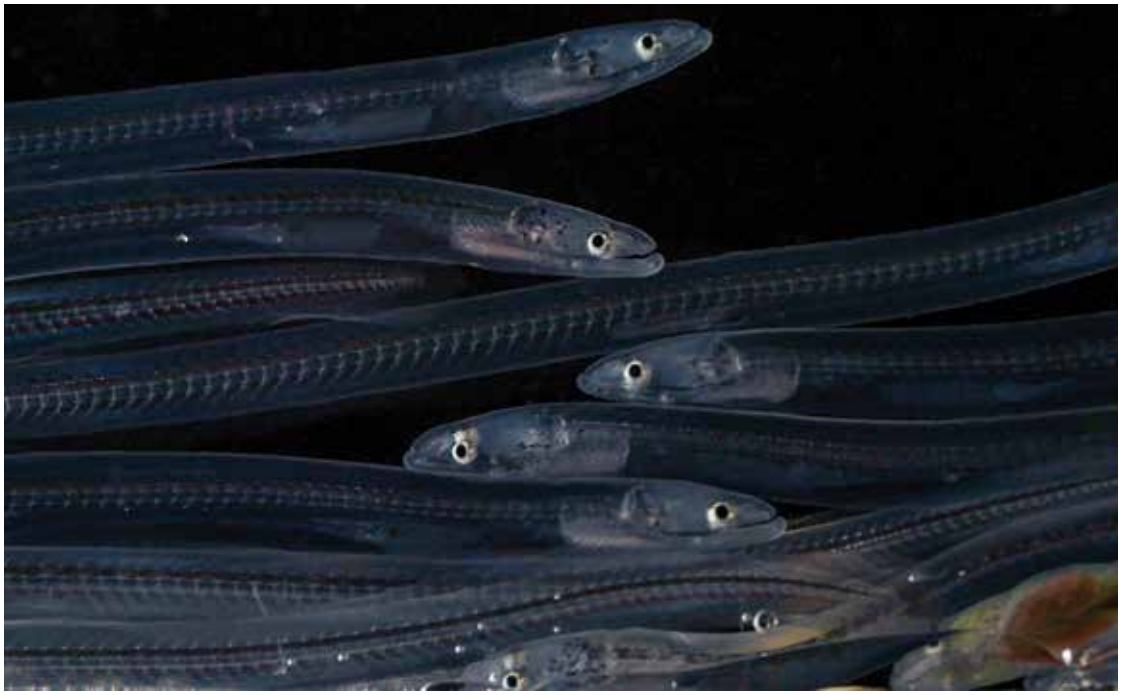
Tuna have a very unusual life cycle that sees them travelling between freshwater and ocean environments, and much remains secret about the mysterious marine phase of their lives.

We know mature adults leave New Zealand's rivers and swim out to spawn in the western Pacific Ocean. We also know that their larvae return to New Zealand's coast, transforming into tiny glass eels (named for their translucent appearance) for the start of their freshwater life.

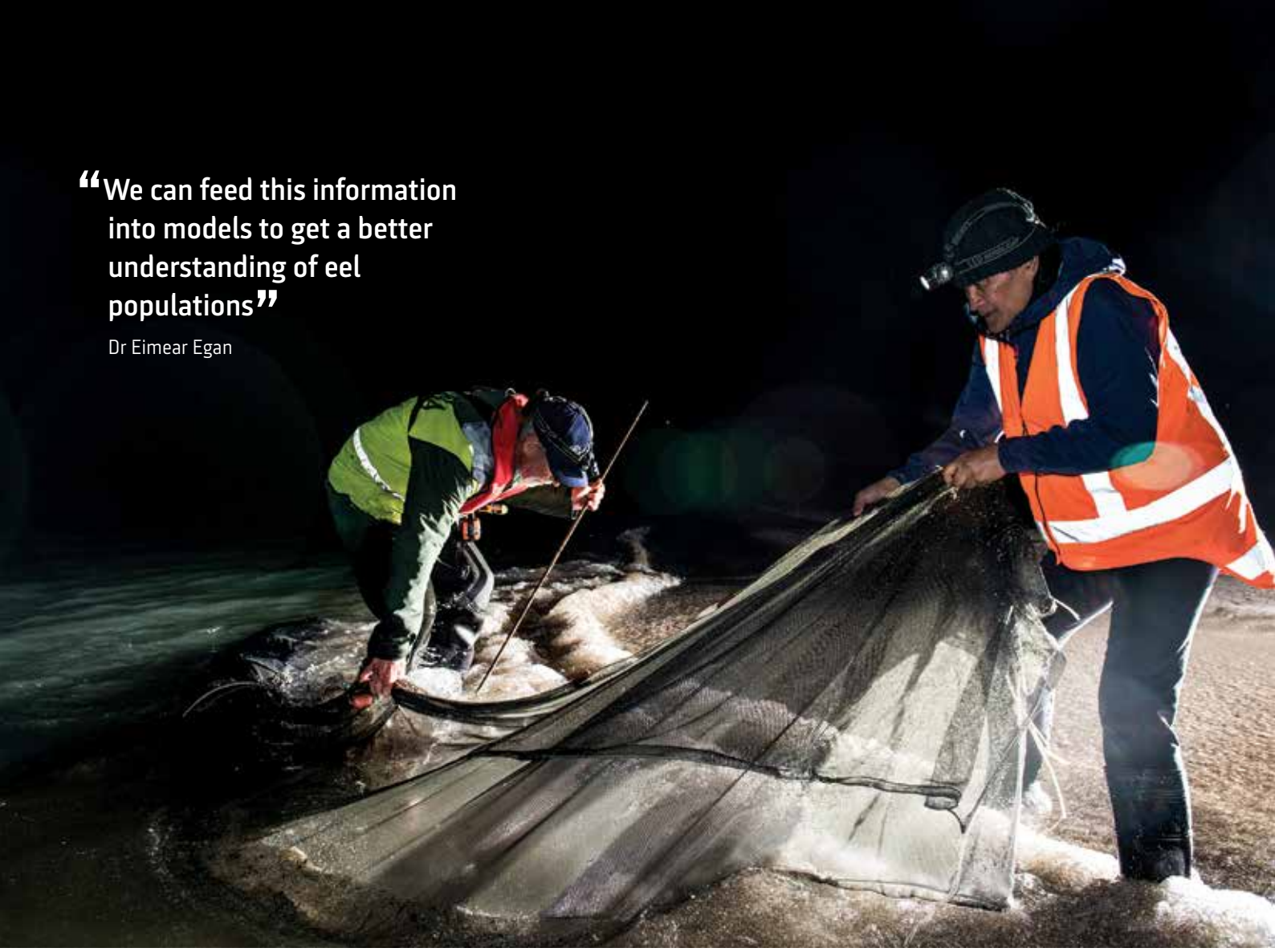
No one knows, however, where those spawning grounds are, which ocean currents the larvae use to return or whether shortfin and longfin eels use different ocean spawning grounds and currents.

Freshwater fish ecologist Dr Eimear Egan is leading an MBIE-funded Smart Idea project which aims to unlock some of the answers.

Over recent months, Egan and her team have been working with mana whenua at three river mouth sites. The chosen rivers are the Rangitāiki, Grey and the



Fresh from their puzzling ocean journey, glass eels – under 7cm in length – congregate in river mouths during spring tides. They soon lose their translucent appearance and continue upstream as elvers. (*Lana Young*)



> **"We can feed this information into models to get a better understanding of eel populations"**
>
> Dr Eimear Egan

Sweeping the incoming waves at the mouth of the Rangitāiki River for an elusive catch. Tiny ear bones and tissue samples may reveal secrets of the glass eels' mysterious journey. (*Rebekah Parsons-King*)

Ashley, where the researchers have been working with Ngāti Awa Rangitāiki Hapū Coalition, Rangitāiki River Forum, Ngāti Waewae and Te Ngāi Tūāhuriri Tuahiwi (Ngāi Tahu).

Egan says the partnership and support from mana whenua in each location has been crucial to their success.

Under the light of the moon, team members trek down to the respective river mouths in search of the elusive glass eels. They have used a variety of methods to catch their tiny translucent targets, including scooping the surf with a modified whitebait net, customised set nets from Australia and electric fishing.

"We even picked a few hundred up from the shoreline after they got stranded on a king tide!" says Egan.

The researchers are now back in the lab hard at work on their tiny catch. This includes extracting and examining the glass eels' minute ear bones (otoliths) and dissecting their tissue for chemical analysis.

A layer of calcium carbonate is deposited on the otolith each day and the microstructure and chemistry of the otolith can reveal information about their marine environments.

"The layers act as a daily diary of an eel's life and can be used to reveal the routes the larvae take to get to New Zealand's coastline," says Egan.

The team are also analysing archived otoliths to reconstruct marine conditions experienced by eel larvae over the past decade.

Egan and her colleagues use Oxygen 18 isotopes to estimate the thermal conditions eel larvae have experienced at sea and around New Zealand's coastline.

She is hoping analysis of the glass eel tissue, using bulk isotopes and compound specific stable isotopes of amino acids will help pinpoint where in the western Pacific Ocean the larvae might have come from.

"We are hoping not only to get a more fundamental understanding about the marine life of eel, but also to begin to understand the potential effects of changing ocean conditions.

"If we can better predict the implications of ocean changes on the survival and recruitment of juvenile eels, then we can feed this information into models to get a better understanding of eel populations themselves."

Egan's glass eel findings will complement work in a related NIWA project where researchers tagged several female longfin tuna before they left New Zealand to spawn.

Gone fishin'

If you want a healthy fishing industry, you need to know how healthy your fish stocks are.

Sam Fraser-Baxter talks to a scientist who went to sea to find out, and looks at NIWA's fisheries science on the high seas.

Rebekah Parsons-King

> **"I went out on research boats and realised I loved being at sea. It really got me hooked"**
>
> Dr Rosemary Hurst

Rebekah Parsons-King

The first time Dr Rosemary Hurst ate raw fish was on a Japanese commercial fishing boat hundreds of kilometres off the east coast of New Zealand.

Hurst was five years into her career as a deepwater fisheries scientist. Her previous experience with raw fish was picking parasitic worms out of fillets. That was for her PhD – this was dinner.

"I was a bit nervous about eating this raw fish. I picked it up with chopsticks and held it up to the light to check for worms before I ate it. I'd never eaten raw fish before and rapidly fell in love with it."

Decades later, Hurst's love for raw fish continues – as does her passion for fisheries science.

She is now NIWA's Chief Scientist for Fisheries, having enjoyed a long and celebrated career delivering the research that underpins the management of New Zealand's wild fisheries.

Hurst's earliest memory of the sea was swimming in freezing waters off the south coast of England. Born and raised in London, she cherished family trips to the coast to visit her grandparents.

"I used to love walking up and down the beach finding little treasures. We didn't have easy access to the sea like we do in New Zealand. It was a special treat."

At nine years old, after occasional encounters with the ocean, Hurst found herself on it – literally. Trading the big smoke for the deep blue, her family packed their bags and spent six weeks aboard an ocean liner to start a new life in New Zealand. She's lived here ever since.

Despite her affinity with the ocean, Hurst admits she never foresaw a career in fisheries.

"I started my PhD working in terrestrial ecology, but switched to working on the life cycle of marine parasites. I went out on research boats and I realised that I loved being at sea. It really got me hooked".

Hurst hasn't let go. Her science career charts the big changes in New Zealand's fisheries over the past four decades and she was recently honoured with a NIWA Lifetime Achievement Award for her contribution to both fisheries science and the development of a sustainable industry.

"Science is fundamental to sustainable fisheries management," says Hurst.

"It is essential for estimating potential yields and monitoring natural fluctuations and the impact of fishing over time."

In 1978, New Zealand declared its Exclusive Economic Zone. With the stroke of a pen the country's fisheries management responsibilities swept from the existing 12 nautical mile limit out to 200 nautical miles offshore.

At the time, New Zealand had virtually no vessels capable of harvesting deep water and a poor understanding of the fisheries themselves. The country was in serious need of fisheries expertise.

Hurst landed a job as a deepwater fisheries scientist with the Ministry of Agriculture and Fisheries, working

> **"Science is fundamental to sustainable fisheries management"**
>
> Dr Rosemary Hurst

on what was then New Zealand's fifth largest and most valuable fishery – barracouta.

As her work evolved to include several other deepwater species, she began survey work on large offshore commercial vessels – often chartered by the New Zealand fishing industry from Russia or Japan.

"One Japanese commercial trawler was the *Akebono Maru 73* – that was an amazing experience. The skipper had fished in New Zealand waters for about a decade and had invaluable experience from the early days of our deepwater fisheries.

"He had his own opinions about the stock size of some of our key species and was always willing to share his knowledge and learn more from us. His early estimate of the long-term sustainability of our hoki fishery, about 150,000 tonnes, has proved remarkably accurate."

New Zealand's world leading Quota Management System (QMS) was introduced in 1986. Until then, fisheries were largely managed by restrictions on when, where and how fish could be taken. But from 1963 to 1973 the number of fishing boats in New Zealand more than doubled, sparking nationwide concern about overfishing.

The Government's response was a catch control system to incentivise sustainable harvest.

The prospect of the new QMS and the promise it held for long-term fisheries management excited Hurst.

"I thought it had a lot of potential, so I was very keen to be involved."

There were two key elements to the NZ QMS – the first major shift was putting a ceiling on the number of fish that could be taken by the commercial sector – the Total Allowable Commercial Catch (TACC).

The second was the introduction of Individual Transferable Quotas – a right to a proportion of the TACC for a particular species in a particular area.

To determine exactly how many fish could be taken under the QMS, fisheries scientists needed to determine how many fish were in New Zealand waters.

Hurst was involved in many of the exploratory surveys attempting to estimate fish abundance. Using research trawl findings, along with years of commercial fishing data, Hurst and her colleagues worked to establish early catch limits under the QMS.

"It was an exciting time because you really started to focus the research you were doing on what the management questions were."

At 30 – just five years into her fisheries career – Hurst was travelling around New Zealand visiting fishing communities to help explain the science behind the big changes the QMS brought.

It was not easy.

"When you're sitting in a room with fishermen visibly upset by the fact their ability to catch fish is going to be cut in half … that was quite an eye opener for a young scientist. It really brought home the responsibility we had to get it right."

As a young scientist in the 1980s, Rosemary Hurst spent months at sea on Japanese and Russian fishing vessels. She was working on the population estimates that shaped New Zealand's early fishing quotas.

> **"We now have the capability to take the next step – from Fishery Plans to Fishery Ecosystem Plans"**
>
> Dr Rosemary Hurst

Fisheries management is political. Communities, individuals and businesses all have their own interests and viewpoints, and balancing those while ensuring sustainable stocks is no easy task.

"There are no methods to work out the absolute biomass of fish.

"It's not like counting sheep in a paddock, or trees in a forest – we've had to develop robust scientific systems for estimating fish populations."

Hurst sees her work building the series of standardised trawl surveys covering inshore and middle-depth waters, now spanning nearly 30 years, as a career highlight. These focus on estimating the abundance and age structure of key commercial species as well as collecting data on all species landed.

Fishing fast facts

$4.2 billion

Estimated total value of the commercial fishing industry to New Zealand

405 million hectares

Area of ocean within New Zealand's Exclusive Economic Zone

"One of the things that I've always enjoyed about the science is that it's directly relevant to management. You also get a lot of valuable feedback on what you're doing through the MPI stock assessment working group process."

She also acknowledges that, even with the trawl surveys and the latest advances in population modelling and acoustic monitoring techniques (*see opposite page*), estimating fish abundance is still challenging, and she continues to look for improvements.

Unexplained changes in some fish populations have led to the need to investigate other components of the ecosystem.

She references the declines in hoki catches in the early 2000s. While fishing pressure and low recruitment were contributing factors, there were potentially other things going on – like prey abundance, water temperature or current variations.

This variability will be better understood by taking a broader ecosystem approach.

RV *Tangaroa*'s recent voyage to the Southern Ocean is attempting to do just this. The science is focused on the effects of climate variability on ecosystem function in the Sub-Antarctic region, including effects on protected species and important fisheries, such as hoki.

Hurst says studies such as this, coupled with the time series of trawl surveys, can build on the QMS single-species approach to develop a wider ecosystem approach to management decisions.

"We now have the capability to take the next step, from Fishery Plans to Fishery Ecosystem Plans.

"Developing formal ecosystem plans would provide more visibility on where we are making progress and the priority areas we need to address."

To illustrate her point, Hurst and colleagues are currently developing a multi-species online fish portal. The portal visualises 27 years of NIWA trawl survey data on the Chatham Rise across more than 30 species. It already enables users to easily compare trends in species abundance, and a further suite of ecosystem indicators is on the way.

"It's made all the data more accessible, so that you can look to join the dots to ask important questions and develop hypotheses on what might be causing changes."

Asked if New Zealanders can be proud of the big changes in our fisheries management regime over the past 30 years, Hurst doesn't hesitate.

"Yes – getting key target species catch under control is the definitely the first important step to sustainable fisheries and ecosystem management, and the QMS has achieved this. Many of the adverse effects of fishing are also being monitored and managed.

"But extending this success to a system that more explicitly incorporates both fishery and broader ecosystem objectives – that will take our fisheries management to the next level."

Science on the high seas

By Sam Fraser-Baxter

Night watch on the bridge of research vessel *Kaharoa*, monitoring acoustic signals from hoki schools up to 1000m below. (*Rebekah Parsons-King*)

> "We all want to have long-term sustainability of the hoki fishery in New Zealand"
>
> Dr Richard O'Driscoll

Ever wondered what fish is served in a Filet-o-Fish at MacDonald's? It's hoki. Fish fingers at the supermarket? Chances are, they'll be hoki too.

A fast-growing, deepwater, schooling species, hoki is New Zealand's largest fishery. The majority of the catch is exported, and it earns New Zealand about $200 million a year.

But how do fisheries managers protect that resource and decide how much fish can be safely taken each year?

This is where NIWA's team of fisheries scientists, led by Dr Rosemary Hurst (*see previous story*) come in.

Hoki, for example, is one of New Zealand's most carefully studied species, and exemplifies the critical role science plays in maintaining both a lucrative and sustainable industry.

NIWA scientists, often working on research vessels *Tangaroa* and *Kaharoa*, have been surveying the fishery since 1995, building on work started by the Ministry of Agriculture and Fisheries about 10 years earlier. Standardised trawl and acoustic surveys are supplemented by data from commercial catches to model populations under various catch scenarios. Fisheries New Zealand (FNZ) uses this information to determine the allowable catch.

The ability to react to observed changes in fish populations, and raise or lower the catch accordingly, is the key to a sustainable fishery.

Every winter, thousands of tonnes of hoki swim from the deep waters around the Chatham Rise and the Sub-Antarctic Plateau, to Cook Strait and the west coast South Island respectively to spawn.

The deepwater canyons in these areas are the main hoki fishing grounds. Because the fish are highly aggregated in spawning schools, the areas are also key sites for NIWA's long-running scientific acoustic surveys monitoring hoki populations.

In the latest Cook Strait survey, NIWA's research vessel *Kaharoa* headed out along a series of randomised transects with an acoustic transducer attached to the hull.

NIWA Fisheries' Principal Scientist Richard O'Driscoll describes the transducer as a "fancy version of a fish finder". Pulses of sound are emitted towards the seafloor. When these acoustic pulses reach something in the water column, they're reflected back to the researchers' computer screens on board *Kaharoa*.

Different fish send back different patterns, and the amplitude of the returning soundwave is proportional to the density of fish. The results are analysed and can be used to estimate species abundance.

A trawl net is used to catch a small representative

> **"What we want to see for a healthy population is a wide range of size classes"**
>
> Dr Richard O'Driscoll

sample of selected schools so researchers can confirm fish species and size.

Once the fish are on board, their weight, gender and size are recorded and the fish's ear bone – or otolith – is removed. Fish add another layer to their otolith every year – like tree rings, these tiny layers can be counted to determine age.

"What we want to see for a healthy population is a wide range of size classes," says O'Driscoll.

Fishing fast facts

$200 million
Annual value of hoki exports to NZ

115,000 tonnes
Total allowable commercial catch for hoki in 2019

"The number of young fish we see is a measure of the number of fish coming into the population. That will tell us how many we can take out over the years to come."

In the last few years, trawl survey and acoustic indices and commercial hoki catches have declined. In September 2018, the fishing industry agreed to voluntarily lower their catch from 150,000 tonnes to 130,000 tonnes. Fishing companies had struggled to land their quota and were concerned hoki numbers may be lower than thought. Then in October last year, the hoki quota was officially reduced to 115,000 tonnes to enable the stock to rebuild.

O'Driscoll says scientists, FNZ officials and the fishing industry work closely together to maintain a healthy fishery, and the hoki quota adjustments are an example of the flexibility of the QMS.

Another example occurred in the 2000s, when the hoki population experienced a dramatic decline. TACCs were cut and the fishery recovered.

"We're all on the same page, we all want to have long-term sustainability of the hoki fishery in New Zealand," he says.

The 2019 survey results, along with industry-supplied catch data, may yet change the TACC again.

Fisheries scientist Dr Yoann Ladroit takes samples from hoki in the wet lab aboard RV *Kaharoa*. Genetic analysis can reveal the fish's breeding stock. (*Rebekah Parsons-King*)

Ear bones – or otoliths – are removed soon after hoki are landed. These tiny bones can reveal a wealth of information, including fish age and growth rates. (*Rebekah Parsons-King*)

Rebekah Parsons-King

The Hill

Castle Hill, on State Highway 73 between Darfield and Arthur's Pass in the Waimakariri Basin, was named for the imposing array of limestone boulders in the area that mirror the look of castle ruins.

It attracts hundreds of rock climbers every year, but it was the sky that grabbed NIWA freshwater ecologist Shannan Crow's attention – especially at night in the middle of winter.

Familiar with working in some of New Zealand's most stunning environments, Crow is particularly attracted to Castle Hill because the limestone boulders add depth and interest to his photographs.

He was voted the People's Choice winner in the annual NIWA Photography Awards, which attracted more than 400 entries from staff. The vast array of environmental science NIWA researchers undertake happens in some of this country's most beautiful natural locations, a happy circumstance which has prompted many staff to take up amateur photography.

Crow used a Nikon D850 camera with a Zeiss Otus 55mm lens to capture his winning shot, which he named The Centre of the Milky Way aligned with the Centre of Castle Hill.

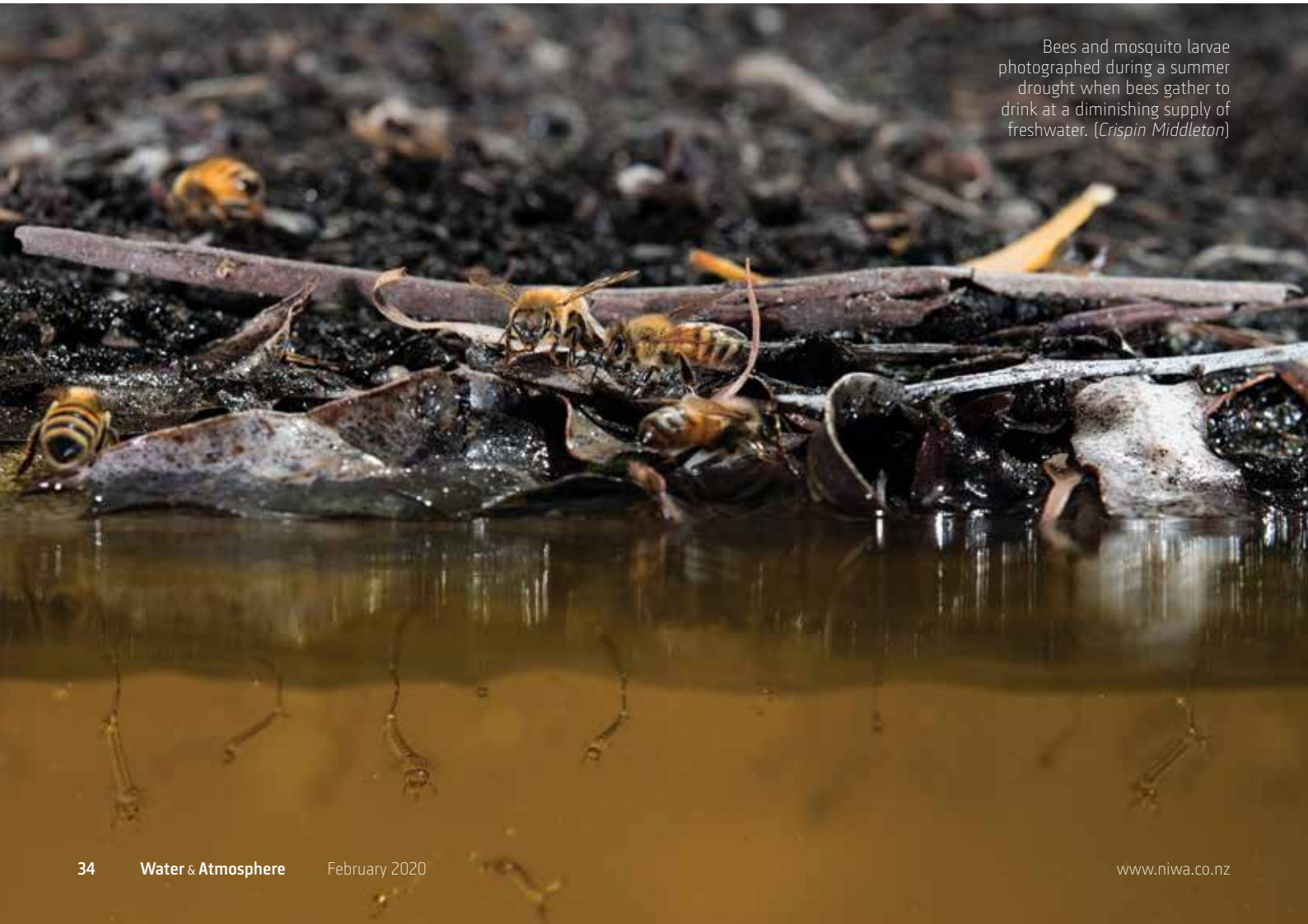
"Winter is the optimum time because the Milky Way core is fully visible, and the dark conditions of the new moon allow more detail to be captured in the sky."

Reaching the end of its planktonic life, this juvenile slipper lobster drifts through the warm shallow waters of the outer Hauraki Gulf. (*Richie Hughes*)

Far North beach seine preparation to sample snapper. The smaller boat sets the net while the larger vessel is used as the "mother ship". (*Crispin Middleton*)

Marine ecology technician Sam Parkes prepares anchors for sea-level and wave monitoring equipment in Tonga. (*Jochen Bind*)

A bird's-eye view of sea-bed coring. (*Sarah Searson*)



Bees and mosquito larvae photographed during a summer drought when bees gather to drink at a diminishing supply of freshwater. (*Crispin Middleton*)

Flight of the kea. (*Shantanu Patke*)

Close up with the native porcelain crab *Petrolisthes elongatus* taken from the intertidal zone in Otago Harbour. (*Chris Woods*)

The frozen menagerie

It's dark, it's cold and it's a scientific gold mine. Susan Pepperell digs deep into the NIWA freezer.

There is a place for everything, its just that most of the places are full.

Just past the locks, alarms and big heavy doors is a rather macabre sight.

To see it, you first need to grab a heavy jacket, pick a beanie out of the box and put on a pair of industrial strength gloves, because it's cold in there: –20°C to be exact.

The NIWA freezer at its Greta Point, Wellington site is huge – shelf after shelf of boxes and bins contain a scientific treasure trove of frozen fish, marine mammals and sea birds. While it looks a little chaotic, everything is carefully labelled and stored in sections labelled "For Te Papa" or "Incoming" or "Seabirds" or "Observer samples". There's a place for everything, it's just that most of the places are full, and it's time for a clean out.

Well over a metre from claw to claw, the king crab (*Lithodes aotearoa*) takes up more than its fair share of shelf space. (*Sam Fraser-Baxter*)

Fisheries technician Jeff Forman says they've had giant squids on the floor from time to time, but "we try not to have those as they take up too much room".

"Look at this bad boy," he says as he pulls a large yellow bin down from the top shelf. Inside is a large king crab, a beautiful specimen that will be used to further scientific knowledge of the species.

Opposite the king crab shelf are the seabirds. There's an albatross in a bag, a few shearwaters and possibly a penguin, although it's a bit hard to tell under the several layers of plastic.

At the opposite end of the freezer is a leopard seal in a plastic bag being stored there by cetacean biologist Dr Krista Hupman. The animal was found washed up dead on a remote beach and delivered to Dr Hupman, who will thaw it out and dissect it when time permits.

In addition to the full leopard seal there are also frozen flippers and heads that Dr Hupman hopes will be the start of a leopard seal bone, tissue and skin archive that will be invaluable for future research.

"There is so much information we can learn from these specimens that can potentially help protect this amazing animal."

Dr Hupman is also the keeper of the leopard seal scat collection – bag after bag of faeces – that will be thawed and sieved, the bones and feathers picked out and identified to work out more about their diets.

The shelf marked "To go to Te Papa" is stacked high and awaiting someone to take the lot to permanent storage in the National Fish Collection.

But as soon as some temporary residents move out, new ones appear.

Every few weeks NIWA receives an assortment of specimens collected by staff onboard research vessels undertaking fishing trawl surveys, or by observers on commercial fishing boats. They pick out unfamiliar fish or ocean invertebrates from the bycatch or specimens that have not previously been spotted in the area.

Most end up in the freezer before being sent for expert identification. Scientists say these opportunistic samples provide a wealth of knowledge about the diversity of the region we wouldn't otherwise have.

Forman mostly works on fish stomachs. A large amount of shelf space is dedicated to frozen fish guts before they are meticulously examined and their diets carefully recorded. This information is crucial to understanding predatator/prey relationships and foodweb interactions within marine ecosystems.

Jeff Forman with two deep-frozen, deep-sea offerings. Both the cusk eel (*Spectrunculus grandis*) and sleeper shark (*Somniosus pacificus*), in front, live in waters more than 1km deep. (*Lana Young*)

The shark section is also pretty big, although a cling-filmed frozen shark looks a lot less threatening than the real live thing.

Shark researcher Dr Malcolm Francis says most of the sharks in the freezer are small, due to limited space, with a number archived and kept indefinitely on behalf of the Ministry for Primary Industries.

Other shark specimens are used to research the age and growth of various species. Sections of shark vertebrae are particularly useful because they contain growth rings. "We cut a thin section out of the middle, put it under a microscope and count the rings."

Cartilage or muscle parts can be used for genetic research, and researchers will also look at reproductive stages along with other important biological information.

Increasingly, NIWA is receiving samples that may pose a threat to New Zealand's marine biosecurity. These specimens are carefully tracked and shelved separately.

And while the NIWA freezer may be the final resting place for some special species, it pays for humans not to linger too long. If the sharks don't get you, the cold surely will.

Weathering new technology in Tonga

By Susan Pepperell

There are about 800km between the southern and northern tips of Tonga – and a lot of ocean.

Many of this Pacific archipelago's 169 islands are remote, exposed, sparsely populated and difficult to access. And when it comes to forecasting the weather in an area known for cyclones and also prone to drought, it's a significant challenge.

However, that is all about to change.

NIWA is in the final stages of completing a project with the Tongan Meteorological Service (TMS) to install new weather stations and sea level monitoring equipment from one end of Tonga to the other. In what has been a huge logistical exercise, six months in the planning and another year in the implementation, Tonga now has 21 new weather stations and two sea-level monitoring stations.

One of the problems faced by TMS was the difficulty in receiving manual weather observations from parts of the country where there were no staff.

TMS head Ofa Fa'anunu says communication, particularly from the outer islands, was challenging.

"We are now able to get data from these remote areas and can now work on building the capacity of the Met Office in all areas of forecasting."

The project was part of the Climate Resilience Sector Project, funded by an Asian Development Bank Grant. It will enable Tonga to be better prepared for extreme weather events and climate change as well as provides improved weather forecasting for businesses such as ferry operators and airlines.

NIWA principal scientist Dr Graham Elley, who managed the installations, says the new system was a complex logistical exercise, but will help Tonga build resilience with effective warning of extreme weather and coastal events.

"The challenges started with how to get the equipment there. In the end we shipped three container loads, which was more than 20 tonnes, to the capital Tongatapu, and then faced the issue of how to get it – and the people we needed – to the outer islands to install it."

The answer came in chartering a vessel from Tauranga, with live-on accommodation, which also had the advantage of being able to take the huge amounts of concrete needed for the job.

But before that a team from NIWA's Instrument Systems Group had to assemble all the equipment and supporting infrastructure in Christchurch.

> **"The challenge started with how to get the equipment there"**
>
> Dr Graham Elley

NIWA's Evgeny Fardman working with staff from the Tonga Meteorlogical Service. (*Shaun Williams*)

From left, NIWA technicians Rod Budd and Dave Bremner at work at Hunga Wharf with Selusalema Vite from the Tonga Meteorological Service. The trio are using local tide boards to verify instrument records. (*Aleki Taumoepeau*)

Without them, says Elley, the project would never have got off the ground.

Installations in Tonga commenced with a network of temporary wave and tide gauges to gather data to refine the models needed to produce continuous localised tide and wave forecasts. These were in place for seven months.

Then the weather stations were installed across each of the seven island groups. The most remote locations were targeted first to ensure they were operating before the cyclone season started in November. In the capital Tongatapu, about 15 staff installed the data management system and web portals needed to make the system operational.

Training has also been a key component of the project.

"At every stage we have provided on-the-job training which started with a couple of Tonga Met Service staff coming to New Zealand while we built the equipment so they could begin to gain an understanding of how the equipment operates.

"Then throughout the installation process, our staff provided training, and it is still ongoing, with staff now providing one-on-one site calibration and maintenance training."

But it takes more than equipment and people power to bring such a large-scale and technologically advanced project to fruition. Elley says NIWA's long history of working collaboratively in the Pacific – it has been involved in the installation of more than 240 weather stations in the region – meant that, despite the many challenges, the project went smoothly.

"We even got ahead of schedule at various times – mainly because of our experience gained doing other projects in the Pacific.

"Ferry and shipping companies are now able to receive forecasts of the routes they use, predicting sea state for the next few days, and at the extreme weather end, there will be a much better understanding of what is happening when and where."

Fa'anunu says TMS's long working relationship with NIWA made the project easier because both organisations take a regional approach to working in the Pacific.

And for one NIWA staff member, working on the project was a homecoming of sorts.

Technician Aleki Taumoepeau left his homeland at the age of 11, so the chance to return and help his people was a career highlight.

"There are so many people who will benefit from this – shipping, ferries, airlines. It's been one of the most satisfying projects I've been involved in – and once everything was planned out it was smooth sailing.

"And knowing you're going to be actually helping your people was a real positive for me."

Back cover: Two Salvin's albatross patiently patrolling off the Kaikoura coast. (*Rebekah Parsons-King*)