FRESH THINKING – NEW SOLUTIONS
Science making a difference

BREATHE FREELY
Air quality during lockdown

OCEAN WANDERERS
Helping to protect our albatrosses

A COLD DAY IN THE OFFICE
Take a plunge under the Antarctic ice

Water & Atmosphere

JULY 2020

CATCH OF THE DAY
Farming kingfish in Northland

Water & Atmosphere

July 2020

Stuart Mackay

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NIWA
Taihoro Nukurangi

Cover: Ready for the discerning diner, these 1-year-old Ruakaka kingfish are sustainably reared in tanks at NIWA's Northland Marine Research Centre at Bream Bay. (*Stuart Mackay*)


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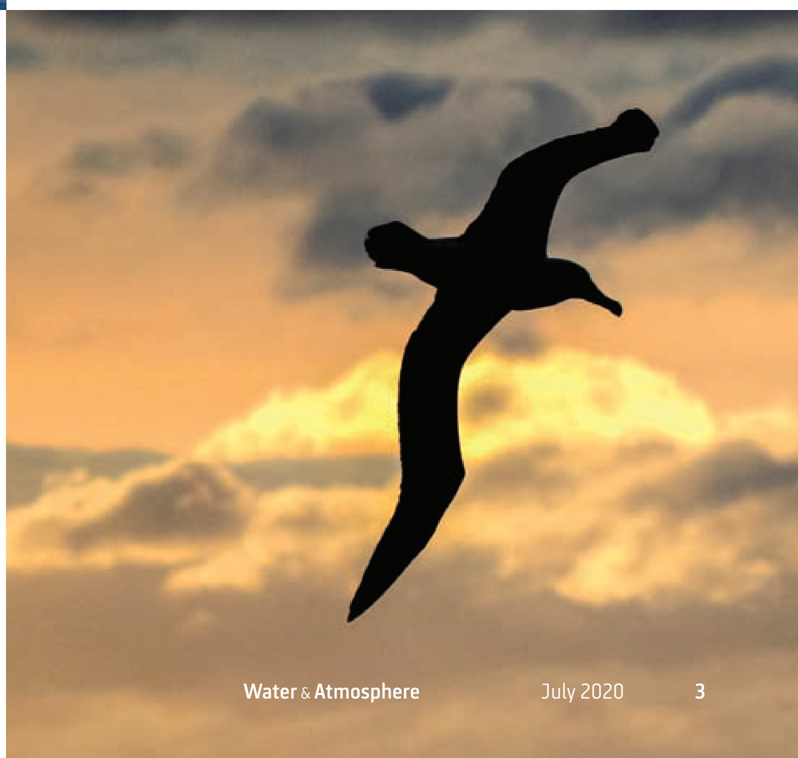


Science helps shape the fightback

NIWA's Chief Executive John Morgan looks at the role science will play in New Zealand's post-Covid recovery.

NIWA's Northland Marine Research Centre at Ruakaka. (*Stuart Mackay*)

"NIWA's science is targeted to deliver fresh options"

John Morgan

It has been a tough few months. We've all been caught up in a global pandemic that has swept lives and livelihoods before it, with unimaginable speed.

Prompt action looks to have shielded our country from the full force of the virus. But New Zealanders are still processing the impacts of that response and learning what will be needed to live and work in a post Covid-19 world.

One thing, however, is already clear. That is the importance of science, both in dealing with the pandemic itself, but also in helping to outline pathways to recovery.

Medical science is not NIWA's area of expertise; however, the processing power of the supercomputers hosted in our High Performance Computing Facility are helping our ESR colleagues unravel the genome sequence of New Zealand's positive Covid-19 cases.

One of our population modelling experts has also been working alongside the multi-disciplinary team producing the epidemiological models shaping New Zealand's response to the virus.

NIWA's major contribution to the nation's coronavirus fightback, however, will come from our capability in climate, freshwater and ocean science. A key focus is on projects that will improve the health of our waterways and oceans, help communities adapt to a changing climate and provide fresh, sustainable opportunities for industry.

NIWA's aquaculture expertise, for example, is the foundation for the innovative, multi-million dollar kingfish farming enterprise fast developing at our Northland Marine Research Centre at Ruakaka. It's a case where science is literally "spawning" new investment and employment opportunities for regional New Zealand.

Whether it is supercharging our abilities to forecast New Zealand's changing climate, mapping the scale of the marine ecosystem services running along our coastline, or arming communities with more effective information about hazardous floods: NIWA's science is targeted to deliver fresh options.

Contrary to popular opinion, science seldom produces a single, magic solution. But focused research programmes, woven together over time do uncover new opportunities and NIWA is committed to keep working with New Zealand communities and businesses to find those new ways of doing things.

It has been a tough few months, but I am more confident than ever that NIWA's science remains on track to help New Zealanders shape a bright, low carbon, post-Covid future.

IN BRIEF

Stuart Mackay

HIGH AND DRY

Auckland residents are entering their third month of water restrictions as a record dry spell has left the city gasping.

Drought conditions across a number of North Island cities and regions this year have been among some of the most severe on record.

Whangarei, Auckland, Whitianga, Hamilton, Tauranga, Whakatane, Napier and Taupo all recorded their driest January-May period ever.

The City of Sails has been particularly hard hit, with city reservoirs falling below half full for the first time in more than 25 years and authorities forced to seek emergency supplies from the Waikato River.

NIWA climate change projections predict increasingly frequent and extreme drought events for northern and eastern New Zealand in the decades ahead.

GRAPPLING WITH ALIEN INVADERS

Tracey Burton

Wet feet were the order of the day for more than 120 Central Otago students who joined NIWA freshwater scientists for an aquatic health check of Lake Dunstan earlier this year.

The year eight Cromwell College students escaped the classroom to explore their lake and the problems it faces, especially from the invasive alien weed species lagarosiphon.

The students used a grapnel to find and identify aquatic plants, tested water clarity, categorised invertebrates and took a dive under the surface using NIWA's virtual reality headsets.

The event was organised along with LINZ and Otago Regional Council to empower the young "citizen scientists" to play a role in protecting their freshwater playground.

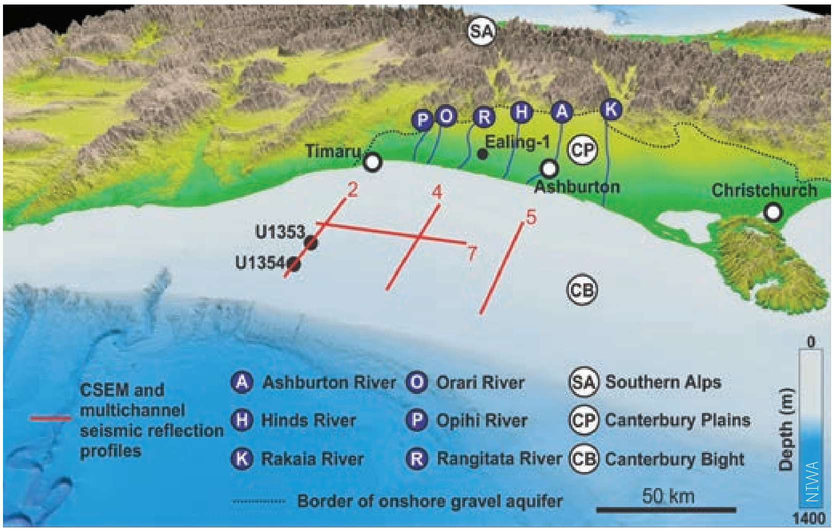
WATER, WATER – EVERYWHERE

A large – and internationally significant – underwater aquifer has been mapped off the Canterbury coast.

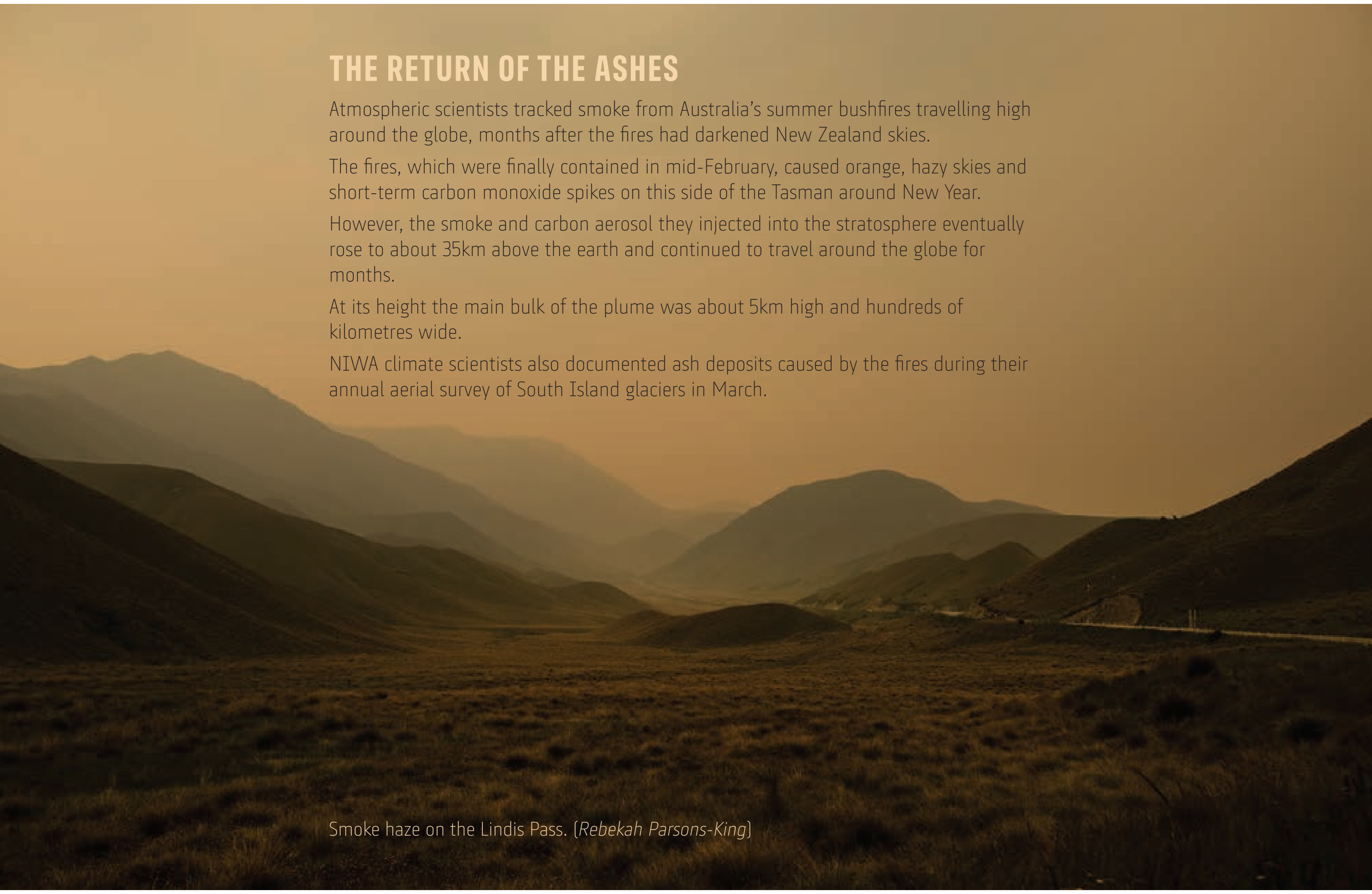
Located just 20m below the seafloor and extending up to 60km out to sea, the freshwater resource is one of the few significant offshore aquifers located anywhere in the world.

The reservoir was uncovered by an international team, including NIWA researchers, working on a European Research Council project. They used remote mapping and geophysical modelling techniques to scope its size.

It is estimated to contain as much as 2000km^3 of water, equivalent to up to half the volume of the groundwater across the entire Canterbury region.



NIWA



THE RETURN OF THE ASHES

Atmospheric scientists tracked smoke from Australia's summer bushfires travelling high around the globe, months after the fires had darkened New Zealand skies.

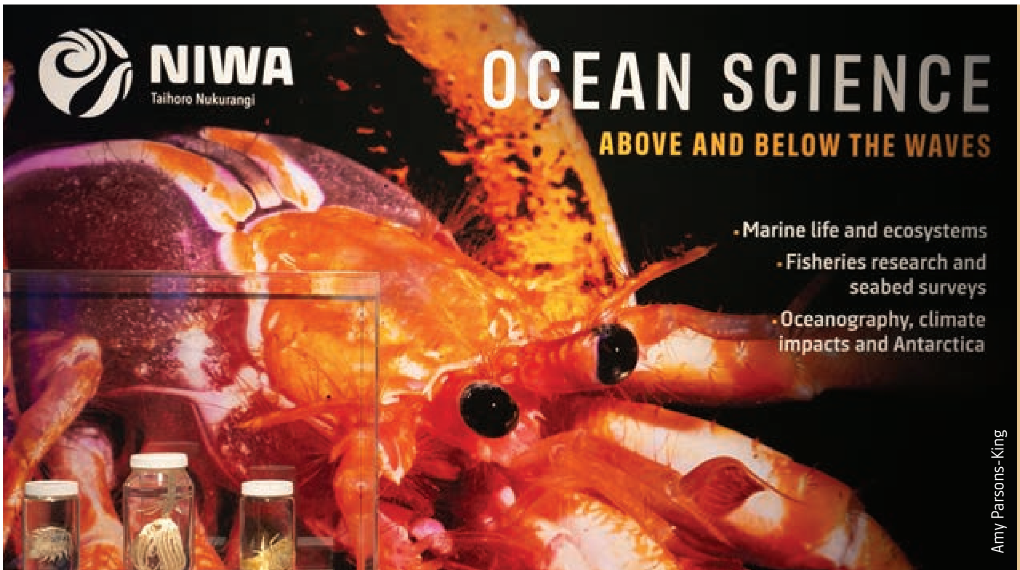
The fires, which were finally contained in mid-February, caused orange, hazy skies and short-term carbon monoxide spikes on this side of the Tasman around New Year.

However, the smoke and carbon aerosol they injected into the stratosphere eventually rose to about 35km above the earth and continued to travel around the globe for months.

At its height the main bulk of the plume was about 5km high and hundreds of kilometres wide.

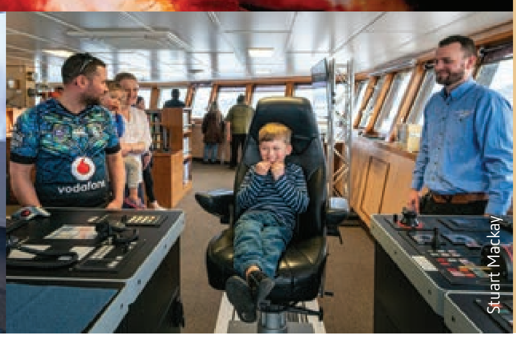
NIWA climate scientists also documented ash deposits caused by the fires during their annual aerial survey of South Island glaciers in March.

Smoke haze on the Lindis Pass. (*Rebekah Parsons-King*)



Amy Parsons-King

Amy Parsons-King



Stuart Mackay

DRAWN TO THE DEEP

More than 50,000 people poured through the doors for NIWA's highly successful "*Dive Deep into Ocean Science*" display at the Otago Museum.

The 8-month-long scientific event ran alongside the museum's hosting of the touring "*James Cameron – Challenging the Deep*" exhibition.

Designed to deliver an "up-close and personal" experience of NIWA's ocean and Antarctic science, the display involved video and photographic exhibits backed by a series of popular scientific talks by NIWA staff.

Virtual reality headsets gave users the chance to plunge beneath the Antarctic ice with NIWA's specialist dive team.

Hundreds also jumped at the chance to tour RV *Tangaroa* during a visit to Dunedin timed with the start of the exhibition.

EMPOWERING STUDENTS

Young New Zealanders can now access the most up-to-date material about the science of climate change, thanks to a new educational resource on NIWA's website.

"*Climate change information for Climate Solvers*" is a plain English guide, jam-packed with images, video and graphics to explain New Zealand's climate change projections and impacts.

The resources are aimed at empowering students to explore the things that they and their communities can do to help combat climate change.

The content has been compiled to complement the climate change teaching resources and wellbeing guide released by the Ministry of Education earlier this year.

LUCKY DIP

A 4m, 110kg giant hauled up from deep waters east of New Zealand has left squid specialists smiling.

The crew of NIWA's research flagship RV *Tangaroa* pulled up the unexpected specimen during a fisheries survey on the Chatham Rise.

Giant squid are rarely encountered globally but New Zealand is fast developing something of a reputation as a hotspot, with specimens landed about once every 10 years.

Fortuitously, one of New Zealand's leading squid researchers was onboard *Tangaroa* when the intact specimen was landed.

Under expert guidance, key body parts such as the squid's stomach and enormous eyes were recovered to enable further insights into the mysterious lives of these deepsea giants.


Brit Finucci


Stuart Mackay

SMOKE SNIFFERS

Air quality researchers are on the lookout for citizen scientists to help sniff out smoke.

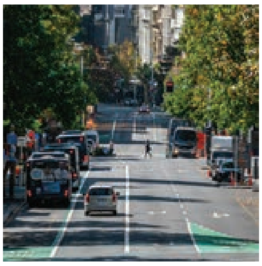
Smoke from home heating is the biggest source of air pollution in New Zealand, and the arrival of winter means home fires have lit up across the country.

NIWA researchers have launched a project via the NIWA Citizen Science app to gather more information on how and when smoke is affecting people.

The team is asking New Zealanders to record where and when woodsmoke is affecting their health and lives, so they can work with regional councils to keep Kiwis warm – and healthy – at home.

Locked down, but breathing freely

Some of the most striking images of lockdown around the world have been the blue skies of cities ordinarily choking in smog. From New Delhi to Los Angeles, Beijing to Paris, the changes were so remarkable they were visible from space.



Scientists commented that while there have been other incidents that led to measurable decreases in nitrogen dioxide (NO_2) and nitric oxide (NO) emitted by vehicles and industry, none had been so intense or happened as quickly as the global shutdown prompted by Covid-19.

Pollution in New Zealand's main cities followed similar patterns to those overseas. NIWA air quality scientist Dr Ian Longley kept a close eye on our air throughout Levels 4 and 3 and provided weekly updates. It was a complex exercise that necessitated the use of unverified data due to the many restrictions operating, but it provided a compelling insight into how much our air quality improves when we keep our cars at home.

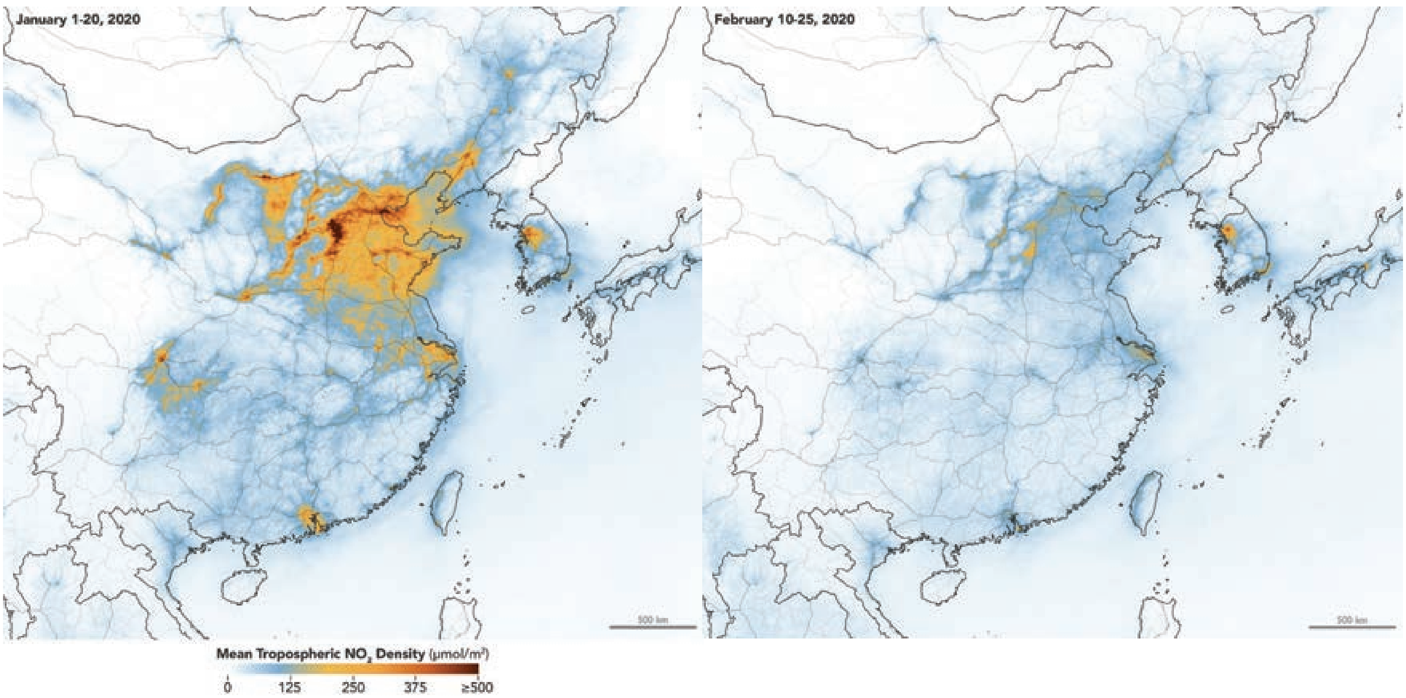
Ian found that under Level 4, concentrations of road traffic exhaust pollutants were about 25–35% of normal in Auckland, Wellington and Christchurch. The drop was sharp and immediate but not quite as pronounced in Queen Street, Auckland's main street, where the drop was about 45% of normal.

Throughout Level 3, when restrictions were eased, concentrations of traffic pollutants rebounded to between 47% and 63% of normal in Auckland and Christchurch and to about 75% of normal in Wellington. Level 2 saw levels more or less the same as pre-lockdown.

Ian says this rare occurrence has provided the opportunity for a natural experiment to improve our understanding of the different health impacts of air pollution.

"Although air quality changed dramatically across the cities monitored – and probably all other towns and cities too – the benefits would not have been experienced equally," Ian says.

"Air quality was improved in our home neighbourhoods, around our workplaces and on the roads we use to travel from one to the other, but to slightly different degrees. Our personal experience was therefore determined by where we live and work and how we experienced lockdown."



Images from the European Space Agency's pollution monitoring satellites reveal NO_2 levels across China before (left) and after (right) the country moved into lockdown late in January.

> “Air quality changed dramatically across the cities monitored”
>
> Dr Ian Longley

During Level 4 lockdown, Auckland's northern motorway was virtually car free. Traffic volumes, however, quickly bounced back by Level 2. (*Stuart Mackay*)

He says those benefiting most in Auckland would be people who normally commute during peak hours from a less polluted home location to a more polluted work location – especially downtown Auckland.

“Not only was air quality improved at home, but they would experience additional benefit from avoiding the downtown area, and not spending time in busy traffic. A rough estimate suggests these people – about 300,000 – could have reduced their exposure to traffic pollution by about 90%.”

Longley says this gain could have been experienced by hundreds of thousands more if through traffic, and especially diesel buses and trucks, had been removed from the city centre.

Lockdown, he says, has provided “vivid confirmation” of how in New Zealand's windy cities – isolated from each other and international neighbours and where heavy industry is largely absent – pollutants can be made to vanish virtually overnight.

“Whether these reductions in exposure to air pollution will translate into improvements in health remains to be seen.”

He estimates it will be another 15–20 years before New Zealand's cities experience similar air quality to this year's lockdown, based on business-as-usual improvements in vehicle emissions technology.

“A rapid transition to electric buses, and establishment of zero emission zones, will not only clean up our urban centres, but should incentivise the adoption of zero emissions transport across whole cities.”

Lasting changes in CO_2 output will also take more deliberate action.

A recent *Nature Climate Change* article estimates New Zealand reduced its CO_2 emissions by 41% during lockdown – more than any country except Luxembourg, which experienced a 44.6% drop.

However, NIWA climate scientists say this was only a temporary dip, and with activity levels quickly returning to normal, global emissions for the year are likely to be less than 5% lower than they would otherwise have been.

Getting the taste for kingfish

This award-winning kingfish sashimi dish is creating quite a splash – but it doesn't come from the sea.

We look at NIWA's latest aquaculture success story and the new opportunities it's on path to deliver.

Stuart Mackay

> **“Five years ago no one would have said ‘let’s do it on land’.”**
>
> Dr Andrew Forsythe

In her Trip Advisor review of an Auckland eatery *Debbie* proclaimed the Ruakaka kingfish to be the best dish she had ever eaten at a restaurant *“anywhere in the world”*

In a separate entry, Chris and his three friends also voted the Ruakaka kingfish sashimi their highlight. *“It was divine,”* he wrote.

Others followed in universal agreement. *“Everything was amazing – especially the Ruakaka kingfish … the kingfish was so yummy we ordered another one … highly recommend the kingfish sashimi … .”*

A memorable meal is one thing, but if they knew how many years and how much expertise and sheer hard work had gone into getting those kingfish slivers to their plates, Debbie and her colleagues might have been tempted to double down on the superlatives.

Scaling up

Every week about 250kg of premium kingfish farmed in tanks at NIWA’s Northland Marine Research Centre (NMRC) at Ruakaka is carefully harvested and sent to a select number of restaurants around the country.

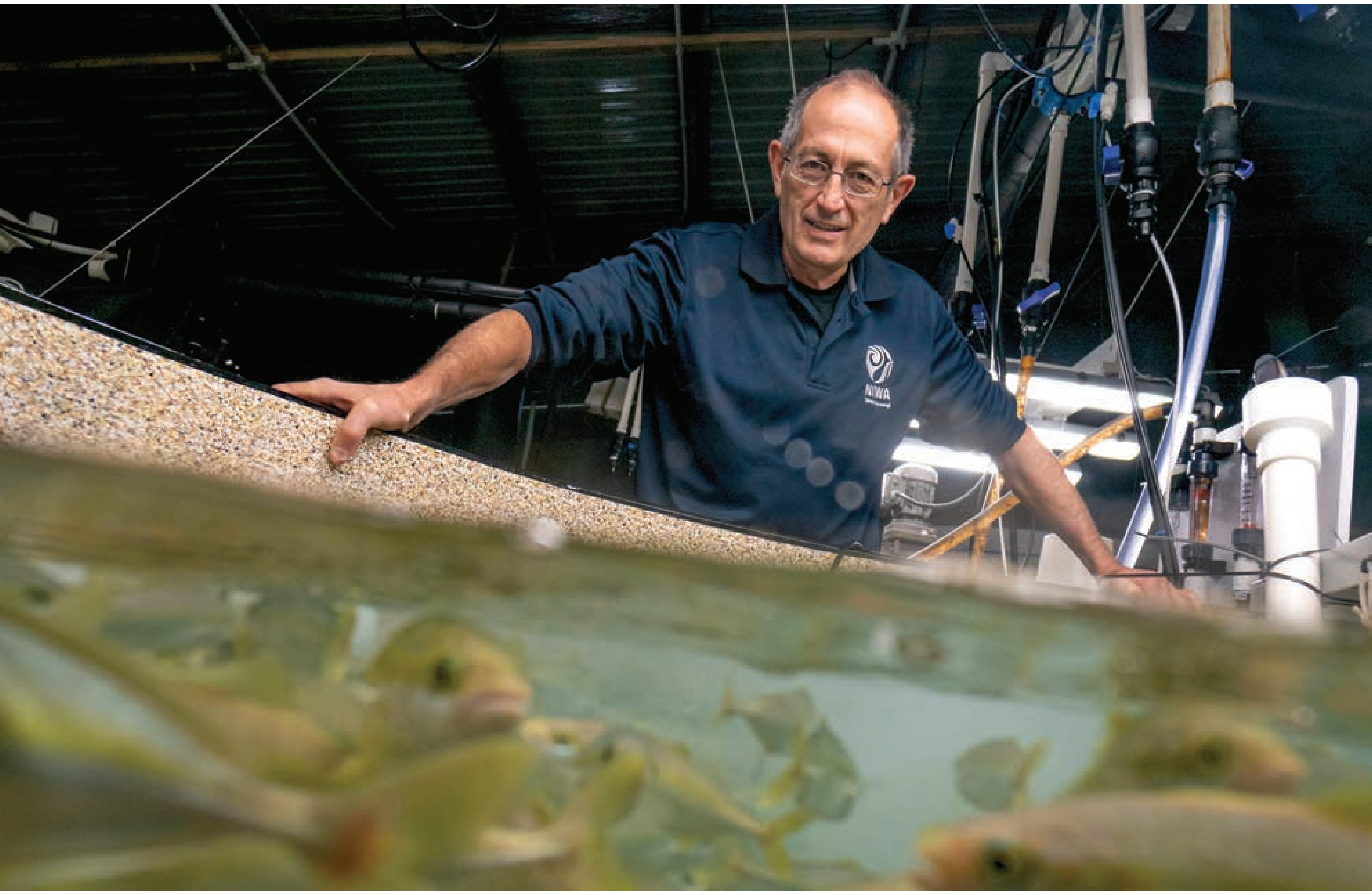
It is a deliberately small operation designed to test the market and provide valuable insight into the viability of a much larger one.

That larger operation is now on its way. Development has started on a recirculating aquaculture system (RAS) at the NMRC that can produce up to 600 tonnes of Ruakaka kingfish per year. It is a sustainable, land-based venture that aims to prove the technical and economic feasibility of farming kingfish in tanks at commercial scale.

NIWA, Northland Regional Council and the Provincial Growth Fund are all investing in this prototype. Success will lead to further commercial opportunities with a full-scale 3000-tonne operation up and running within five years and creating about 75 new jobs for the region.

Mature kingfish are harvested weekly from tanks at NIWA’s Northland Marine Research Centre at Ruakaka.

Each fish is individually recorded to maintain ongoing population and growth data.
(*Stuart Mackay*)



Aquaculture chief scientist Dr Andrew Forsythe with a tankful of young kingfish inside NIWA's marine research facility.

These premium fish are born, bred and harvested on land. (*Stuart Mackay*)

Regional Economic Development Minister Shane Jones calls the plan the type of innovation the Provincial Growth Fund wants to invest in. "It is testing technology that could bring major sustainable economic growth not only to Northland, but the rest of the country."

End game

The story of how Ruakaka kingfish is now poised to become a premium product on the menus of restaurants both here and overseas is one where scientific discovery and commercial reality are neatly intertwined.

Scientific discovery relies on the expertise and innovation of scientists. But with aquaculture research, that scientific enquiry is also firmly shaped by the end-game – overcoming the challenges and risks that will be faced by a commercial operation.

NIWA established the NMRC at Ruakaka in 2002 with a focus on researching the potential for aquaculture of high-value species.

"Aquaculture research has had a history of studying many species in small-scale laboratory experiments, often divorced from commercial realities," says NIWA's GM Strategy, Dr Bryce Cooper.

"We deliberately wanted to turn that on its head at the NMRC. We chose just two species with market appeal – kingfish and hāpuku – and we concentrated on research at scale and on overcoming the hurdles to commercial uptake."

In 2005, Dr Andrew Forsythe arrived at Bream Bay fresh from the Canadian salmon industry to take up the role as NIWA's Chief Scientist – Aquaculture.

Andrew agrees that keeping scale and commerce front of mind has been the key to the NMRC's success.

"Kiwi scientists can figure out how to grow almost anything, but there is no point unless the species can be reliably produced in a form and at a price that consumers will buy. Scale is a critical factor when controlling the cost of production."

So, as scientists developed the techniques that would enable NIWA to have almost complete control over the kingfish reproductive cycle, Andrew says there was a parallel workstream looking at how to apply that knowledge to a commercial proposition.

"I think the NIWA senior managers over the years deserve a lot of credit for recognising this was not a simple science question – it was a continuum of work."

Land versus sea

As with any primary production venture, successful farming of fish requires good genetics, good husbandry and good food. These three factors are the focus of ongoing research at the NMRC.

Equally important, however, the production system also had to align with NIWA's product vision of 'a high-quality healthy food sold in premium markets because of its exquisite taste, provenance and environmental credentials'.

"When we looked at the usual sea-cage farming of fish we weren't confident that these principles could always be met without some radical re-invention, primarily because of the lack of control over the production system," says Andrew.

Access to coastal sea-space was also becoming increasingly difficult, and that helped prompt a shift in thinking from sea-based farming to land-based alternatives.

"Five years ago no one would have said 'let's do it on land'.

"But the evolution in almost any production system – including aquaculture – is to give the farmer more control while minimising adverse effects, both on the environment and the stock being farmed."

He says this is particularly important today, with increasing climate variability and growing consumer demand for products with verifiable environmental credentials.

"These evolving external drivers, when combined with technology advances, led us to thinking about taking kingfish from egg to market in a land-based recirculating system."

A very big aquarium

A recirculating aquaculture system is a lot like an aquarium – just on a bigger scale. Between 95% and 99% of the water circulating in the system is treated and reused.

The reduction in water needed by recirculating systems brings many advantages: it allows the water to be filtered and temperature-regulated to exclude diseases and parasites and optimise growth rates.

Auckland chef Cameron Knox with his award-winning Ruakaka kingfish sashimi dish – a highly popular delicacy at his Mt Eden eatery, Xoong. (*Stuart Mackay*)

> **“We concentrated on research at scale and overcoming the hurdles to commercial uptake”**
>
> Dr Bryce Cooper

The water being discharged can also be treated to reduce environmental impacts – a key advantage over sea-cage farming.

The end results are impressive.

Andrew says the team can now order 20 million eggs in six months' time and know exactly how many fish to put in a tank to get them. They also know what light pattern to use and the amount and type of feed to add so they can collect the eggs on the day they specify.

For a commercial aquaculture operation, that kind of certainty is gold.

Market demand

Andrew says while aquaculture has been expanding around the world to meet demand, the high-value, premium end of the market has been growing even more rapidly.

“Amberjacks, including our yellowtail kingfish, are globally popular fish in both western and Asian cuisine. Consumers also recognise the superior culinary attributes of the farmed product.”

“We've conducted product surveys with international chefs which confirm that Ruakaka kingfish is a premium product and in demand.

Demand – and brand recognition – is also growing locally. Ruakaka kingfish currently goes to restaurants in Auckland, Wellington, Tekapo and Queenstown via Leigh Fisheries.

At the Taste of Auckland event in 2018 a dish of Ruakaka kingfish tartare, created by chef Cameron Knox of Mount Eden eatery Xoong, received the Best in Taste award.

Last year he followed that with a silver award in the Best Dish category.

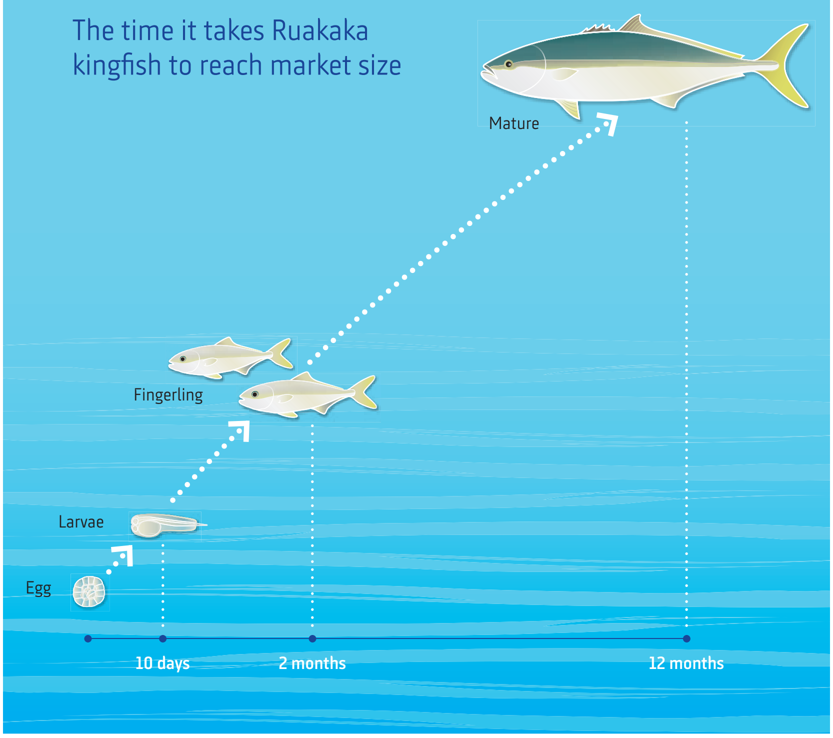
Cameron is effusive about the product, saying its rich creaminess is something not present in wild kingfish.

“It's incredibly versatile – you can serve it as sashimi, roast it, poach it, whatever you like. It's super sweet with flavour, but maintains its delicacy. In my opinion, it's the best fish in the country, hands down.”

Yellowtail kingfish (*Seriola lalandi*)

- Yellowtail kingfish/haku are highly fertile and fast growing.
- They first spawn after three years, becoming good breeders two years later.
- Each female releases hundreds of thousands of eggs into the water and these are inseminated by multiple males. Spawning happens between December and March, but can be manipulated.
- At Ruakaka, where kingfish are farmed in a recirculating aquaculture system, the fertilised eggs are collected once they float to the surface of the tank. They are quality checked, disinfected and incubated.
- Eggs hatch after two days and larvae are transferred to a nursery area four days later.
- The developing larvae are initially fed tiny aquatic animals. After about three weeks they move to a special formulated diet.
- The fingerlings are separated as they mature and transferred into larger tanks.
- Individuals grow rapidly, weighing between 2.5kg and 4kg after a year, when they are ready to be harvested for market.
- A small proportion are selected for future breeding. These fish are put on a broodstock diet, breeding three to four years later.

The time it takes Ruakaka kingfish to reach market size



> **“All the feedback continues to tell us this is an exciting economic opportunity for the country”**
>
> Dr Andrew Forsythe

Opportunity

Expansion plans at Ruakaka are designed to show investors that there is an opportunity to develop a land-based kingfish industry in New Zealand, as well as the technology to develop land-based aquaculture of other species.

“All the feedback continues to tell us this is an exciting economic opportunity for the country,” says Andrew.

“The proliferation of Japanese cuisine has changed our perception of good quality seafood all over the world, and although we’re not targeting Japanese cuisine specifically, this is hugely significant.”

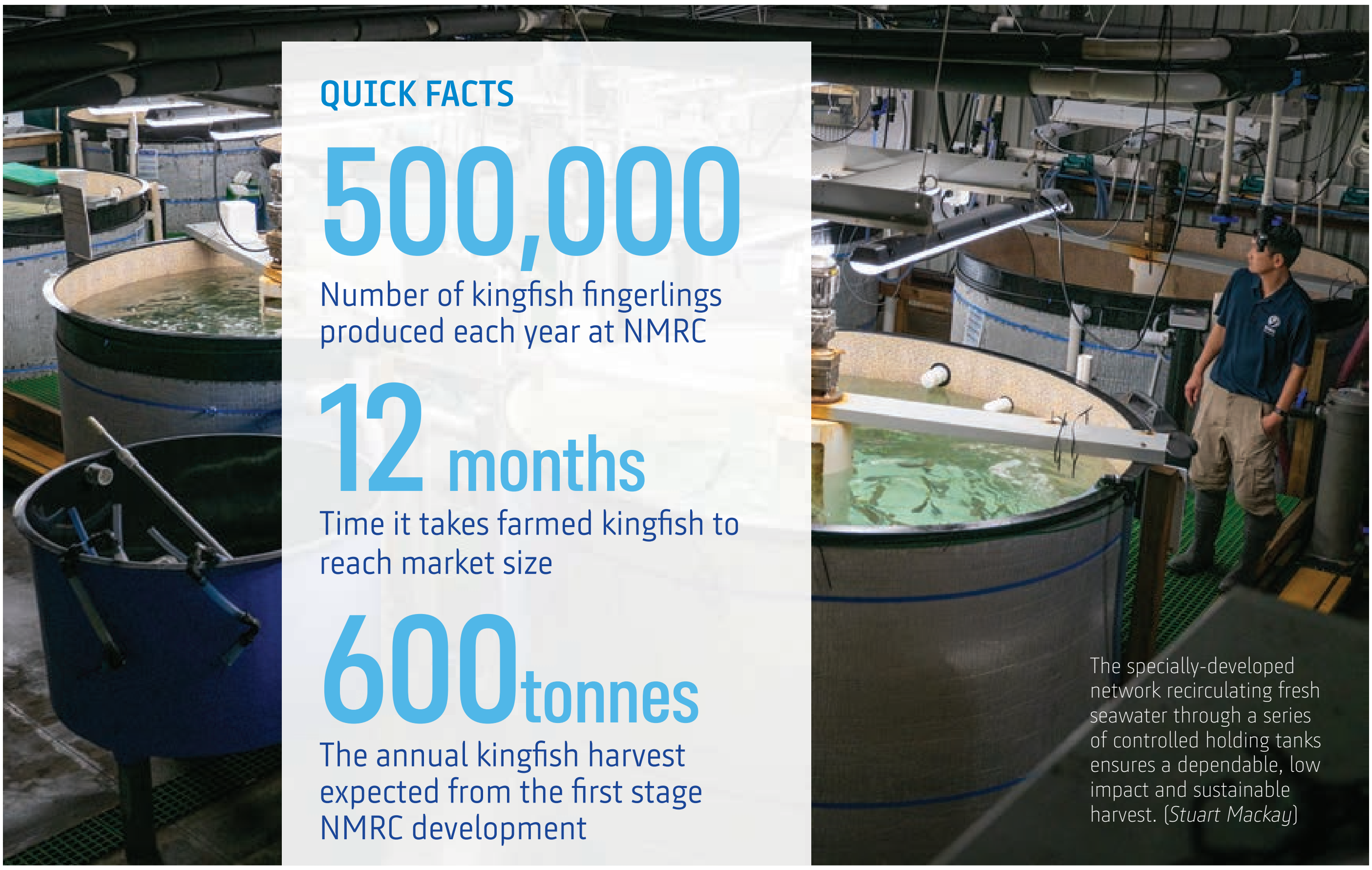
It’s hugely significant for Northland too, a region that has a long history of economic struggle. Anchoring production at Ruakaka will not only generate local jobs, but also filter opportunity into a range of other regional businesses that will be required to service the facility.

Equally importantly, it’s a model which can be adopted in other locations and with other species, creating wider regional growth opportunities for Northland and elsewhere.

Bryce acknowledges that building a successful land-based aquaculture operation has been a long haul, but he’s very enthusiastic about what lies ahead.

“None of this would have been possible without the foresight of our directors over the years and the continued support by MBIE, Northland Regional Council and many others.

“It’s about having the courage to invest and seeing the longer game.”



QUICK FACTS

500,000
Number of kingfish fingerlings produced each year at NMRC

12 months
Time it takes farmed kingfish to reach market size

600tonnes
The annual kingfish harvest expected from the first stage NMRC development

The specially-developed network recirculating fresh seawater through a series of controlled holding tanks ensures a dependable, low impact and sustainable harvest. (*Stuart Mackay*)

Aquaculture technician Michael Exton packs a freshly harvested 4kg Ruakaka kingfish in ice, ready for dispatch to the chef. (*Stuart Mackay*)

Building pathways

It has been a whirlwind first six months for Ngāpera Keegan and Tekiteora Rolleston-Gabel, the first two young researchers in NIWA's newly established Māori Graduate Internship Programme.

Alex Fear caught up with them to check on their experiences so far.

Ngāpera Keegan

Iwi: Waikato-Maniapoto, Ngāti Porou, Ngāti Raukawa ki Te Kaokaoroa-o-Pātetere. Hapū: Ngāti Apakura

Ngāpera Keegan worked for two nights under the June full moon alongside Masters student Siobhan Nuri catching glass eels as they entered the Rangitāiki River mouth in the Bay of Plenty.

"We caught over 1400," explains Ngāpera.

"We identified all the glass eels to species under the microscope, measured and weighed a subsample of them and returned them to the river the next day. We also counted all other fish species, which included herring, smelt and even a recently hatched īnanga larva."

"This year's sampling was six weeks earlier than in 2019, and we weren't expecting to catch that many. We sat on the bank watching the moon rise on the second night, trying to work out why there were so many this time of the year. It was so cool to be part of that."

The interns work across NIWA for 12 months gaining, practical experience, building networks and developing a platform from which to consider a long-term research career. They gain experience in freshwater, marine and estuarine science, fisheries, aquaculture, climate change and hazards, social research and mātauranga Māori, while learning how to communicate effectively with Māori and work collaboratively across disciplines.

The internship has involved a diverse range of projects to date for the Bachelor of Sciences graduate. As well as field work, analysing samples and processing data, Ngāpera has created an educational booklet about īnanga as part of NIWA's taonga species series.

"I chose to do īnanga because it's an important species for inland tribes, so being from Waikato and Maniapoto, it's an important species to research for me," says Ngāpera.

"I am so grateful to have had this opportunity to experience all that I have so far. I want to tell everyone that if they get the chance to be part of this – do it."

NIWA Māori Graduate Internship Programme

NIWA, through its Māori Environmental Research team Te Kūwaha, is working in collaborative partnerships with Māori businesses, and whānau, hapū and iwi throughout Aotearoa, combining their skills in scientific enquiry with mātauranga Māori expertise, within the frame of tikanga Māori. Demand for this capability in Aotearoa–New Zealand, is growing, and the pathways for early career researchers are few, resulting in a scarcity of expertise.

NIWA's Māori Graduate Internship programme has been established to help address this growing need, while also supporting and creating visible pathways for the next generation of Māori researchers. The purpose of the programme is to encourage Māori science graduates to consider ongoing postgraduate study and Māori environmental research as a career pathway.

Tekiteora Rolleston-Gabel

Iwi: Tūhoe, Ngāti Kahu, Ngāi Te Rangi, Ngāti Awa

A double graduate in ecology and Te Reo Māori from the University of Waikato, Tekiteora Rolleston-Gabel says she is not just interested in the interactions between animals “but also people, places and the environment.”

“I’m amazed by the range of projects NIWA is involved in, and how they’re being implemented to support communities and their environmental aspirations.”

Tekiteora saw this in action on a recent trip to Umupuia marae to support a tuangi (cockle) survey. Ngāi Tai ki Tāmaki kaitiaki have been working with the Te Kūwaha team to develop a cultural assessment framework for their rohe moana. This draws on their cultural values, observations, monitoring and mātauranga, while also using some of the assessment tools in Nga Waihotanga Iho – NIWA’s estuarine monitoring toolbox.

“I got to see how Te Kūwaha supports this whanau-led process,” says Tekiteora.

“It was so exciting to be part of this. It made me wonder about how these tools may be applied to contribute to the environmental aspirations of my own hapū and iwi.”

Tekiteora says it’s the little, unexpected moments of discovery that have been the most memorable for her.

“Getting to experience those moments, and working with so many researchers in such diverse fields, has been such a great experience. It has reinforced my desire to go on with environmental science. This is where I want to be.”

Fresh thinking – new solutions

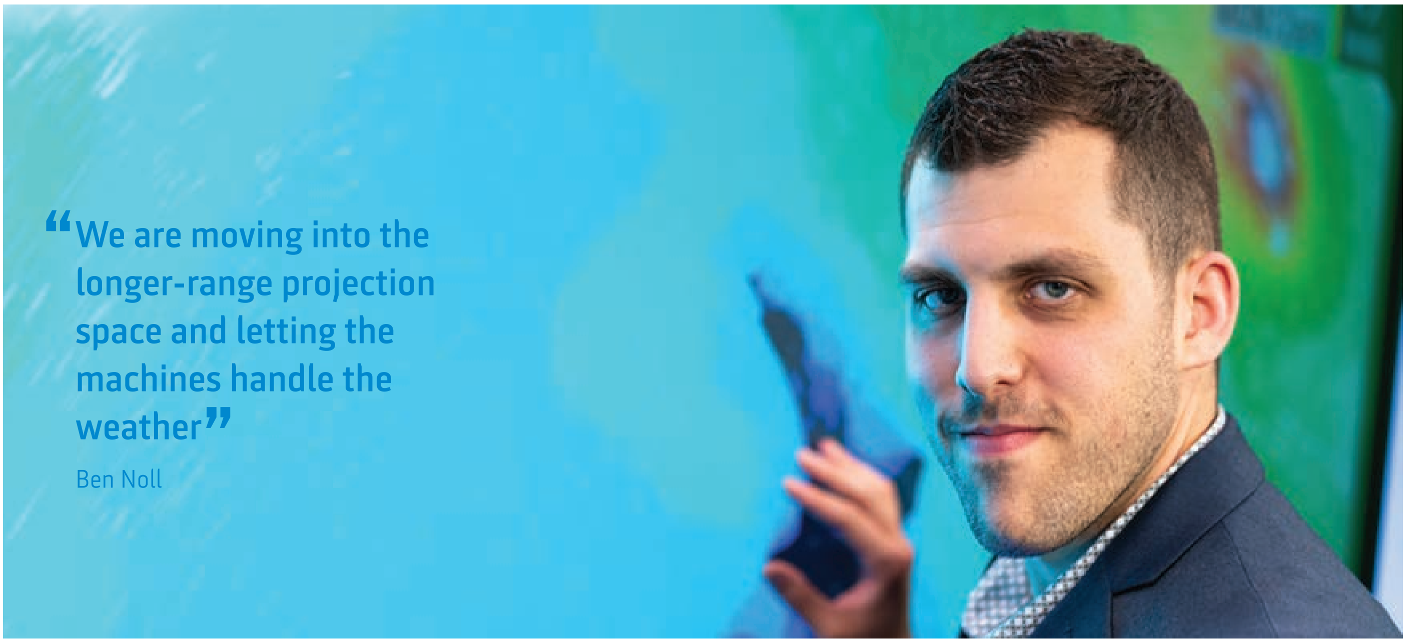
Getting tangled up in seaweed or using supercomputers to unravel climate change – NIWA scientists go to great lengths to find fresh answers.

Sam Fraser-Baxter talks to five researchers about their innovative projects and what difference their work may mean for New Zealand.

Marine biologist Dr Roberta D'Archino maps forests underwater. (*Rebekah Parsons-King*)

Climate is the new weather

Scientifically, says meteorologist Ben Noll, we have the weather sussed.



We know what causes it, where it comes from, how it forms, why it rains one day and is sunny the next. We also know what it's going to do tomorrow and the day after, and we can take a pretty good stab at what it'll do next week.

"We can give a really solid forecast that will be accurate for 28, 29 days of the month," says Ben.

So, job done then? Not quite. These days, at least for meteorologists, climate is the new weather. In other words, the focus has moved to using climate patterns to predict what the weather might do months – or more – into the future.

Think of it this way: in 2003 a five-day weather forecast was as good as a one-day forecast in 1953. Fast forward to 2020 and a five-day forecast is as good as a three-day one in 2003.

"This illustrates that the time horizon upon which we can make accurate forecasts has increased dramatically. Now we are moving into the longer-range projection space and letting the machines handle the weather."

For NIWA, one example of this is extending the utility of the New Zealand Drought Index (NZDI). This sits on NIWA's website and is a climate data-based indicator of drought. It is presented as a map, updated daily, and has five categories: dry, very dry, extremely dry, drought and severe drought.

For a snapshot of how New Zealand is faring in prolonged dry spells it is an extremely useful tool.

"But what if we can create a forecast of the NZDI? We have talked about using the information we have to forecast where that drought will occur over an entire season," says Ben.

NIWA is also working with Emirates Team New Zealand as it counts down to the next America's Cup. NIWA uses its supercomputers to run weather models at higher resolutions than ever before. The forecasts are so detailed, says Noll, you can see the wind bending around tiny islands in the Hauraki Gulf.

"These models help us understand the atmospheric and sea state better than ever, and to see Emirates applying and using our model is really exciting."

The supercomputers also run what are known as "ensembles", in which weather models are processed 18 times, and the differences between them analysed to better understand the potential for hazards and extremes.

Work is also ongoing to combine seasonal forecasting modelling with machine learning to identify weather extremes over a given season, with the aim to forecast how many days might exceed 30 degrees or have more than 25 mm of rain, and much more.

You might even say – as Ben does – that the future looks bright for forecasting.

Trawling to order

Marine ecologist Dr Emma Jones and fisherman Karl Warr share the same goal.

Dr Emma Jones

Both look forward to the day when Karl can offer his customers an underwater online shopping experience; the customer orders what they want each day, and Karl only catches what is ordered.

It's a reality that Emma believes isn't too far off.

"Because so many of the world's fisheries are overfished, a highly targeted approach to fishing is the way forward."

Emma has been working with Karl on targeted fishing systems for the past four years. Karl had already taken some novel steps on his own Hawke's Bay-based boat towards reducing bycatch – the undersized or non-target species that must either be thrown back or landed, with penalty costs incurred.

The mesh sizes on a standard, fibre-based cod-end at the end of a trawl net close up as the net is pulled in. This tends to cram the catch – large or small – together at the back. But Karl now uses a sturdy, metal cage at the end of his trawl net, enabling small fish to more easily escape through the rigid openings.

He avoids undersized specimens and because the fish he does land are in better condition, restaurants around the country are willing to pay top-dollar for Karl's sustainable catch.

A study by Emma demonstrated that Karl's cage cod-end reduced unwanted bycatch by up to 80%. But Karl was already thinking of how to go further.

Emma says that Karl referred to his cage as "the analogue version."

"A digital version would be something that had 'eyes in the trawl', providing real-time knowledge of what's going into your net and being able to make decisions about what you keep and what you don't."

At the time, Emma was aware of projects using underwater cameras and artificial intelligence to automate fish identification. If those technologies could be used in a scientific study, why not on a commercial fishing boat?

The pair have been working on prototypes over the last few years.

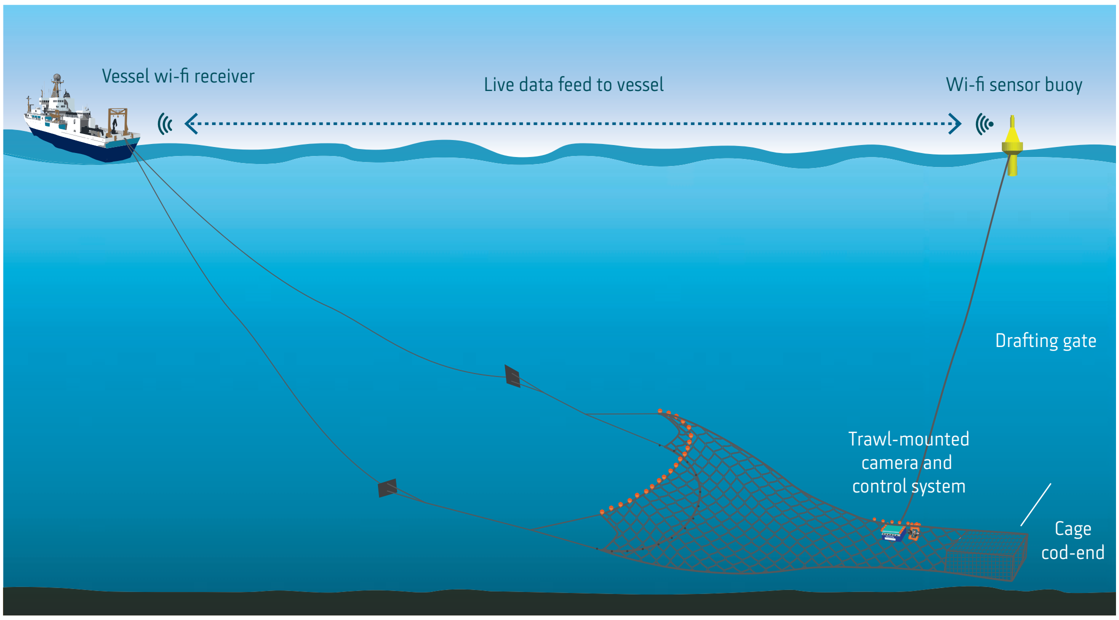
Cameras attached to the trawl film fish entering the net. Onboard, an operator watches the video and chooses when to open the gate, determining which fish are retained in the net and which fish aren't, similar in concept to the drafting of sheep.

In the future, Emma says the process of identifying, measuring and selecting fish for retention will be automated by artificial intelligence.

While the technology is still being developed, Emma believes it has the potential to enhance the economic and environmental future of fishing industries worldwide.

Asked if the technology could lead to the fishing industry's holy grail of eliminating bycatch, Emma is unequivocal.

"Yes. Absolutely."



Cameras and control systems mounted on the trawl net enable fishing operators to control the net entrance and avoid unwanted bycatch. (*NIWA*)

A river runs through it

At 5.45pm on 27 March 2019, a state of emergency was declared in Westland.

Hydrological forecaster Dr Céline Cattoën-Gilbert. (*Simon Hayes*)

A prodigious front had descended on the South Island's West Coast, bringing record rainfall.

Swollen rivers burst their banks and just hours later floodwaters washed away the Waiho bridge – severing the only road running through south Westland.

The rainfall was a sobering reminder of the threat posed by climate change. New Zealand is expected to experience more frequent and more intense rainfall events in future.

So, when the rain comes, where does it go? And when does it go there?

Dr Céline Cattoën-Gilbert is working to answer these questions. She is a hydrological forecasting scientist developing New Zealand's first national-scale river flow forecasting system.

The tool will provide hourly river flow forecasts, 48 hours in advance, for more than 60,000 rivers across New Zealand.

Céline will be the first person to tell you that she and her team are standing on the shoulders of giants. The project has been "a long-term NIWA vision" and is built on mind-boggling amounts of science and environmental data collected by others over decades.

The system couples the skills of NIWA's weather forecasting experts with the capabilities of its hydrological researchers – scientists focused on understanding how water moves through New Zealand.

"The weather model gives you precipitation for particular areas, and then the hydrological model tells you how the water travels through a catchment and a river," says Céline.

The information is then fed into the supercomputers at NIWA's High Performance Computing Facility to generate detailed flow forecasts.

Céline sees the results as a key tool to help New Zealanders better prepare for flooding events – the most frequent and costly natural disaster in the country.

Céline and her team have been working closely with local authorities and others to co-design and improve the forecasts. Céline says the system complements local models by providing insights into rivers and catchments that councils don't closely monitor.

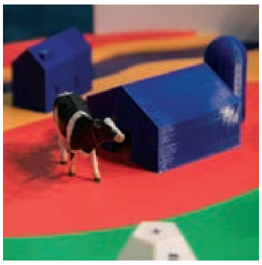
This wider overview of the way different rivers respond to rainfall events is designed to enable councils to better target civil defence responses.

The project won't just help forecast floods. Farmers would be better placed to predict if, and when, rivers may start to run dry. It could also be used to help warn weekend trampers, hunters and anglers about the threat of rapidly rising rivers.

While the future is looking wetter and wilder, we won't necessarily have to turn to Noah's Ark. When the rains come, Céline's river flow forecasts should help us weather the storm.

Game changer

When most people think of a science research institute, they think of scientists measuring, monitoring, calculating and comparing.



All of that is true, but the usefulness of science is also determined by whether people actually take the information learned and apply it in a way that will enhance their lives.

That is why NIWA's team of social scientists plays such a vital role across its research disciplines. They anchor people at the centre of the science, focusing on how they see and understand the world and what influences their decision making.

For Dr Paula Blackett it's one of the most exciting spaces to work in. "We bring to NIWA the importance of people and places, what they value and why and how values will impact their decisions."

The significance of those values has never been more starkly obvious than with the different individual responses to Covid-19.

"It's a classic example – everyone was roughly getting the same information, but their responses were completely different, and that is due to the weighing up of values. It also proves that providing information on its own and expecting people to act in a particular manner is a complete fallacy – it just doesn't work like that."

Blackett particularly enjoys working in the field of climate change adaptation. Alongside the engineers, climate scientists and council planners who deliver the facts, she will work with a community to enable them to find the best way forward.

One practical way to help communities through this process is use of the "serious games" Blackett and her team have developed.

Whether played at the table or online, these games enable players to literally roll the dice on their climate futures – wrestling with all the risks that entails. The games are highly effective in encouraging individuals or groups to understand what their options are, the sequence in which decisions are likely to be made and what they need to do to make their choices occur.

"The games are designed to hammer home that risks can be immediate, but they also catalyse people to think about things more deeply, and give them experience of making decisions under uncertainty.

"Really what we're trying to do is to get adaptation and change that will help people to have a livelihood and a happy life, as our climate continues to change."

Putting people at the heart of the climate science.

Dr Paula Blackett uses a NIWA Serious Game to highlight the challenges of managing a dairy farm through climate change. (*NIWA*)

Tangled up in blue

It was love at first sight.

Roberta D'Archino was 18 years old when she discovered the beauty of seaweed for the first time. She was scuba diving off the Tuscany coast in Italy in 10m of crystal-clear water.

"It was my first dive and I thought I would be interested in fish and invertebrates, but when I saw the red patch of seaweed, I stopped. The instructor had to move me away. Nobody could tell me what the seaweed was, so I was really intrigued."

Roberta is now Dr Roberta D'Archino, and the marine algae specialist is still very much intrigued. She has worked at NIWA for 14 years and says we have a lot to learn about our seaweed.

"We know we have more than 1000 species in New Zealand, and many species are still undescribed. Every time I go scuba diving I come back with something new."

She knows one thing for certain, however – seaweed looks set to play an increasingly important role in New Zealand's future.

Marine ecosystems need seaweeds. They protect coastal habitats from the impact of waves. They allow biodiversity to flourish, providing shelter and food for other marine inhabitants, such as fish, pāua and lobsters.

But seaweeds also deliver crucial services to those living above the water. As well as a growing list of nutritional and medicinal products, seaweeds produce oxygen, absorb nitrogen and, significantly, fix carbon. They may even help mitigate the amount of methane livestock produce.

So how do we gauge the size of the potential carbon sinks stretching along our coastline? And are New Zealand's seaweed stocks in a state of growth or in decline?

Scuba divers working their way through kelp beds to ground truth images derived from satellites or drones make slow progress in answering these questions.

Thankfully, Roberta and her colleagues have devised a clever alternative. It involves towing a video camera behind a boat and using a computer – and a specially-developed artificial intelligence (AI) programme – to analyse the resulting video back in the lab.

AI is not only cost effective, it is up to 75 times faster than a human can operate and unerringly accurate.

"It can identify the three common species of brown algae along the Wellington coast with more than 90% accuracy."

It is a big step towards surveying our seaweed resource at scale and setting up the frameworks needed to enhance our "blue carbon" potential.

Equally important for the woman intrigued by all things seaweed, it is a tool that should help New Zealand's seaweed forests flourish for generations to come.

Dr Roberta D'Archino combines cameras and computers to survey seaweed stocks along coastal shorelines. (*Rebekah Parsons-King*)

A cold day in the office

Five specialist NIWA divers were left 'gasping' during their recent plunge under the ice near Scott Base.

The researchers were working with Antarctica New Zealand to set up experiments and equipment to monitor coastal currents and the marine environment.

Full dry suits are mandatory in such icy waters, and you know it's a cold day at work when your dive mouthpiece sticks to your lips.

But it wasn't the cold that really took their breath away – the team say it was the clarity of the water and the rich diversity of marine life under the Antarctic ice.

Photography Peter Marriott

More than 20m under the ice, a large orange sea spider negotiates the delicate thecate hydroid branches attached to a sea squirt (*Cnemidocarpa verrucosa*). The sea squirt's open siphon filters plankton and bacteria from the rich Antarctic waters.

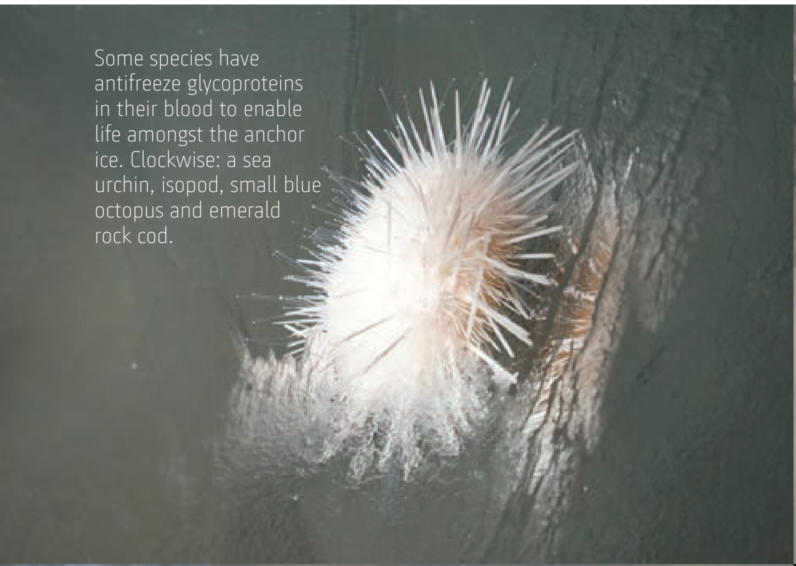
Part of the mission was to investigate the strength and direction of underwater currents near Scott Base. This Acoustic Doppler Current Profiler was one of two deployed under the sea ice.

Scientific dive specialist David Bremner descends through a 2m thick hole in the ice to begin work. Water temperatures of below minus 1°C cause plate-like ice crystals – known as anchor ice – to form along the seabed.

A delicate spiral egg case – probably deposited by a nudibranch – decorates the outer coating of a large sea squirt. Brittle stars, sponges, soft corals and bryozoans dominate the background.

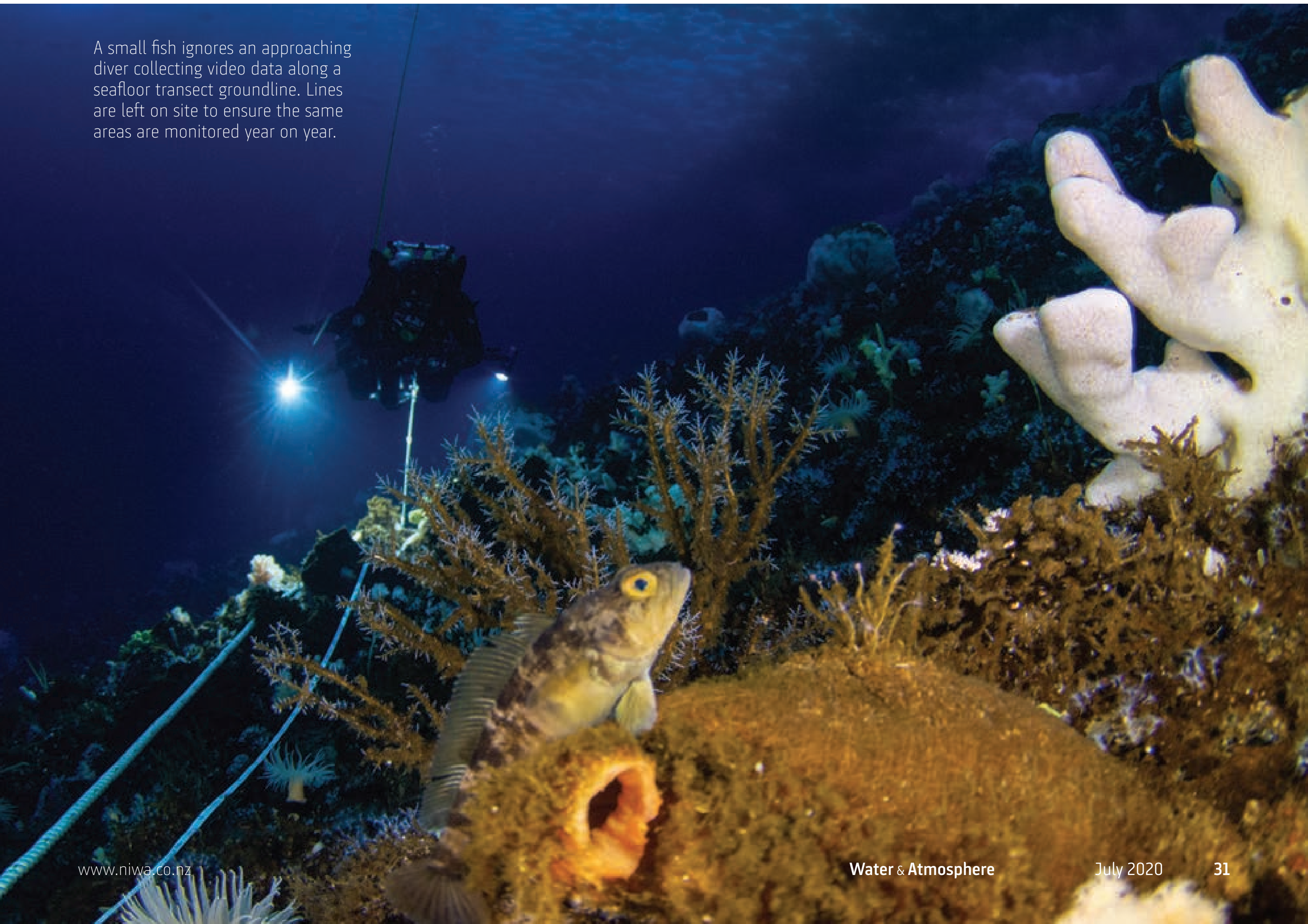
Sitting on the sea floor 12m below, this 0.5m tall sponge (*Rossella racovitzae*) is fully encased by anchor ice, yet the aperture which expels filtered water remains free.

Antarctic creatures often provide vital habitat for others. This large spiky sponge (*Rosella racovitzae*) is both a platform for a hitchhiking 1m ribbon worm and a hiding place for fish.



Some species have antifreeze glycoproteins in their blood to enable life amongst the anchor ice. Clockwise: a sea urchin, isopod, small blue octopus and emerald rock cod.

Dark patches of algae grow on the sea ice above. Algae are an important food source for seafloor dwellers such as these anemomes, finger-like "bush" sponges and fan worm polychaetes.



A small fish ignores an approaching diver collecting video data along a seafloor transect groundline. Lines are left on site to ensure the same areas are monitored year on year.

Tracking our ocean wanderers

Albatrosses may be masters of the skies, but they are surprisingly vulnerable on the water.

Campbell Gardiner talks to two scientists working to keep these magnificent seabirds airborne.

Susi Woelz

Salvin's albatross in flight – Salvin's are one of the most common albatross species accidentally caught by fishing fleets. (*Peter Marriott*)

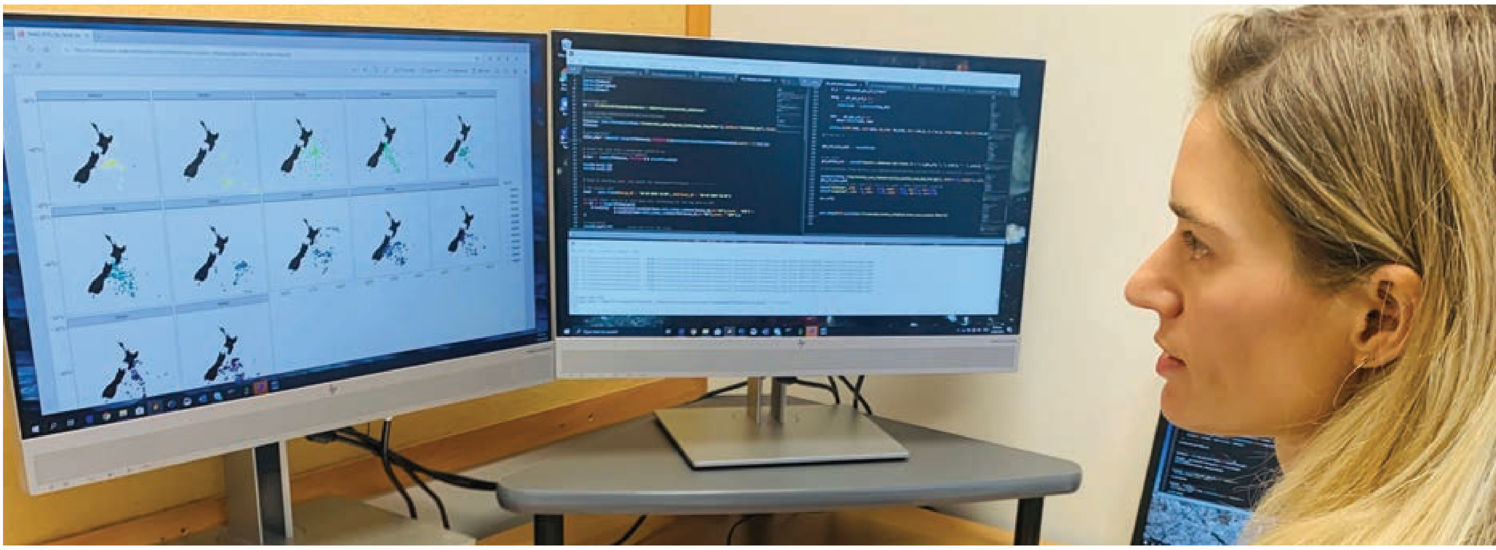
A Salvin's albatross lifts slowly away from the barren Bounty Islands south east of New Zealand.

It harvests the raw energy of the Southern Ocean winds on the start of its marathon journey towards the west coast of South America – more than 9,000km away.

As it sweeps in shallow arcs across the waves, a GPS tag taped to its back pings its location to a satellite above.

Moments later the Salvin's position reaches NIWA marine ecologist Dr Dana Briscoe. Dana is more than 800km to the west in her Nelson office and she is modelling the bird's prospects of survival.

The albatross doesn't know it, but it is at the centre of a cutting-edge conservation programme that is matching state-of-the-art software with global wildlife tracking techniques.



Dr Dana Briscoe uses geo-location data from albatross and fishing fleet activity to pinpoint potential mortality hotspots. (*NIWA*)

> **“… a good south wind sprung up behind,**
> **the Albatross did follow**
> **and every day for food or play,**
> **came to the mariner’s hollo!”**
>
> The Rime of the Ancient Mariner

Fatal attraction

Mapping the path of ocean wanderers like this Salvin’s albatrosss is no mean feat. But thanks to the efforts of researchers like Dana and her NIWA colleague Dr David Thompson, we’re learning more about the lives of these commanding creatures – where they fly, forage and feed.

It’s vital information because albatrosses are a study in contrasts. For all their strength, stamina and ability to fly thousands of kilometres over vast stretches of open ocean, these largest of seabirds are highly vulnerable to fatal encounters with commercial fishing vessels.

“...a good south wind sprung up behind,
the Albatross did follow
and every day for food or play,
came to the mariner’s hollo!”

– The Rime of the Ancient Mariner

So wrote Samuel Taylor Coleridge, almost 200 years ago. It’s the same old story today, and often with equally tragic results. Lured by the prospect of an easy meal, hundreds of birds are killed or maimed each year, accidentally hooked up on longlines or caught in incoming trawl nets.

Over the years, NIWA has tagged and tracked the year-round movements of many species of albatrosses, including white-capped, Buller’s, Salvin’s, northern and southern royals.

A new dataset, currently being assembled for the Department of Conservation (DOC), focuses on Salvin’s and Buller’s. The hope is that, over time, deeper insights can be gleaned into where they overlap in space and time with fishing fleets.

It’s valuable information that can be used to inform fisheries management and encourage seabird-safe fishing techniques, such as weighted longlines, that quickly pull hooks toward the seafloor, and coloured bird-scaring lines.

Tag and track

Helping save New Zealand’s 17 species of albatrosses from such deadly run-ins starts with knowing more about their sweeping sojourns. Enter tagging, tracking, GPS and geo-location.

Tagging albatrosses is surprisingly simple – it’s getting to them during nesting season that’s the challenge. Many New Zealand albatrosses breed only on our rugged southern islands, exposed to the full fury of the Southern Ocean.

Dr David Thompson attaching a geo-location tag to an albatross on the Campbell Islands. The tags are robust and economical, but must be physically retrieved to access information. (*Paul Sagar*)

Buller’s albatross, for instance, nest exclusively on Solander Island in Foveaux Strait and the remote Snares. Campbell albatross reproduce on its namesake – an ancient volcanic island with steep coastal cliffs some 600km south of Stewart Island.

For Wellington-based seabird ecologist David Thompson, getting close to the birds for tagging often means long voyages in huge seas with his head near a sick bag. Once on land, however, the tagging process itself is comparatively easy because albatrosses nest just metres apart.

“We walk up to them when they’re incubating or looking after their small chicks and lift them off their nests. They resist, but don’t run away. It’s a two-person job. One person lifts the bird, the other attaches the tag.”

On a recent trip to The Snares, David and fellow researchers took just two and a half hours to tag 50 Buller’s albatross.

Tag technology has developed in leaps and bounds since the late 1980s. Back then, tags were large and cumbersome. The new generation is smaller, faster and less power hungry. That’s important, because most albatross species migrate away from New Zealand – spending months travelling the globe. The units need to go the distance.

> **“All albatross species are at risk of being entangled in fishing gear”**
>
> Dr David Thompson

These days, NIWA’s tagging armoury consists of GPS and retrievable geo-location tags. Attached with waterproof tape to an albatross’s back feathers, GPS tags are expensive, but can deliver real-time data every day, hour or minute. Transmitting the information via satellites, they enable researchers to track flight paths with pinpoint accuracy.

Geo-location tags aren’t as accurate and must be physically retrieved to access the data. But they are robust, can deliver large amounts of information and are considerably cheaper.

Attached with cable ties to a metal band on the bird’s leg, the tags feature a clock, light sensor, memory and battery. By recording light levels, they can register and record a bird’s latitude and longitude.

“These tags will last for years on a bird if you’re able to deploy them for that length of time and then retrieve the tag. They calculate two locations for the bird every day – one at midday; one at midnight.”

The number of albatrosses tagged and tracked by NIWA at any given time varies. Usually, there are about 50 birds fitted with geo-location tags and 20 with GPS tags.

Crunching the data

Back in Nelson, Dana Briscoe opens the software development package R and navigates hundreds of rows of tracking data. R is heavily used in the scientific community for computing and graphically representing statistical data. Clicking into a map plot, she can see where the GPS-tagged Salvin’s has been flying, and gets an inkling of where it may be heading.

The idea behind this DOC-funded project is to understand the movements and at-sea distribution of tagged Salvin’s leaving their breeding site on the Bounty Islands.

Dana says there are high rates of bycatch in this population.

“We’re aiming to use the tag data to get a better sense of where they’re spending their time in New Zealand’s Exclusive Economic Zone, and what sort of fisheries overlap there is.”

Seabird tracking can result in formidably large datasets. The beauty of using R is that raw data can be efficiently batch-processed without manual

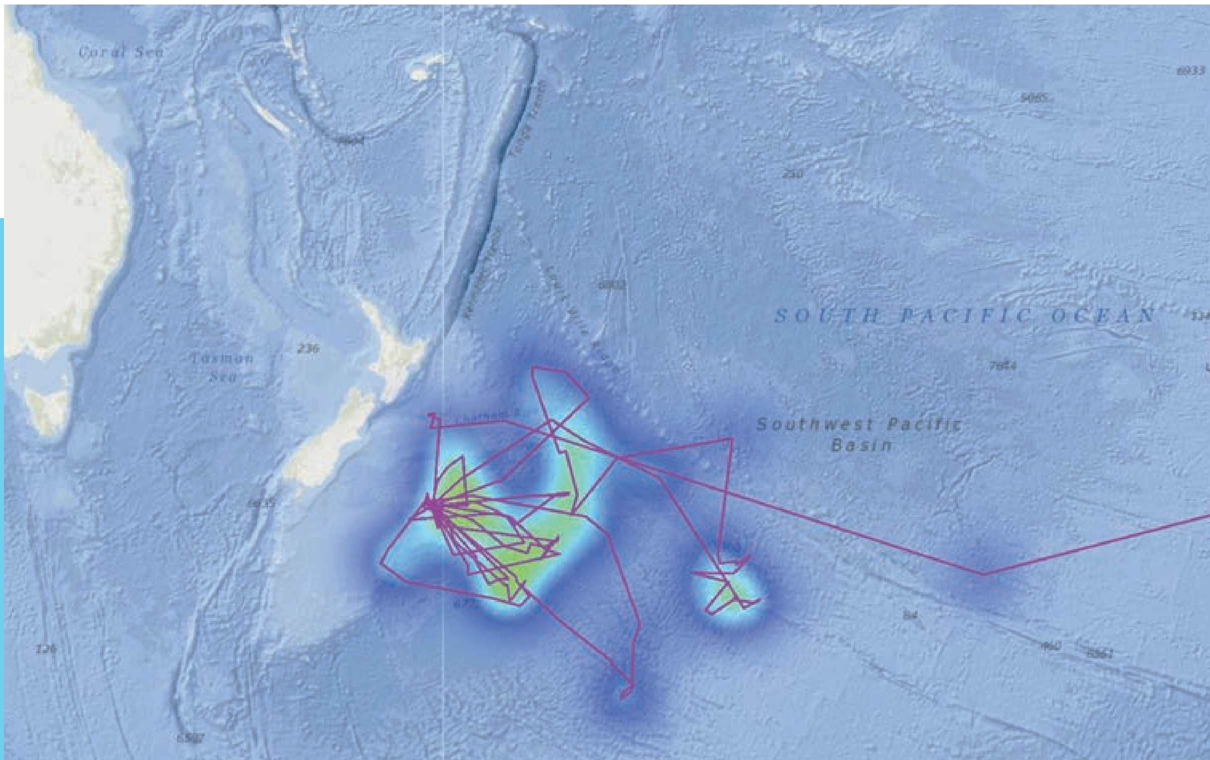
QUICK FACTS

17

species of albatross live in New Zealand

3.5m

The wingspan of a wandering albatross



intervention, she says. That takes up-front scripting smarts.

Different kinds of environmental information, such as bathymetry, can be imported into the models. Some species of albatross are known to react strongly to bathymetry, feeding only in deep waters also frequented by commercial fishers.

Vessel location data can be included to identify fishing overlap hotspots or opportunities for separation. It's early days, but the research team want to compare hotspots for individual Salvin's. Dana says they're especially interested in seasonal flight trends, types of fisheries interacted with and the gear the fishing vessels are using.

The team also wants to compare tag types.

"Geo-location tags provide fewer daily fixes compared with GPS tags, but we get more long-term information and they're cheaper. We're wanting to identify what combination of tags, from a modelling and cost perspective, gives us the optimum amount of information," she says.

This tagged Salvin's albatross clocked up more than 49,000km over the course of its six month journey from the Bounty Islands to Peru.

Onwards and upwards

All albatross species are at risk from being entangled in fishing gear. But there are nuanced differences, says David Thompson.

"If an albatross population, for example, is very small, then extra mortality from behind fishing boats makes a difference. If the population is very large, then that mortality doesn't make much difference at all."

Statistical modelling work done by Dana and colleagues will identify – and quantify – which New Zealand albatross species are at greatest risk.

But the threats from fishing vessels do not stop at New Zealand's territorial limits, and the team's work is shared by DOC and MPI with their counterparts in Chile and Peru as part of international efforts to protect the birds.

Modelling longer-term tracking and environmental data could also be used to examine how the albatrosses might fare under the influence of climate change and events like El Niño and marine heatwaves.

The future of New Zealand's albatross species hangs in the balance. But with the support of NIWA's technology, tagging and risk assessment methodologies, New Zealand's efforts to limit fishing bycatch are world leading.

Encouraging signs to support these magnificent seabirds on a smooth glide path forward.

'JUST POPPING OUT'

White-capped albatrosses that breed on the Auckland Islands may fly to Tasmania just to find food. When they finish breeding, about 20% travel west across the Indian Ocean to South Africa and Namibia.

Sooty shearwaters repeatedly fly to the 60th parallel during their breeding season. That's deep into the Southern Ocean, where waves can reach 15m and wind speeds can top 145km/h.

The west coast of South America is a common destination for several species of New Zealand albatross. Buller's, for example, regularly travel to Chile and Peru.

If they're successful in raising a chick, biennial breeders like the northern and southern royal albatross will take a year off from breeding. It's not uncommon for them to circumnavigate the globe.

Rust coding

Campbell Gardiner explains how hundreds of lines of computer code generated each week are helping biosecurity authorities keep a close eye on a plant pathogen.

The fungal disease myrtle rust attacks a wide variety of plants in the myrtle family and spreads easily, particularly through windborne spores. Species at risk include natives such as pōhutukawa, rātā, mānuka and ramarama along with commercially valuable exotics such as eucalyptus and feijoa.

The disease has affected more than 350 myrtle species since its arrival in Australia in 2010 and was first detected on mainland New Zealand just over three years ago. It has never been successfully eradicated in any country and, despite early attempts to contain it here, it has quickly spread through the North Island and the top of the South.

To date, the native shrub ramarama appears most susceptible, but its full impact on other species is still unclear, and Ministry for Primary Industries (MPI) biosecurity teams are monitoring its progress closely.

This is where NIWA comes into play, because myrtle rust's powdery yellow spores travel large distances by wind, and the infection risk is very dependent on climate conditions.

Over the past three years NIWA researchers have combined climate forecasting capability with GIS (Geographic Information Systems) technology to produce weekly maps for MPI, showing myrtle rust infection, spore formation and latency period.

Each Monday, NIWA Wellington-based climate GIS technician Vijay Paul runs an automated script that generates the maps. Data for the maps comes from the NZCSM – an ultra-high-resolution weather prediction model powered by NIWA's supercomputers.

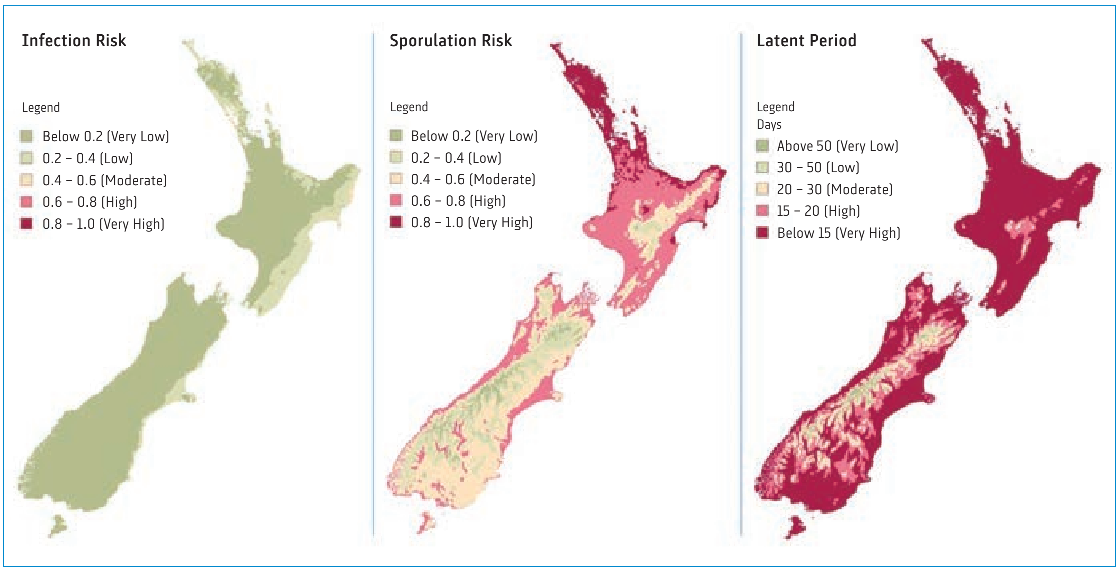
Initially Vijay was running his script manually and making the maps available to MPI through logins to a walled-off section of NIWA's GIS server. MPI then needed to take additional steps to embed the maps into their systems.

But after putting his head together with NIWA GIS data analyst Dr Tilmann Steinmetz, Vijay figured out a more interactive way to share the information. This involves using NIWA's ArcGIS Enterprise Portal and ArcGIS Online and means MPI now has online, interactive versions of the maps to help plot and predict the spread of the disease.

"My script publishes all the raster layers into the ArcGIS Portal. There's a group within the portal that is synced to ArcGIS Online, which itself has another group, including MPI staff. They automatically access the maps each Monday."

NIWA is contracted by Plant & Food Research to do the mapping work. It's part of a myrtle rust collaboration between Plant & Food, MPI and NIWA that last year picked up a NZ Bio-Protection Research Centre science award.

When myrtle rust was first detected here, NIWA also helped with aerial dispersal modelling – forecasting the trajectories of spores from Australia and modelling the spread within New Zealand.



Weekly interactive maps show biosecurity teams monitoring myrtle rust the infection and spore formation risk along with the disease's latency period. (*NIWA*)

(*Top*) Pōhutukawa is one of a number of native species at risk to the recently arrived plant pathogen myrtle rust. (*MPI*)

(*Left*) Myrtle rust symptoms developing on a ramarama in New Plymouth.

The shrub has been shown to be vulnerable to the imported disease, but impacts on other natives are still unclear. (*MPI*)

Back cover photo:

Young kingfish at NIWA's Northland Marine Research Centre at Ruakaka. (*Crispin Middleton*)