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Water & Atmosphere

DECEMBER 2023

Farming kingfish on land

Unlocking aquaculture opportunities

Water & Atmosphere

December 2023

Stuart Mackay

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NIWA
Taihoro Nukurangi

Cover: Premium harvest size kingfish, born and bred at NIWA's Northland Aquaculture Centre in Ruakākā, and destined for tables around the world. (*Stuart Mackay*)

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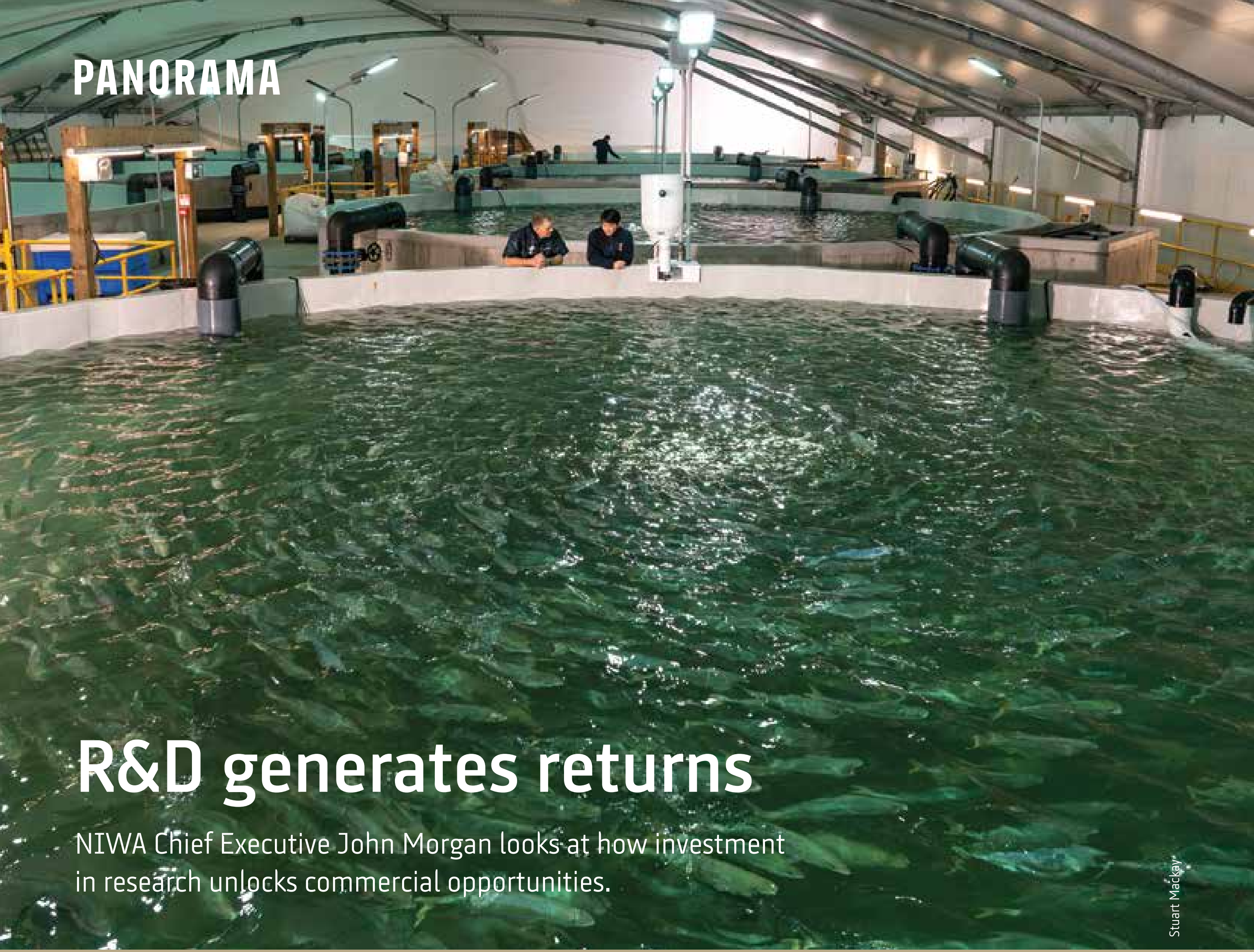


R&D generates returns

NIWA Chief Executive John Morgan looks at how investment in research unlocks commercial opportunities.

Stuart Mackay

> "Helping to grow a resilient seafood sector is a key focus for applying our research"
> John Morgan

The release earlier this year of tens of thousands of specially bred kingfish into eight 350,000 litre tanks at Ruakākā in Northland is a major milestone for New Zealand aquaculture.

It is also an excellent example of the power of applied science.

These kingfish were selectively bred, generation after generation, from wild-caught broodstock by NIWA fisheries experts at our Northland Aquaculture Centre. The fish reach harvest size of 3kg in our Recirculating Aquaculture System (RAS) – a unique facility designed to prove the viability of commercial-scale, on-land finfish production, the result of years of research and development at the centre.

Significantly, this is also the first new, high-value finfish species to be added to New Zealand's commercial aquaculture offering since farming salmon in sea cages took off in the 1980s.

The construction of the RAS facility was carried out in collaboration with Northland Regional Council, who recognise the potential of a new aquaculture industry based in the North.

NIWA is committed to using our science expertise to support the sustainable management and development of New Zealand's natural resources.

Helping to grow a resilient seafood sector is a key focus for applying our research.

The RAS is the culmination of a remarkable NIWA story. It started two decades ago with the search for new high-value species suitable for aquaculture, and it has evolved into the development of a sustainable, land-based fish farming system.

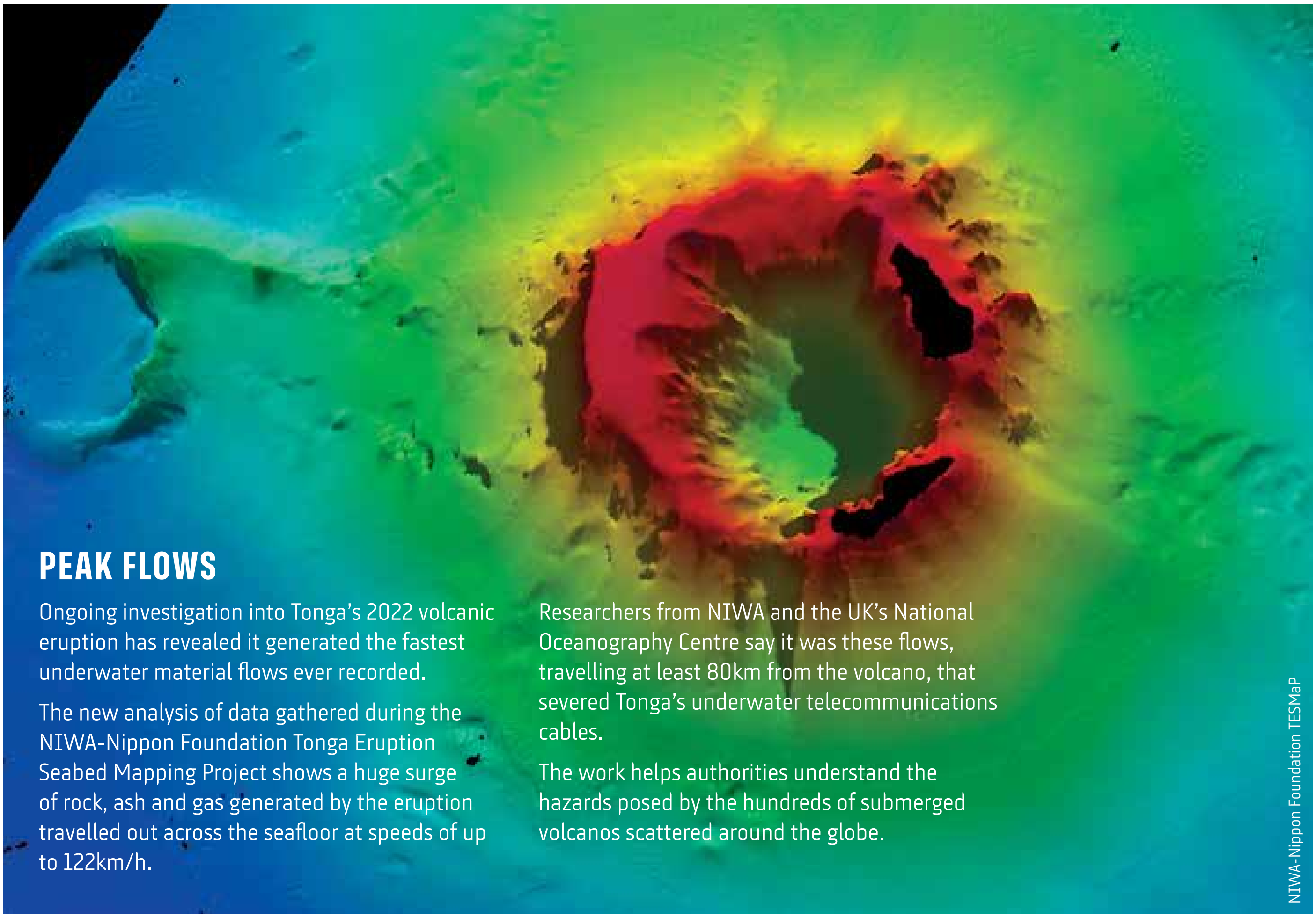
This long-term research investment is on track to deliver 600 tonnes of premium grade kingfish a year, with the potential to scale up production to 3,000 tonnes per annum.

The system is designed to be easily adapted for other species and other locations around New Zealand, and we have already developed the expertise and the broodstock needed to trial taking hāpuku to commercial production.

New Zealand aquaculture aims to turn the current $500 million industry into a $3 billion industry by 2035.

That is an ambitious target. What is clear, is that science will continue to play a vital role in accelerating the growth of aquaculture in New Zealand – unlocking employment and investment opportunities along the way.

NEWS BRIEFS



NIWA-Nippon Foundation TESMaP

PEAK FLOWS

Ongoing investigation into Tonga's 2022 volcanic eruption has revealed it generated the fastest underwater material flows ever recorded.

The new analysis of data gathered during the NIWA-Nippon Foundation Tonga Eruption Seabed Mapping Project shows a huge surge of rock, ash and gas generated by the eruption travelled out across the seafloor at speeds of up to 122km/h.

Researchers from NIWA and the UK's National Oceanography Centre say it was these flows, travelling at least 80km from the volcano, that severed Tonga's underwater telecommunications cables.

The work helps authorities understand the hazards posed by the hundreds of submerged volcanos scattered around the globe.

Evan Baddock

HIGH WATER

NIWA technicians have successfully developed and helped install new flood measurement systems for Fiji.

Like many island countries, Fiji is subject to intense rain events, but the accuracy of downstream flood warning systems is severely limited by the lack of back country river flow data.

To address this issue, NIWA staff recently travelled to Fiji to train local technicians in using water speed reading techniques to gauge rising flood flows.

They also worked with their Fijian colleagues to install automatic monitoring systems which use stereoscopic cameras to measure surface water speeds in remote hill country areas.

The project is funded by the World Meteorological Organization.

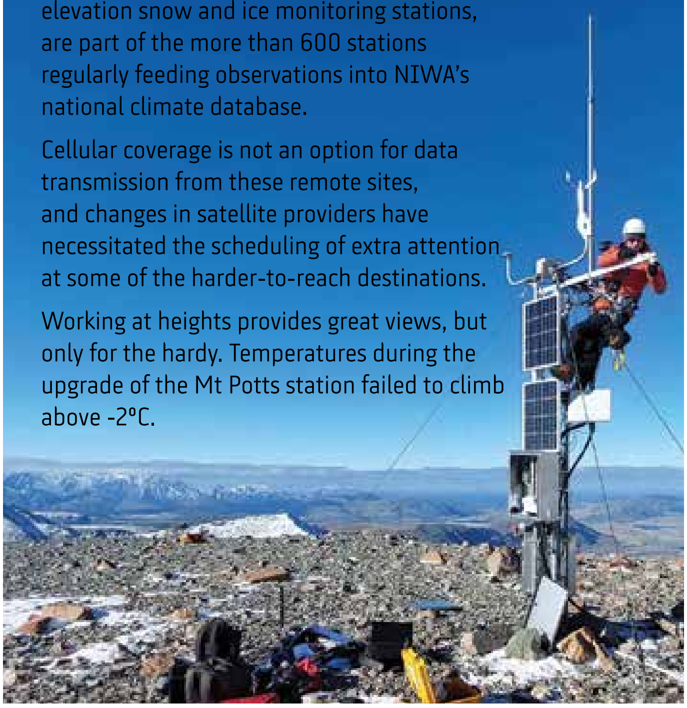
COLD CALLING

NIWA environmental technicians have had a busy year upgrading transmission facilities on about 70 remote weather stations.

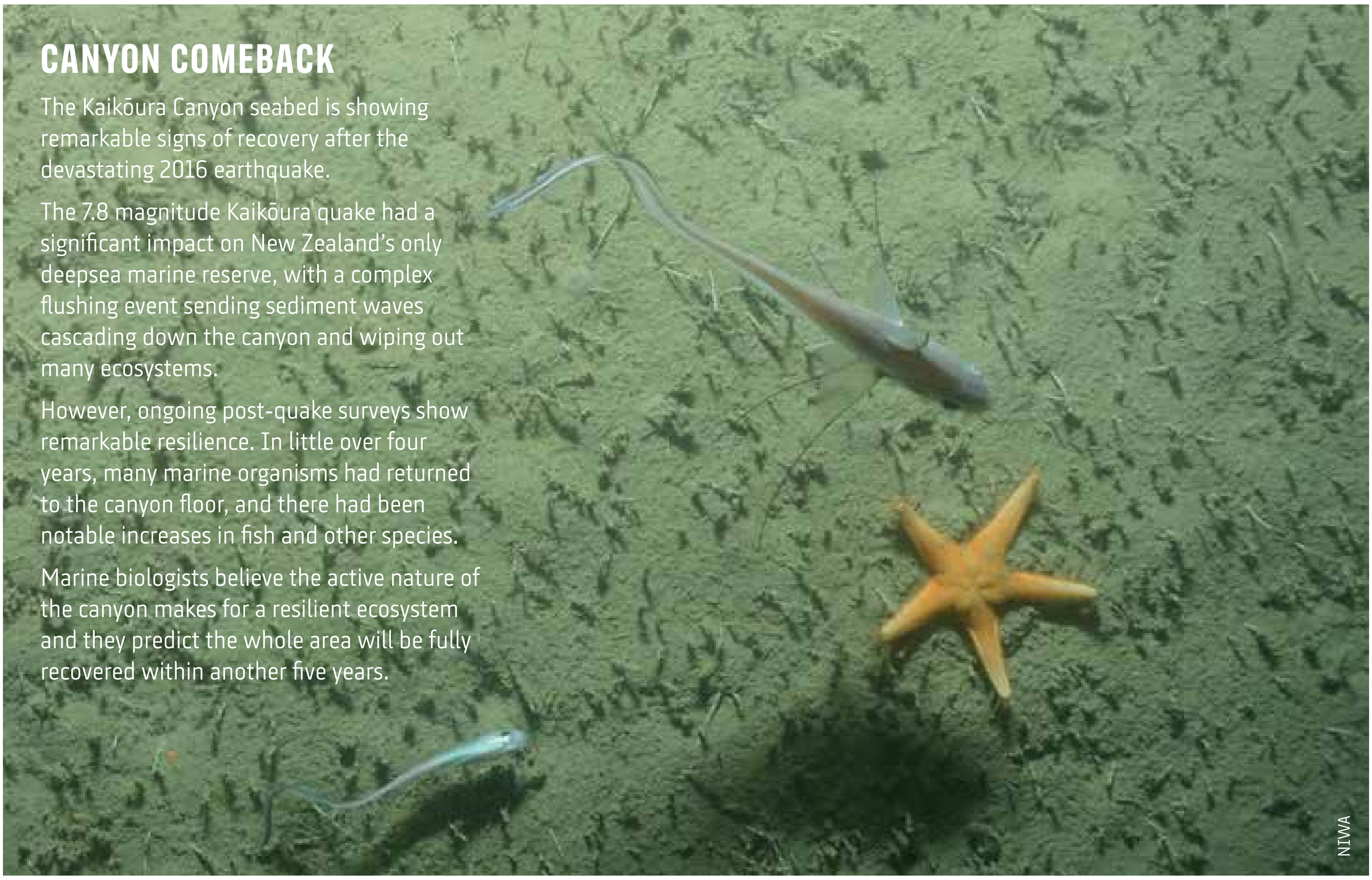
The facilities, including NIWA's 11 high-elevation snow and ice monitoring stations, are part of the more than 600 stations regularly feeding observations into NIWA's national climate database.

Cellular coverage is not an option for data transmission from these remote sites, and changes in satellite providers have necessitated the scheduling of extra attention at some of the harder-to-reach destinations.

Working at heights provides great views, but only for the hardy. Temperatures during the upgrade of the Mt Potts station failed to climb above -2°C.



Alec Dempster



NIWA

CANYON COMEBACK

The Kaikōura Canyon seabed is showing remarkable signs of recovery after the devastating 2016 earthquake.

The 7.8 magnitude Kaikōura quake had a significant impact on New Zealand's only deepsea marine reserve, with a complex flushing event sending sediment waves cascading down the canyon and wiping out many ecosystems.

However, ongoing post-quake surveys show remarkable resilience. In little over four years, many marine organisms had returned to the canyon floor, and there had been notable increases in fish and other species.

Marine biologists believe the active nature of the canyon makes for a resilient ecosystem and they predict the whole area will be fully recovered within another five years.

Lana Young

MUSSEL UP

Climate scientists have developed a new forecasting tool to help Marlborough's Pelorus Sound mussel farmers predict how much meat their farms will produce.

The region dominates New Zealand's mussel farm industry, which employs about 2,500 people and generates more than $200 million annually.

Climate and marine conditions strongly influence farm yield, and NIWA specialists have worked closely with the industry to pull together climate, marine and farm production information.

Using advanced data science, researchers have developed a web-based tool to enable farmers to forecast yield up to six months ahead.

The new tool will help farmers better plan industry productivity and harvest schedules.

SEA HORSES?

Fisheries scientists have solved a 10-year mystery surrounding the origins of cryptic markings found deep on the seafloor.

Researchers first noticed the horseshoe-shaped seabed imprints in 2013 when they were reviewing survey footage from the Chatham Rise.

The source of the deepsea 'hoof prints' remained a mystery until colleagues recently suggested the marks seemed shaped like the mouth of a rattail – a species of deepsea fish, also known as grenadier.

Overlaying rattail images on the markings revealed the imprints are most likely to be made by fish feeding on seafloor inhabitants.

As well as resolving a long-running puzzle, the discovery will help fisheries scientists pinpoint rattail feeding grounds.

NIWA

CLEAR PASSAGE

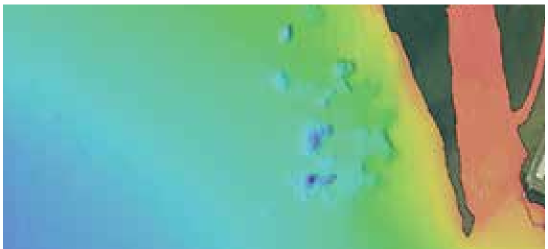
NIWA has started a series of workshops with regional councils and iwi to help local authorities develop fish passage action plans for their region.

With three-quarters of our native freshwater fish species under threat, legislation requires any new structure put across rivers or streams to be designed to enable fish to get past.

Councils must now actively develop plans to encourage fish passage, and NIWA freshwater scientists are running workshops across the country to provide the necessary advice to landowners.

The workshops, which include additional specialists from Australia, involve a mixture of theory, practical design and site visits to explore case studies.

Paul Franklin



UNDERWATER WATER

NIWA marine researchers have used acoustic soundings, remotely operated vehicles and seafloor sampling techniques to help map Wellington's Waiwhetū Aquifer.

The large freshwater aquifer runs deep under the Hutt Valley and continues beneath Wellington Harbour's seafloor. It is recognised as a crucial alternative water source for the quake-prone capital.

To bypass costly underwater drilling programmes to map the extent of the aquifer, scientists used a range of new techniques to accurately identify freshwater springs across the harbour floor.

These methods can now be replicated to investigate other large freshwater aquifers found off the Marlborough, Canterbury and Hawke's Bay coasts.

NIWA

AIR QUALITY

A new study has mapped the outdoor winter air quality for Invercargill and Alexandra in more detail than ever before.

The major cause of health hazards was smoke from domestic fires. Researchers, using atmospheric sensors, found that air in the most polluted locations contained three times as much particulate matter as the air in the least polluted areas.

Wind patterns and geography meant low lying suburbs were most susceptible to pollution build up.

Trials also showed domestic air filtration units could help reduce pollution levels indoors by up to 90 percent.

Stuart Mackay

Beneath the waves

What does a cyclone mean for coastal ecosystems? Ryan Willoughby talks to the researchers investigating the marine legacy of Cyclone Gabrielle.

Dr Mark Morrison has had his share of rough seas in his 27 years at NIWA. But RV *Kaharoa*'s June research voyage to waters off Hawke's Bay and Tairāwhiti involved some of the worst conditions he has experienced.

The marine ecologist and his colleagues battled big swells and high winds for 19 days, collecting valuable data on the undersea impacts of Cyclone Gabrielle, before it was literally washed away.

The voyage was the second of three detailed marine surveys focused on building a comprehensive picture of Gabrielle's legacy for the seabed and marine life in Hawke Bay and along the Tairāwhiti coast.

"The cyclone resulted in the transport of vast amounts of freshwater, sediment and debris to the marine environment," says Morrison.

"We've seen pictures of fishers in the area pulling up nothing but wood and a few fish. We found the same on our first voyage on *Ikatere*."

Funded by Fisheries New Zealand, the researchers are using three main tools to investigate conditions beneath the waves: multibeam sonar for mapping the seabed; a towed video camera for imaging the seafloor and its habitats; and a sediment multicorer to sample the seafloor and the life within.

The team use the data primarily to help build models of where the sediment has ended up and ecosystem impacts. Changes observed across the three voyages will give an early indication of impacts and possible recovery times.

Researchers aboard RV *Ikatere* use a multibeam echosounder to map Pania Reef just off Napier Port. (*Stuart Mackay*)

Marine Electronics Technician Ethan Carson-Groom keeps a close eye on the live feed coming back from the towed camera surveying the Hawke Bay seafloor below. (*Rebekah Parsons-King*)

Dr Daniel Leduc is a marine biologist and the project leader. He says detailed results from the surveys are still being collated, but early indications suggest Gabrielle has had a marked impact.

"One of the most shocking sights on land was those huge sediment deposits that buried houses to their rooftops. The home of our marine life has also been impacted, only it is harder to map.

"The sediment and debris are constantly moved around by water currents, waves and tides – on and around the rocky reefs, but also in gravelly and muddy areas."

Leduc says initial movement of sediment might smother life or lead to a long-term change in habitat, and many areas required repeat investigation.

"The Wairoa Hard, which hosts an important nursery for juvenile fish, showed no large-scale sediment build-up when we mapped the area in April. However, sediment cores taken in June had high mud contents that could be cyclone-related.

"In addition, when the team conducted research trawls in June, they returned little biology, but lots of wood debris," says Leduc.

Fisheries New Zealand's Director Science & Information, Simon Lawrence, says the research provides a baseline to help inform how to manage affected fisheries.

"It is important to understand what is happening beneath the water now so that we can make good decisions about it for the future."

Work is also focusing on the nearshore marine coastal zone, an area too shallow for *Kaharoa*.

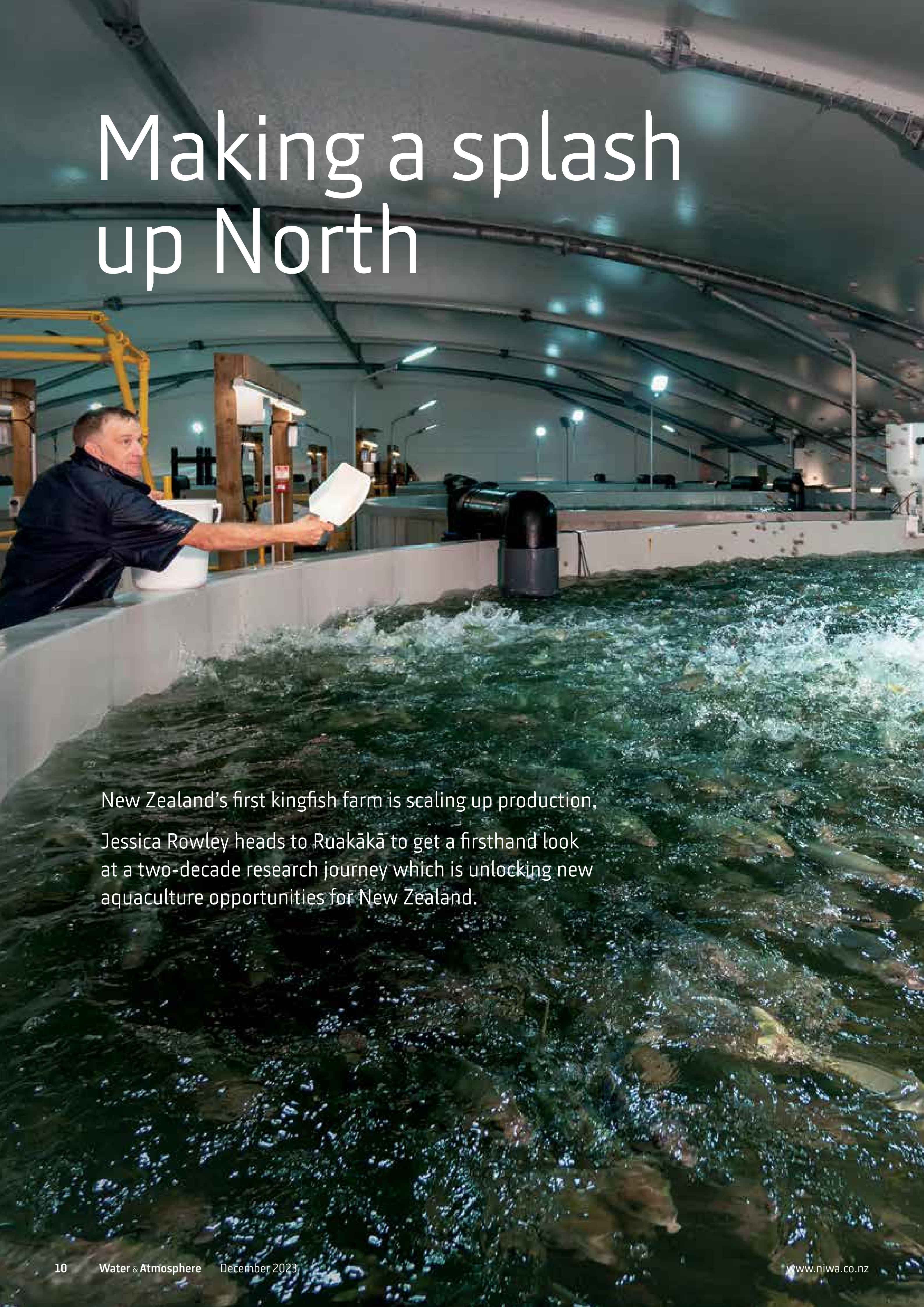
Debris washed into Hawke Bay by flood-swollen rivers dominates the catch of a local commercial trawler. (*Supplied*)

Led by marine ecologist, Dr Leigh Tait, researchers are using drones and underwater cameras to gather data on the impact of storm sediment and woody debris on bottom-dwelling organisms, fish stocks and breeding areas.

"We are trying to identify management objectives associated with commercial and culturally significant marine species, particularly kaimoana like pāua, kina and kōura, and the habitats supporting them, such as kelp forests, seagrass and shellfish beds," says Tait.

The team are intent on involving local communities in the research. There have been several visits to both regions to discuss the project, including the Ngāti Kahungunu Fish Hook Summit, which explored Cyclone Gabrielle's impact on the region and its communities.

"The full picture takes time. But these are important areas to the community, so we want to bring everyone along on the process by sharing what we find as we go," says Leduc.



Making a splash up North

New Zealand's first kingfish farm is scaling up production.

Jessica Rowley heads to Ruakākā to get a firsthand look at a two-decade research journey which is unlocking new aquaculture opportunities for New Zealand.

Aquaculture technician Aaron Therkleson creates his own 'boil-up' as hundreds of hungry kingfish compete for the feed pellets heading for their tank at the Northland Aquaculture Centre. (*Stuart Mackay*)

The Recirculating Aquaculture System delivers fresh, oxygenated seawater to these kingfish, removing waste, carbon and ammonia from their tank. (*Stuart Mackay*)

"Be careful. There is a lot of water here."

This safety warning comes as we wrestle on our slightly-too-small, company-supplied gumboots. We are at NIWA's Northland Aquaculture Centre, home to the recently completed Recirculating Aquaculture System (RAS).

In front of us are eight huge, circular, concrete tanks. So big, that to see inside we have to climb a flight of metal steps onto a viewing platform.

As we reach the top, the first things to capture our attention are the tanks' scale – each contains 350,000 litres of treated, recycled seawater – and then, the beautiful fish swimming around inside, in mesmerising synchronicity.

These yellowtail kingfish, or Haku, are the result of almost two decades of meticulous research and applied science. Fish that are destined for high-end dining tables, around New Zealand and across the globe.

The fish are strong, healthy and, according to many of the country's leading chefs, very tasty.

"We are finally at a stage where we can get these fish in front of customers in New Zealand and abroad, at a commercial scale", says NIWA aquaculture technician and kingfish ambassador, Jeremy Singleton.

Singleton is an ex-chef who has worked at an impressive roll call of top restaurants in both Wellington and Melbourne. He is giving us a tour of the facility, beaming over the tanks.

"I moved to NIWA after years working in fine dining, so I know how difficult it is to find a reliable source of quality seafood. The fish we have here, they're incredible – a chef's dream."

> "The fish we have here, they're incredible – a chef's dream"
>
> Jeremy Singleton

Aquaculture is big business

More than three billion people around the globe rely on seafood as a source of animal protein and, with ongoing declines in wild fish stocks, more than half the fish consumed worldwide are now produced by aquaculture.

Some of the highest industry growth rates have come from farming high-value finfish like salmon.

However, farming fish at sea is not without its issues. As climate change continues to warm and acidify our seas, and parasites and disease become more prevalent, operating in the ocean is increasingly problematic.

Both internationally and locally, the industry is moving coastal sea pens out into deeper, cooler waters to address some of these concerns, along with disquiet over the accumulation of food waste and the industry's environmental footprint.

So, how can aquaculture continue to meet the ever-growing demand for high quality, healthy protein, while at the same time mitigate its environmental challenges?

One answer – move it on land.

Kingfish – the ideal candidate

Take yourself back to the early 2000s. Apple unveiled the first iPod, Lord of the Rings – Return of the King scooped 11 Academy Awards, and 'blog' was Merriam Webster's 2004 Word of the Year. At about the same time, NIWA was reviewing its aquaculture science strategy.

"We wanted to develop a new high-value fish species that could meet market demand," Dr Rob Murdoch tells me.

Murdoch is NIWA's General Manager for Science and Deputy Chief Executive. He has a special interest in marine ecology and has been with NIWA since the genesis of the RAS.

"New Zealand's aquaculture sector desperately needed to diversify into high-value species if it was to meet its growth aspirations to become a billion-dollar industry by 2025." That target later became $3 billion by 2035.

"We saw a clear problem – and an opportunity."

The first challenge was to identify the right species – ones with an uncomplicated life cycle and commercial potential.

"We'd researched several different options, but it was hard to find a good candidate. Scampi, for example, are incredibly cannibalistic. Put two in a tank, and only one is coming out."

After myriad investigations, yellowtail kingfish (*Seriola lalandi*) moved squarely into frame. Known more affectionately as 'kingi', these fish are also called amberjack and are found throughout the warm-temperate waters of the southern hemisphere and in the northern Pacific. They have a simple life cycle and a rapid growth rate.

They are also highly valued and already established within the aquaculture industry. In some places across Europe, companies are even stopping salmon aquaculture and moving to kingfish, because of their higher return.

"We had our ideal candidate," says Murdoch.

To expand their portfolio and maximise potential return on investment, the team also decided to trial hāpuku. This is an equally promising colder water species, meaning there was potential to grow species at either end of the country.

Now they had their target species, Murdoch and his colleagues returned to their vision for the end product – a high quality, healthy fish sought after in premium markets because of its exquisite taste, provenance and environmental credentials.

The production system and supply chain needed to be constructed and operated in a sustainable and ethical manner to ensure superior fish health and welfare. It needed to provide efficient conversion of raw materials and energy, waste capture and treatment, and an overall low environmental footprint.

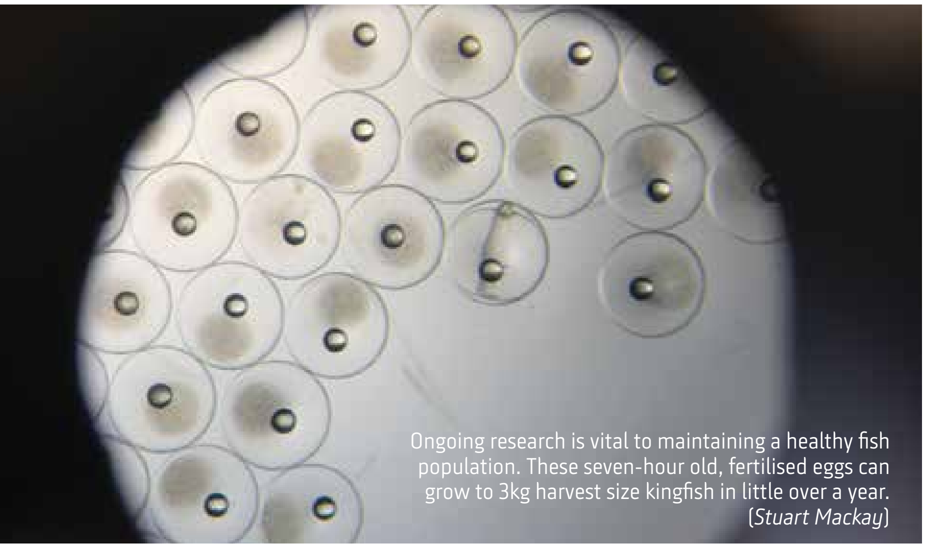
The system was also required to deliver direct benefits to the local community and, finally, profitability.

"Initially we were considering sea-cage production, but in the end the answer was obvious – a land-based aquaculture system. They were already doing it in Europe with great success, so why not here?" says Murdoch.

> **"We wanted to develop a new high-value fish species that could meet market demand"**
>
> Rob Murdoch

Sited metres from Bream Bay, the experimental RAS facility houses eight 350,000 litre tanks. Seawater intake and discharge infrastructure could accommodate a full-scale commercial operation up to five times the size. (*Stuart Mackay*)

> **"Our research shows kingfish thrive in RAS – circular tanks suit their natural schooling and feeding behaviour"**
>
> Jeremy Singleton



Ongoing research is vital to maintaining a healthy fish population. These seven-hour old, fertilised eggs can grow to 3kg harvest size kingfish in little over a year. (*Stuart Mackay*)

Taking control

"We don't see RAS as a replacement for ocean aquaculture, rather as an addition to sea-caging. The beauty of it is that you can control many of the problems that ocean-based farming has," says operations manager Steve Pope, pointing at a panel worthy of a spaceship.

"Everything is monitored by machines, but controlled by a team of experts – temperature, oxygen levels, lighting, you name it. We want to grow the stock as efficiently as possible. Luckily, this is where NIWA's science comes into play – we are dab hands at experimenting."

Over the years, fisheries experts have narrowed down the perfect conditions to get the biggest and best quality fish. And, crucially, the healthiest and happiest.

It has taken years of applied science, but the broodstock programme has resulted in significantly higher growth rates. What starts off as an egg the size of a full stop, becomes a 3kg fish in less than 12 months. The fish can also be spawned at any time, which promises a constant supply year-round.

"As you can see, they're a hungry species", says Pope, as his colleague launches trowels full of specially developed pellets into the water, kicking off a feeding frenzy.

"We've developed our own systems. This food, for example, is highly digestible and causes the faeces to stick together, meaning we can remove the waste much easier.

"We get rid of ammonia too, which is toxic to fish. Ammonia is produced when they metabolise protein. To overcome this, we grow bacterial colonies which consume and convert the ammonia into a non-toxic state."

With fish living together in close proximity, carbon dioxide build up is inevitable. The RAS uses a process called degassing – which does what it says on the tin. Metal cylinders spew out vast amounts of bubbles, which froth up over the top and cascade down the sides. Exactly what you'd imagine a science experiment to look like.

"We vigorously bubble large volumes of air through the water to get rid of the carbon dioxide," says Pope.

"Carbon dioxide moves from the water into the air, and we then pump the water back to the fish. Just before it enters the tank, we add oxygen to ensure the fish are never deprived or distressed."

The equivalent of one 350,000-litre tank of water goes through the process every 20 minutes. When the tanks refill, an impressive 98 percent of the water is reticulated through the system.

Nursing the next generation

The number of eggs that a single female fish produces is mind-boggling. In just a week, they can spawn two million eggs. Within their two-month spawning season, that's over 10 million. But there is a good reason for this. In the wild, a minuscule number will reach maturity – on average, only two, in fact. The rest die from trauma, disease, or in the stomach of a hungry predator.

However, NIWA's kingfish are not in the wild.

"Eighty percent of our eggs hatch and about four to eight percent grow into adult fish. Compared with survival in the ocean, that survival rate is off the charts," says Singleton.

When the eggs hatch, the larvae are transferred to a nursery area where they are fed a range of tiny aquatic animals, before being weaned onto a specially formulated diet after a few weeks.

Jeremy Singleton examines a master culture of algae, grown to help produce large quantities of tiny aquatic animals called rotifers. Kingfish larvae initially feed on rotifers before moving on to a specially formulated diet. (*Stuart Mackay*)

They are transferred to larger tanks as fingerlings, before being transferred again into the RAS tanks, where they continue to grow rapidly.

Once they reach market weight (3kg, after about 12 months), a small proportion are selected for future breeding. These fish are put on a broodstock diet and breed three to four years later. For the rest, it's time to be harvested.

Singleton stresses that animal wellbeing is a key pillar of the team's work.

"Our research shows that kingfish thrive in RAS – circular tanks suit their natural schooling and feeding behaviour. The systems for exchanging and refreshing the water are engineered to ensure a consistent, healthy rearing environment.

"And, because land-based RAS affords full environmental control and exclusion of pathogens or parasites, medications are rarely needed.

"We care about these animals deeply and do our best to ensure they are looked after," says Singleton.

In recent years, NIWA has been supplying up to 600kg of premium Haku a week to selected high-end restaurants all over New Zealand and some select international customers. The aim has been to test the market and gather initial feedback on the product.

NIWA fisheries researchers have developed special feed pellets, which are both highly nutritious and digestible, enabling easy removal of waste from the system. (*Stuart Mackay*)

It's safe to say, it's going down a storm. Award winning chef Makoto Tokuyama of Ponsonby's Cocoro Restaurant describes it as an excellently balanced fish and superior to the wild product.

"Haku is amazing. It is a beautiful, beautiful fish."

But the current trial distribution operation is a drop in the ocean compared with what's now on the horizon.

Dr Andrew Forsythe is NIWA's Chief Scientist for Aquaculture & Biotechnology, based at Bream Bay. He says the RAS is finally ready to move from science to full commercialisation.

> "The council couldn't be more pleased to be involved"
>
> Phil Heatley, Northland Regional Council

NIWA's understanding of the market, combined with the biological, technical and financial feasibility of growing these fish, means up to 600 tonnes of Haku kingfish can now be confidently harvested from the facility each year.

Forsythe says the past six months have established the system's performance, and discussions with commercial partners about marketing the harvested fish are well advanced.

"A single large tank can hold up to 30 tonnes of fish. You can imagine the logistics involved in managing, harvesting and moving all of that. It's a big operation.

"We have a huge amount of interest already. Not just from the seafood sector, but also from other investors who are keen to get involved," says Forsythe.

Growth opportunities

Not only does the RAS facility offer fresh opportunities for fine diners and the seafood industry, but it also represents a significant new avenue for regional growth.

The current, experimental, commercial-scale operation is located on an eight-hectare freehold title owned by NIWA, with seawater intake and discharge infrastructure to accommodate considerable expansion.

A full-scale 3,000-tonne operation could be up and running within five years, creating about 75 new jobs and substantial annual income for the region.

The Northland Regional Council (NRC) collaborated with NIWA in the RAS development, and has its eyes firmly set on regional growth.

NRC's strategic projects manager Phil Heatley says the council and local businesses identified the finfish sector as a key opportunity when working together on a regional aquaculture strategy almost a decade ago.

He says the council was excited by the opportunity to combine this thinking with NIWA's science expertise.

"The RAS has an ultra-low impact on the environment and it's using resources efficiently in the production of high-value protein.

"Add to that the benefit of diversification to the current aquaculture market, and the creation of new employment opportunities for the region, and the council couldn't be more pleased to be involved."

Northland's role as the anchor stone of the RAS is self-evident, but the long-term implications of the development could yet reach much further.

The technology has been deliberately developed to enable it to be readily replicated for both different species and different locations.

Work is already well advanced on adding hāpuku to the RAS stable.

The system is also capable of being set up in multiple locations, provided there is an adequate source of seawater nearby.

Given New Zealand has the ninth longest coastline in the world, the options are far from limited.

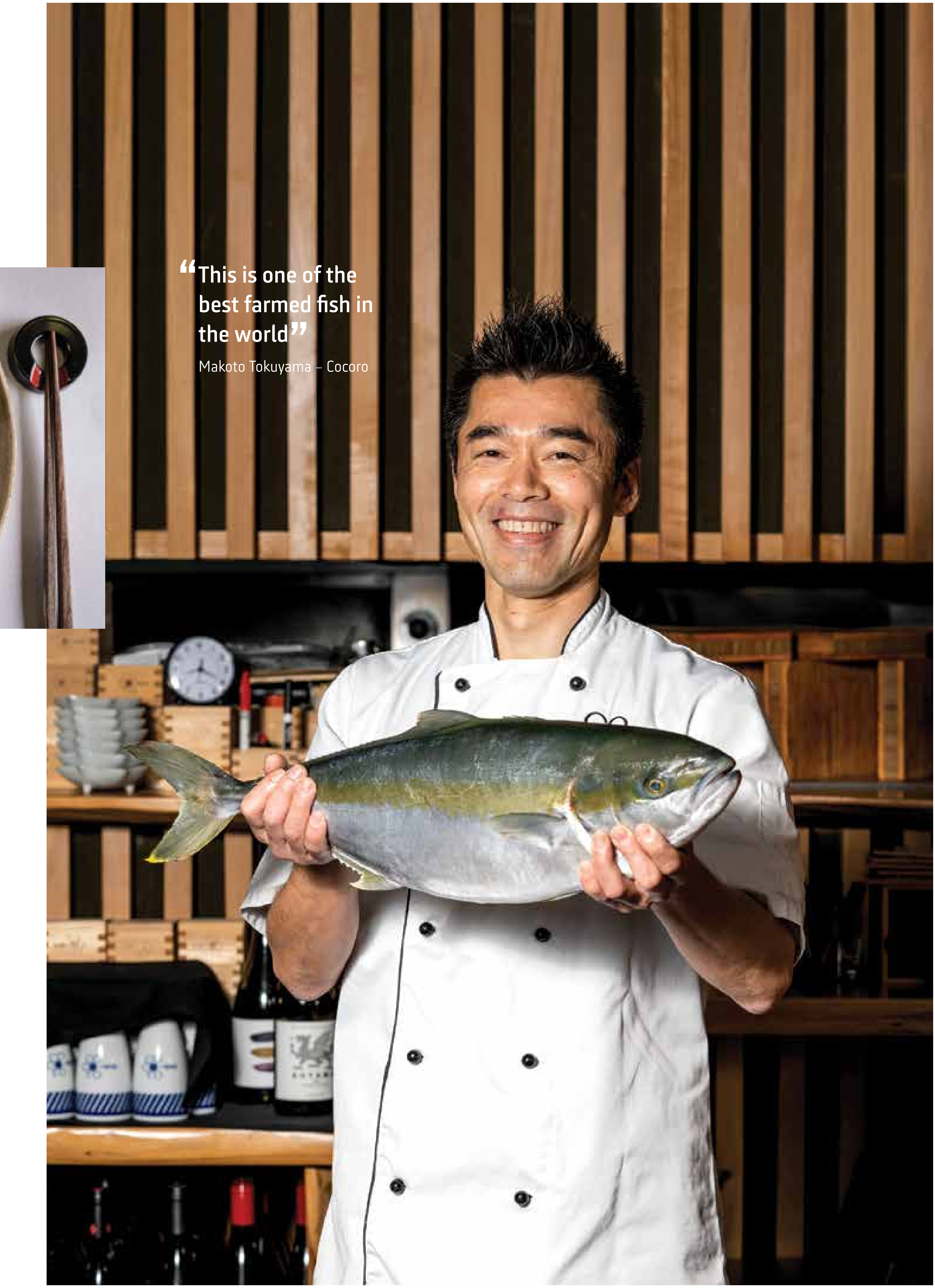
Whatever the years ahead hold, with worldwide demand for high quality, low-impact, sustainable seafood ever growing, the future for the RAS and Haku kingfish in the North looks exciting.

Cocoro's Tokuyama, for one, has few doubts.

He says Haku is firm and crisp, with a really clean flavour, and customers love it.

"This is one of the best farmed fish in the world – even compared with the quality of Japanese-farmed fish.

"Haku is amazing." W&A



"This is one of the best farmed fish in the world"

Makoto Tokuyama – Cocoro

Turbocharging research

Melissa Bray meets the geologist, with a strong sideline in maths, driving NIWA's data science revolution.

Most days, Dr Jess Robertson jumps off the train and straps on his inline skates.

He is hoping the wind is at his back and he won't have to battle the southerly to complete the commute to his Greta Point office.

That is about as 'low tech' as the Wairarapa resident's working day goes.

Robertson is NIWA's new Chief Scientist – High Performance Computing and Data Science.

His role is all about using the latest technology to drive NIWA's science forward, and once he reaches the office, his world is consumed by machine learning, artificial intelligence (AI), data systems and supercomputing.

Robertson has long been interested in the relationship between systems and science. Originally from Dunedin, he studied geology and mathematics at the University of Otago before moving to Australia where he completed his PhD in geological fluid dynamics.

His introduction to machine learning and high-performance computing came when he joined the Commonwealth Scientific and Industrial Research Organisation, working between the Minerals and Data groups.

Then came work with an Australian tech startup focused on data science opportunities with big resource companies, before he made the move back across the Tasman to lead science innovation policy at the Ministry of Business, Innovation and Employment.

Robertson now manages NIWA's team of AI and deep learning data scientists and high-performance computing engineers.

The data scientists are tasked with using machine learning, digital twin and computer vision systems, along with customised AI, to support NIWA's research.

The Greta Point High Performance Computing Facility houses NIWA's Maui supercomputer and provides the processing power needed to drive many of these systems. It plays a significant role in forecasting and climate science, but is also used widely across NIWA's research platforms.

The move to NIWA, says Robertson, gives him the opportunity to 'get back on the tools' and he relishes the opportunity to bolt the power of fast changing technology on to research science.

"NIWA is uniquely positioned to bring together excellent domain science, coupled with state-of-the-art machine learning and data science. We've also got a good understanding of the end users of our science, whether they are communities, industry or government."

Robertson says NIWA is already putting data science to practical use for those end users. He cites examples such as using computer simulations to enable higher resolution weather forecasting or river flood predictions using large computational models.

However, he believes there's huge potential for data science to drive research further and make discoveries faster.

"The rate at which innovative new approaches are popping up has been nothing short of stunning.

"For example, five years ago machine learning was useful for problems that a 10-year-old could solve.

"Now, with some of the large language models like ChatGPT and stable diffusion methods for images, it's not the work of 10-year-olds, it's undergrad-level work that is being done."

With change happening at lightning speed, Robertson sees the need to constantly re-evaluate the available technology.

"You might have looked at the use of AI five years ago and decided it's not worth it, but you have to continually reassess."

And that, says Robertson, is where the data scientists come in.

"It's time to take a careful look and to connect the science we're doing with the tools available.

"There's already a lot of great ideas across NIWA which could be turbocharged with new approaches.

"The ability to bring in these rapidly changing tools from anywhere around the world and use them to do something cool, that's what I want to build on."

"The rate at which innovative new approaches are popping up has been nothing short of stunning"

Dr Jess Robertson

Jess Robertson, in NIWA's High Performance Computing Facility with the Cray supercomputer, Maui in the background. (*Lana Young*)

Deep reveal

The WW2 minesweeper HMNZS *South Sea* sank after a collision in the main channel of Wellington Harbour in 1942.

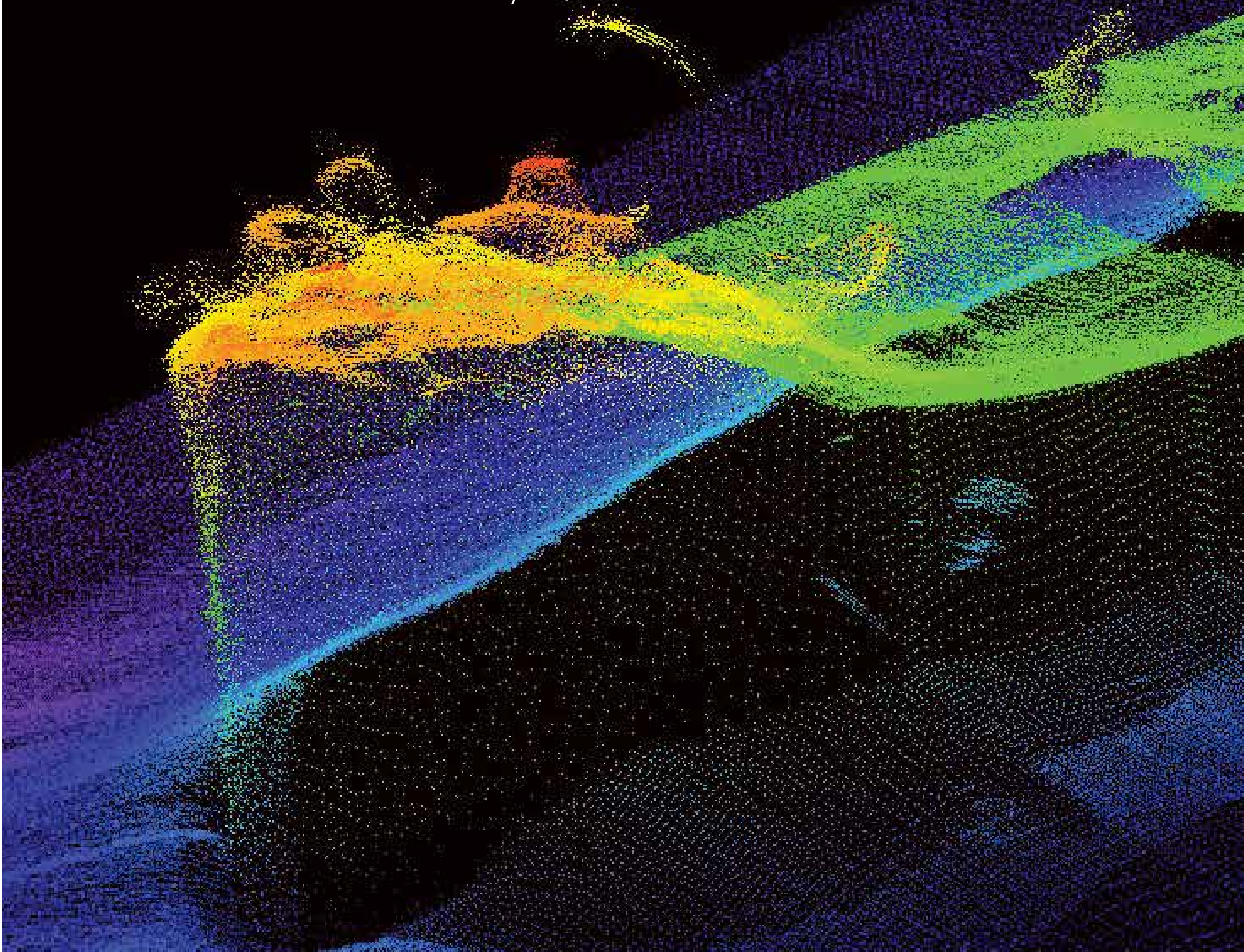
This 3D image of the vessel's remarkably intact hull was generated by Marine Geology Technician Sam Davidson, using multibeam echosounder data gathered during a harbour seabed survey.

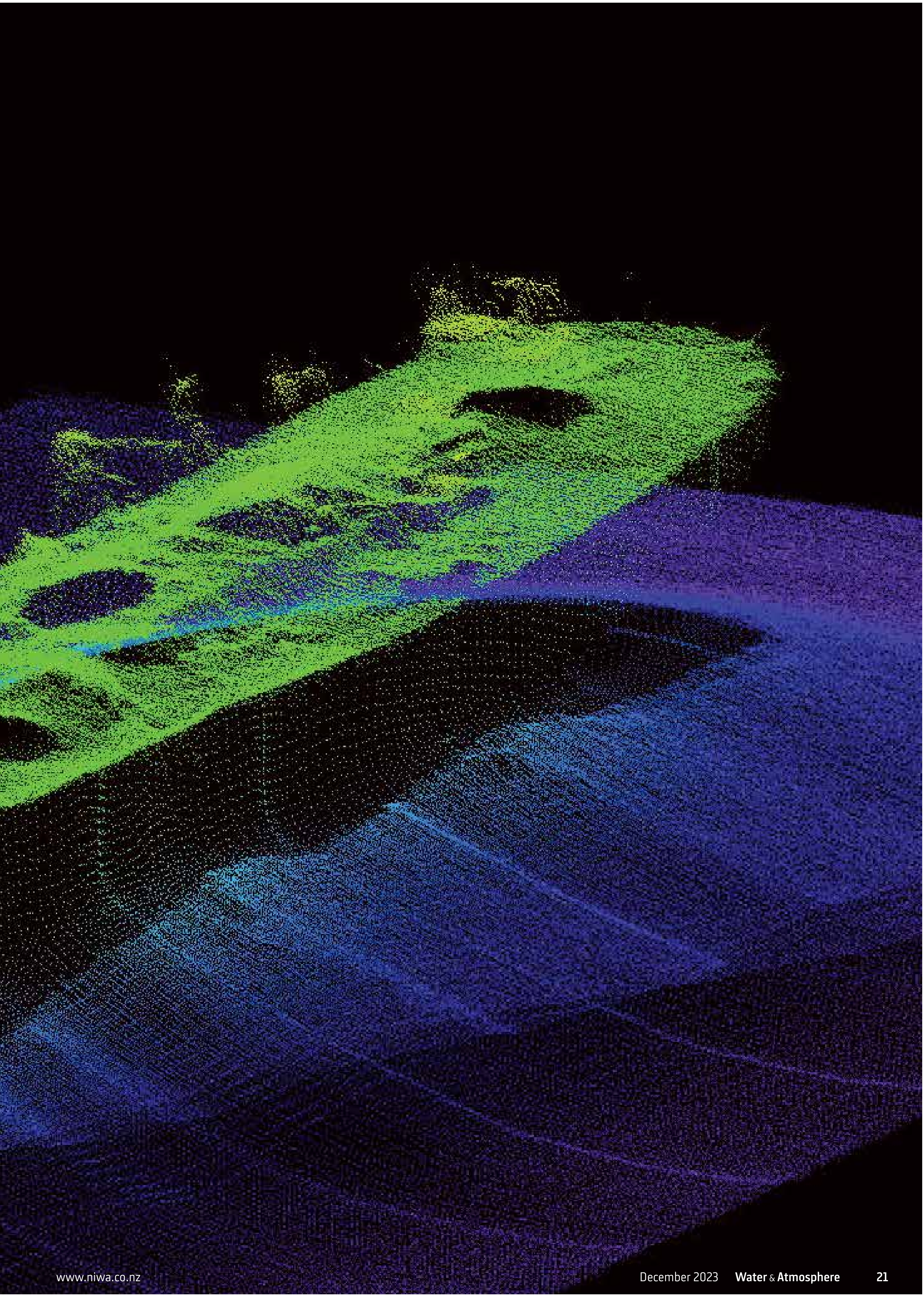
Davidson used advanced processing techniques to reveal the 20m deep wreck resting almost perfectly on the muddy seafloor.

While much of the vessel's superstructure has been removed to avoid navigation hazards, some features, including an extended lifeboat davit (yellow), are still visible.

Davidson entered the image in the data visualisation section of the 2023 NIWA Staff Photography competition.

As the following images show, the *South Sea* wreck is just one of many colourful scenes NIWA staff encounter working in the world of environmental science.





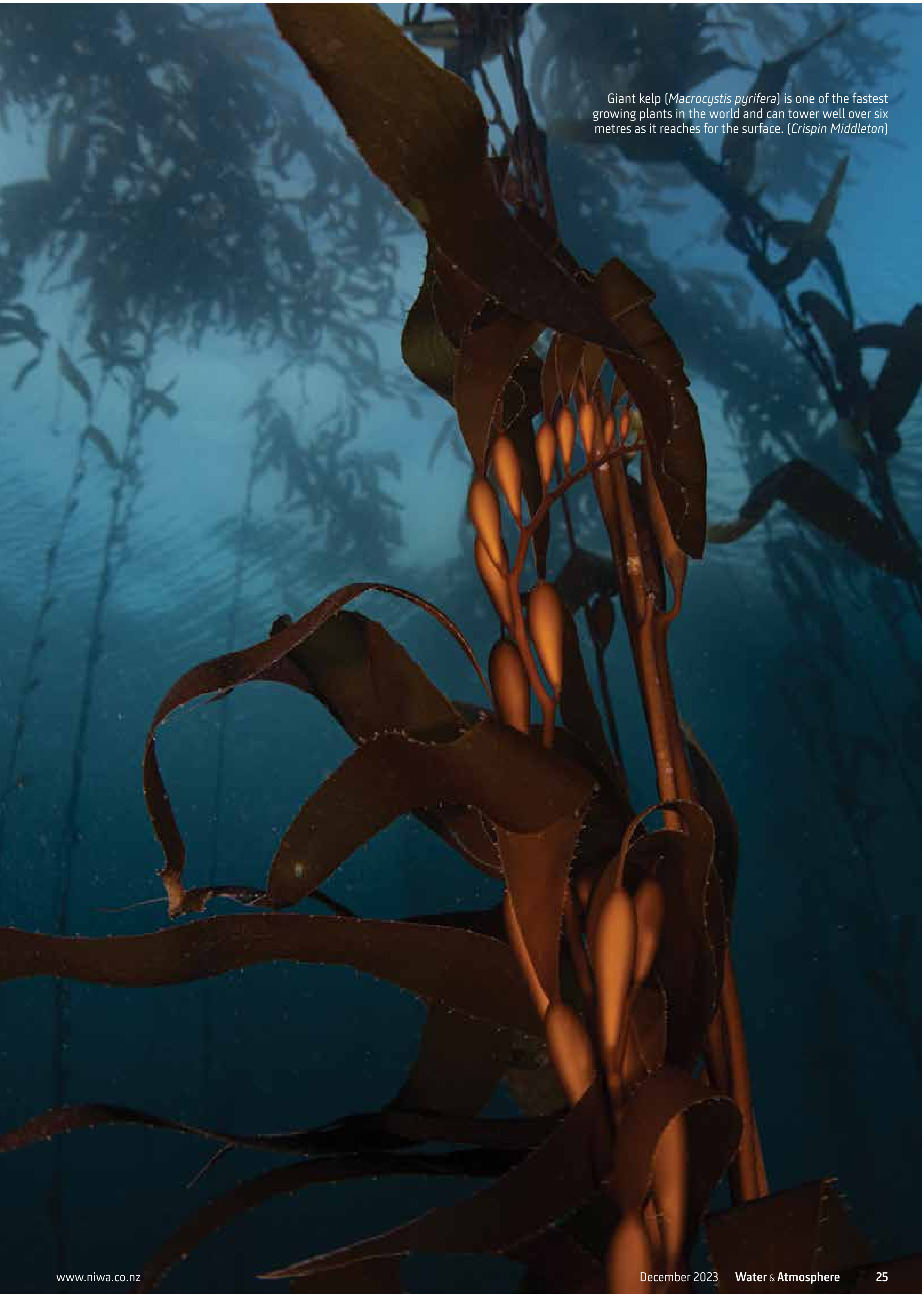
A transluscent slipper lobster larva caught hitchhiking along the Northland coast on a mauve stinger jellyfish, with school of trevally circling in the background. (*Irene Middleton*)

Fresh August snow adds extra bite to environmental monitoring technician Andrew Willsman's servicing trip to the remote Takahē Valley climate station in the Murchison Mountains. (*Martin Bylsma*)

Hydrodynamics technician Jochen Bind was working on the Southland coast when he caught the Milky Way illuminated by a late summer aurora.

Scientific dive specialist Richie Hughes couldn't resist a selfie as he documented a bloom of mauve stinger jellyfish drifting past in the Poor Knights Islands.

A late afternoon winter squall sweeps across the southern end of the Two Thumbs Range, shrouding Mt Edward near Tekapo. (*Hayden McDermott*)



Giant kelp (*Macrocystis pyrifera*) is one of the fastest growing plants in the world and can tower well over six metres as it reaches for the surface. (*Crispin Middleton*)

Freshwater ecologist Elizabeth Graham heads towards a remote Fiordland tarn in search of rare aquatic insects. High altitude waterways hold a surprising diversity of unique invertebrates. (*Brian Smith*)

A garden of sea pens anchored on the seafloor of Doubtful Sound. Named for their resemblance to old fashioned quill pens, the soft corals filter plankton through their tentacles. (*Irene Middleton*)

An 11-armed starfish (*Stichaster australis*), hunting limpets in the newly formed intertidal zone on Wellington Airport's breakwater. (*Crispin Middleton*)

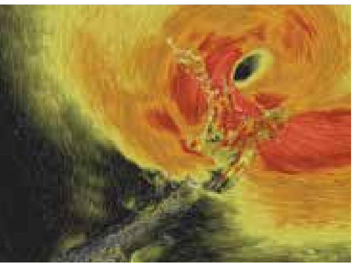
Scientific diver Aleki Taumoepeau emerges from Southland's Waituna Lagoon, draped in the native aquatic plant ruppia. Ruppia is a key ecosystem indicator and NIWA surveys the lagoon annually. (*Inigo Zabarte-Maeztu*)

Impact forecasting

Extreme weather is the new norm, and the science of forecasting is rapidly evolving to meet the challenges. Stacy Mohan looks at how NIWA researchers are joining forces to predict the impacts of extreme events, so communities can better prepare for their future.

Woody debris strewn across this Hawke's Bay orchard reveals the devastation of stopbank breaches caused by Cyclone Gabrielle's record back country rain. Researchers are using flow data from aerial LiDAR surveys to map the impact of extreme weather systems at ground level. (*Justin Stout*)

> **“What people really want to know is not just whether the river is running high, but what areas will be flooded”**
> Nava Fedaeff



Forecast models accurately predicted the extreme wind and rainfall associated with Cyclone Gabrielle. (*NIWA*)

Cyclone Gabrielle swept into Hawke’s Bay and Tairāwhiti in the second week of February, unleashing torrential rain and record floods.

Less than 10 months later, farmers and orchardists hit by that deluge are now facing the prospect of a summer with too little rain.

Rapidly warming ocean temperatures in the mid-Pacific have resulted in one of the strongest El Niño weather patterns seen in recent decades.

For those in Hawke’s Bay and Tairāwhiti, the westerlies look set to be stronger for longer this summer, likely bringing extended dry spells and potential water shortages.

It is an unwelcome reminder of the realities of living in a highly variable and changing climate.

Predicting impact

New Zealanders are fast realising that climate change means living with an increased risk of climate extremes. The same climate drivers that are powering up El Niño, have prompted warnings of a higher risk of tropical cyclones in the Pacific Islands this summer and could also bring flooding to Fiordland and the West Coast.

NIWA forecasting, climate change, hydrology and natural hazards researchers already work on a whole raft of programmes dealing with the challenges of climate change.

However, in recognition of the devastation storms like Gabrielle deliver, NIWA has prioritised further resource into predicting what extreme weather events will actually mean for affected communities.

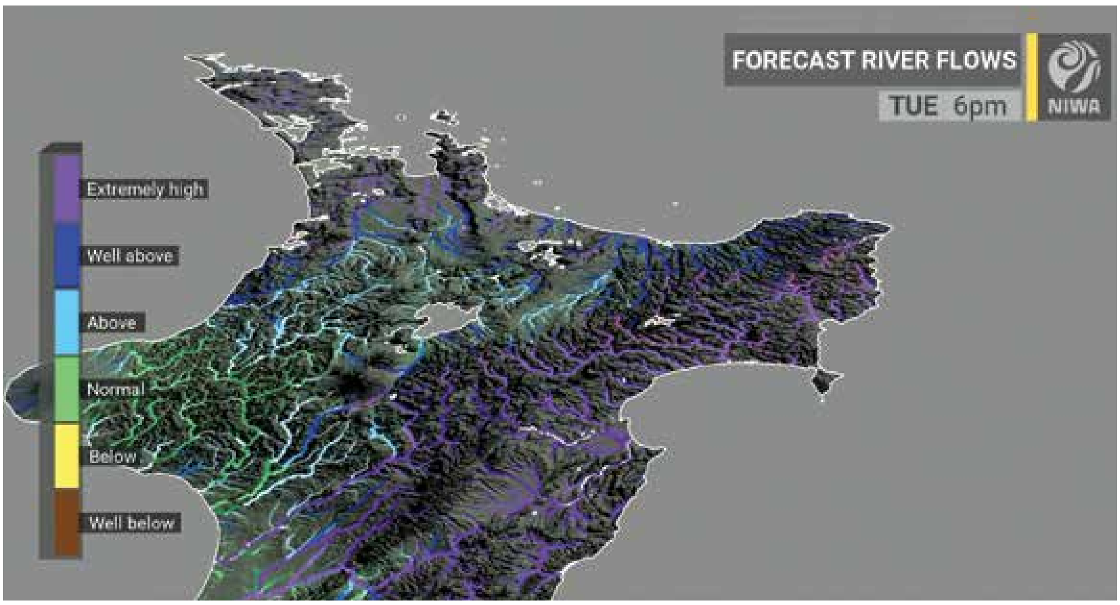
Chief Executive John Morgan has announced an additional $5 million a year for a package of projects focused on the impacts of extreme weather events (see box on page 32).

Cyclone Gabrielle clearly demonstrated that advanced supercomputers and weather modelling mean NIWA forecasters can already accurately predict the arrival of storm systems, along with the rainfall totals and wind strengths they will deliver.

The focus now is on improving the forecasting of how those rainfall figures and wind strengths will interact on the ground for communities, environments and ecosystems in the line of fire.

The new funding will enable NIWA scientists to investigate new ways of predicting the potential impact of a combination of storm outcomes, such as floodwater, slips or coastal surges, to help communities prepare for hazards peculiar to their region.

NIWA climate scientist Nava Fedaeff is spearheading one such project. The research pulls together the skills of NIWA’s climate, meteorology, hydrology, data science and hazard specialists, combining five-days-ahead ensemble weather forecasting, river flow predictions and inundation mapping.



NIWA hydrologists and weather forecasters are working together to combine rainfall predictions with catchment data to enable detailed flood warning days before storms hit. (*NIWA*)

The El Niño-fuelled dry spell in the summer of 2020 forced Hawke's Bay farmers to buy extra feed and cost New Zealand more than $600 million in lost farm production. (*Caroline Beamish*)

The team are producing models to detail – down to street level – people, property or infrastructure at risk when storms strike.

Fedaeff stresses the importance of early warning. "The two to five-day window is a critical timeframe for taking proactive measures," she says.

Ensemble forecasting is a method used in numerical weather prediction to look at possible outcomes. Instead of making a single forecast of the most likely weather, forecasters run several computer models at a time, each under slightly different scenarios. This set of forecasts indicates a range of future weather conditions. Where these scenarios converge on a particular outcome, forecasts can be issued with greater confidence.

In this new project, Fedaeff and team are linking weather ensembles with river flow modelling, to show where flows could be highest under different scenarios. And then taking this a step further to link with inundation mapping.

"What people really want to know is not just whether the river is running high, but what areas will be flooded, and what's at risk from that potential flooding," says Fedaeff.

"We're exploring the potential of artificial intelligence to enable us to move from weather forecasts to inundation forecasts, quickly enough to get useful information out to those who need it."

Taking the project beyond forecasting and into predicting impacts also involves the use of RiskScape – a software tool that enables risk and vulnerability analyses of multiple hazards. It is a tool that was developed by NIWA and GNS Science, alongside more recent partner Toka Tū Ake EQC and collaborator Catalyst IT.

Initially the project will focus on mitigating the risks associated with river flooding, but the intention is to look at the impacts of other weather-related hazards – such as marine heatwaves, coastal storm surges, droughts or wildfires.

Drought forecasting

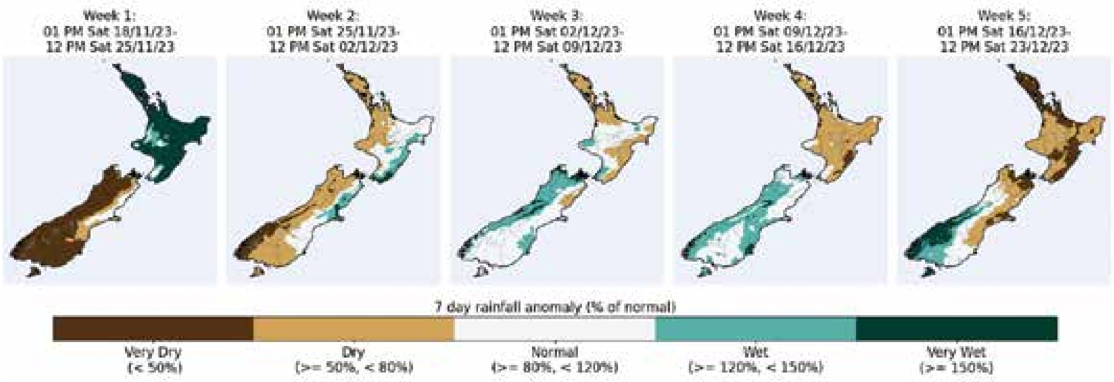
The flood forecast project complements other NIWA work already underway in relation to extreme weather events.

This year's El Niño is coupled with another pronounced southern hemisphere climate driver, a positive Indian Ocean Dipole. This last occurred in 2019. The result was record-setting dry spells in the north and east of the North Island and a water crisis for Auckland City. The water supply issues alone cost Auckland ratepayers more than $200 million.

NIWA meteorologist Ben Noll says his team has already been briefing key agencies and authorities in drought or fire risk areas about the threats El Niño may deliver in the months ahead.

“It enables district-level predictions of dryness and drought, and helps farmers and growers better prepare”

Ben Noll



NIWA's new Drought Dashboard uses climate modelling and data science to deliver dryness predictions up to five weeks ahead. (*NIWA*)

“Along with reduced rainfall, strong westerly winds are expected to be a theme for several regions throughout summer and possibly into autumn,” explains Noll.

“NIWA's role last summer in providing wind and rain forecasts to councils and emergency managers has now swung to include regular information briefings for the agricultural and horticultural sectors.”

NIWA has provided New Zealand with seasonal rainfall and dryness predictions for more than 20 years, steadily increasing the accuracy, resolution and time length of these forecasts.

The latest version uses climate modelling and data-driven techniques to deliver district-level dryness predictions up to five weeks out. Called the Drought Dashboard, it was launched earlier this year by NIWA and the Ministry for Primary Industries.

“The Drought Dashboard is part of the NIWA35 platform, which is marrying artificial intelligence with physical science to make high resolution, sub-seasonal climate predictions up to 35 days ahead,” explains Noll.

NIWA35 is based on input data from a model issued daily by the US National Oceanic Atmospheric Administration (NOAA). NIWA uses this data and enhances its accuracy and precision over New Zealand using data-driven techniques.

The improved model better captures the climatic variability that occurs across the country's complex terrain.

“The tool updates daily to provide forecasts at a much higher spatial resolution than previously available.

“It enables district-level predictions of dryness and drought, and helps farmers and growers to better prepare,” says Noll.

NIWA35 shows the power of turning weather and climate data into accessible tools that communities can use to prepare for what the climate is now throwing at them.

Elsewhere, NIWA scientists are working with research colleagues on a wide range of similar projects. These include using new data techniques to predict what extreme rainfall may mean at a catchment level for subsidence risk, and mapping the combined impact of rising sea levels and storm surges.

With further storms and droughts on the horizon, demand for applied climate science and impact forecasting will only grow. W&A

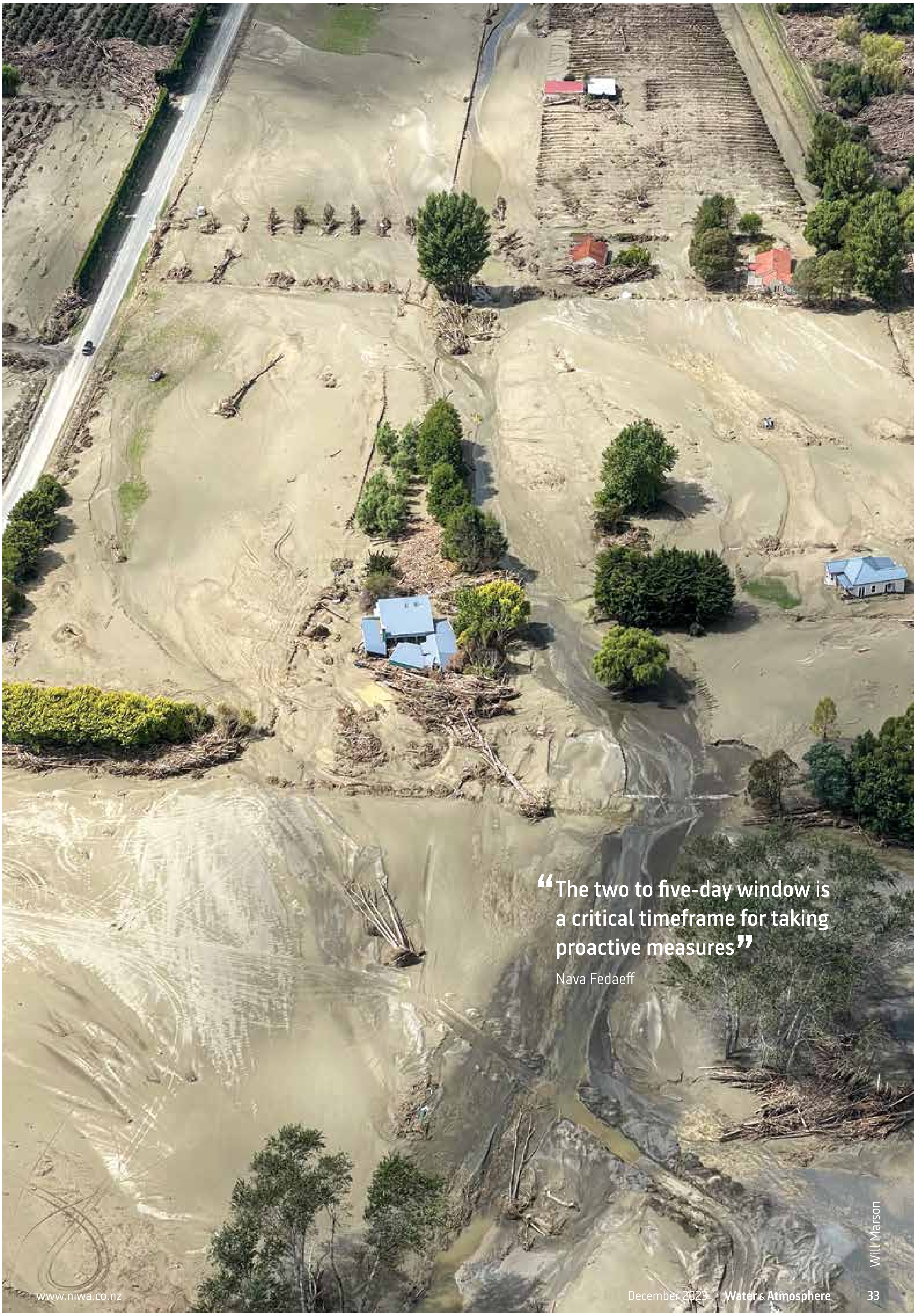
NIWA boosts extreme weather research

Almost half of NIWA's new $5 million per year package for extreme weather-related research will go to improved forecasting of the impacts of extreme weather.

Funds will also go to supporting the development of climate change resilient infrastructure and working with iwi/hapū and Māori business on climate adaptation.

“We know that such extreme events are going to become more frequent and more intense, and we need to be better prepared,” says NIWA Chief Executive John Morgan.

“Advanced, high-precision forecasts that link different hazards will help all New Zealanders – including iwi, emergency managers, government, councils and the public.”



"The two to five-day window is a critical timeframe for taking proactive measures"

Nava Fedaeff

Will Marson

Passing on the torch

NIWA's long serving Research Vessel *Kaharoa* is nearing the end of an extraordinarily busy life of science. But, as Ryan Willoughby reports, the next generation already looms large on the horizon.

There are few staff left in offices around NIWA who remember RV *Kaharoa* being launched in Whangārei back in 1981.

Fewer still remember the remarks on the day by New Zealand's then Fisheries Research Director, Duncan Waugh, who described it as the smoothest launch he'd ever seen.

Fast-forward 42 years and the brand new replacement vessel, *Kaharoa II* slides into the ocean for the first time with similar ease. However, this *Kaharoa* is in a different ocean, half a world away in a shipyard in Vigo, Spain. Nestled up against the wharf, it's currently undergoing final fit-out and harbour trials, in preparation for its delivery voyage to Wellington early next year.

Kaharoa and NIWA's RV *Tangaroa*, are New Zealand's only dedicated, open ocean research vessels. And after more than 400 voyages, with an average of 200 days at sea per year, it's time for *Kaharoa* to make way for the next generation.

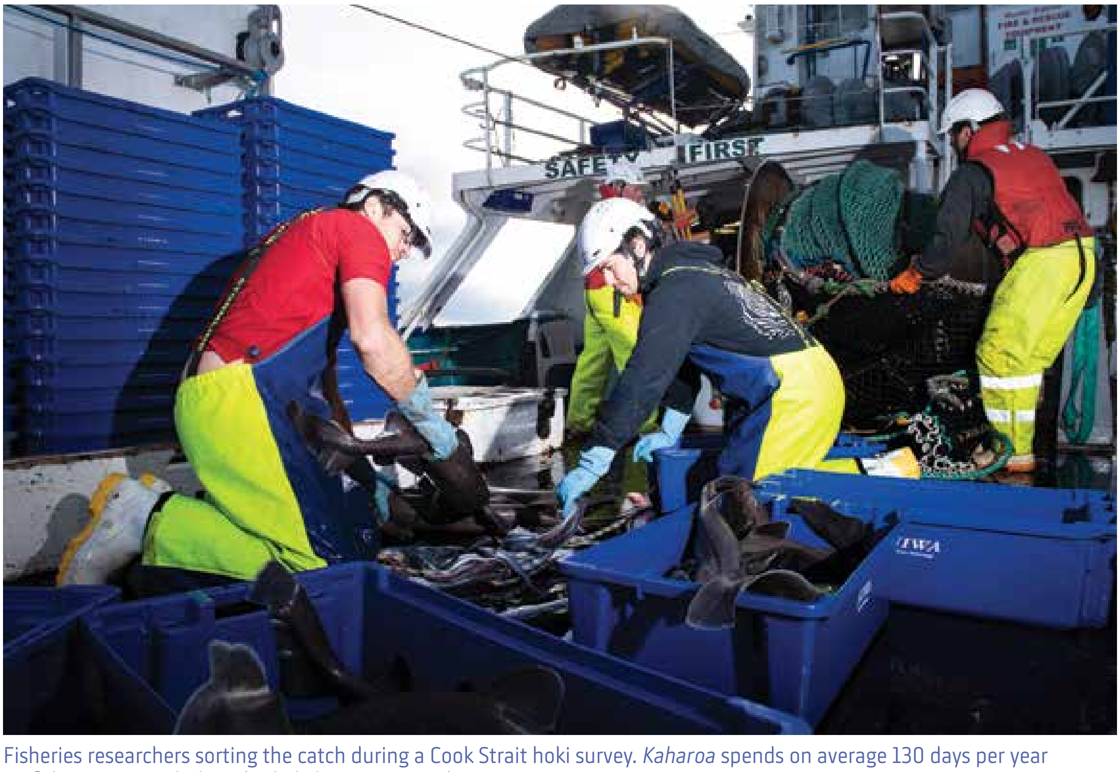
The replacement brief from NIWA's scientists and partners was clear – a state-of-the-art, coastal and ocean-going, multidisciplinary research platform with similar operating costs, but enhanced capabilities.

Kaharoa II is the result of six years of planning, from stakeholder engagement to detailed design, construction and launch.

"It's been the complex project, creating a multifunctional vessel to meet the needs of fisheries, oceanography and a variety of maritime commercial operations," says Manager – Marine Resources, Rob Christie, who's been directing the project.

Eight metres longer than its predecessor, *Kaharoa II* has increased laboratory and deck space, can accommodate more scientists and is able to support a whole new array of technologies and instrumentation.

It is a prospect Dr Richard O'Driscoll, Chief Scientist – Fisheries, relishes. His team spend an average of 130 days per year at sea on the existing vessel, undertaking fisheries research.



Fisheries researchers sorting the catch during a Cook Strait hoki survey. *Kaharoa* spends on average 130 days per year on fisheries research duty. (*Rebekah Parsons-King*)

Moments after sliding down the slipway, *Kaharoa II* is towed by a Vigo shipyard tug to a nearby wharf to complete the final fit-out. (*Armon*)

"It's great to see all the years of planning turning into reality. *Kaharoa II* will allow us to continue monitoring the abundance and distribution of New Zealand inshore fish for the next 40 years," he says.

Affectionately known within NIWA, as 'The Little Ship That Can', *Kaharoa* has ably supported the work of the significantly larger *Tangaroa*, working across the Indian and Pacific oceans from Cape Town to Santiago. *Kaharoa II* will extend the scale of operations.

"Our vessels work as platforms for our science. *Kaharoa II* will transform what we are able to do, with a broader range of inbuilt capacity and a more flexible layout," says Chief Scientist – Oceans, Dr Mike Williams.

"We are going to be able to move from an inshore trawl survey one week, to exploring the ocean depths to understand the impact of climate change the next.

"The new vessel will also have the capability to support some areas that were solely *Tangaroa*'s, such as the deployment and maintenance of the New Zealand Tsunami detection network," says Williams.

Kaharoa II will also continue to support signature projects like Seabed 2030, an international effort to map the world's ocean floor, and the Argo programme, a global ocean monitoring initiative involving more than 30 countries.

Argo helps researchers understand the complex interactions between our oceans, weather and climate through a global network of nearly 4,000 ocean-going floats providing near real-time measurements of ocean temperature, salinity, currents and biogeochemical data.

Kaharoa has played a key role in this international science collaboration. Since 2001, it has travelled across the southern oceans, deploying over 2,220 Argo floats. About one-third of the world's active floats have been deployed from *Kaharoa* – far more than any other research vessel worldwide.

Fittingly, *Kaharoa II*'s first job will be adding to the Argo float network in the North Atlantic and the Pacific on its delivery voyage to New Zealand.

Upon arrival, *Kaharoa* and *Kaharoa II* will begin a series of joint missions, operating together for two months at sea to intercalibrate fisheries survey methods.

This work is needed to ensure the valuable survey time-series built up by *Kaharoa* over the past four decades, and crucial to New Zealand's marine resource management, continues.

"I'm super excited to see this vessel arrive in New Zealand. I can't wait to get on board to start counting and measuring fish," says O'Driscoll.

Back cover photo:

Cocoro Japanese Restaurant in Ponsonby, Auckland. Owner and chef Makoto Tokuyama uses yellowtail kingfish as part of his menu, sourced from NIWA's Northland Aquaculture Centre in Bream Bay. (*Rebekah Parsons-King*)