WATER & ATMOSPHERE

June 2016

Tangaroa

The modern-day *Endeavour*

Weather diaries
New Zealand's first meteorologist

Science and diplomacy
New Zealand-US collaboration

Sustainable fisheries
30 years of quota management

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Cover: RV *Tangaroa* is proving that good science and good business go hand-in-hand. (*Dave Allen*)

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NIWA
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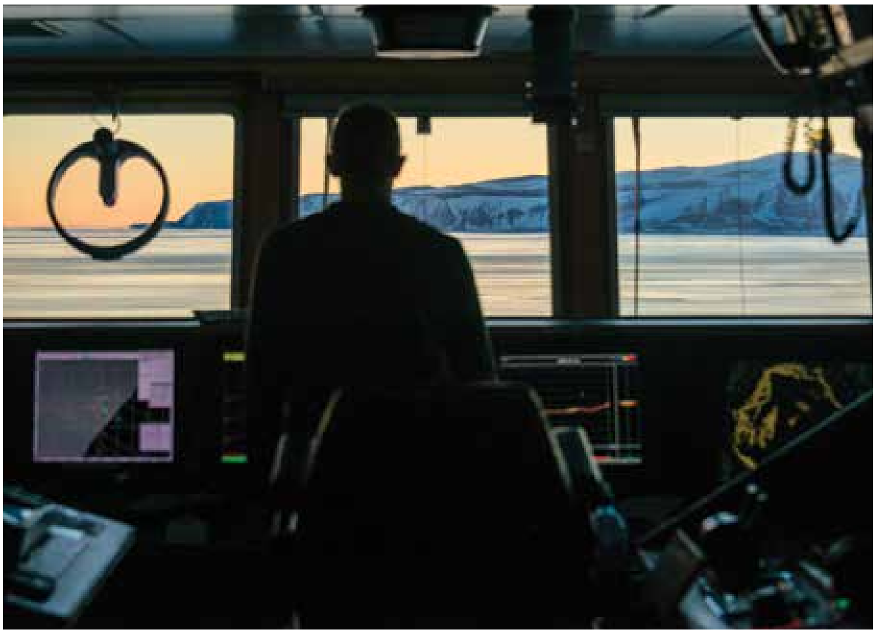
enhancing the benefits of
New Zealand's natural resources



Queen's Birthday Honours

NIWA Chairman
Sir Christopher Mace.
(*Dave Allen*)

Sir Rob Fenwick speaking at last year's NIWA Leaders' Forum. (*Dave Allen*)

NIWA was delighted to see two of its most passionate supporters receive high recognition in the 2016 Queen's Birthday Honours List.

Knighthoods were bestowed on NIWA Chairman Chris Mace and environmental entrepreneur Rob Fenwick.

Sir Chris has chaired the NIWA Board for seven years, and is passionate about education and science. He combines that with comprehensive business experience that has seen him become a director or investor in more than 50 companies.

In 2012 Sir Chris was named Māori Business Leader of the Year and, in addition to his NIWA responsibilities, he is also a commissioner of the Tertiary Education Committee, chairman of the Sir Peter Blake Trust Awards selection panel and serves on the Antarctic Heritage Trust Board.

"For me education is the centre of the universe and if we can that right and get this education to employment pathway sorted, then we're going to have the skills and motivated capability that will take the country forward.

"Of course the work that scientists do in their research and their applied science is critical to ensure we try to make the right decisions going forward."

Sir Rob chairs the Sustainable Seas National Science Challenge and is a board member of the Deep South challenge, both led by NIWA. Sir Rob also leads Predator Free New Zealand, chairs a trust to save kiwi, and initiated the New Zealand Antarctic Institute.

"What I am most satisfied about is how business generally in New Zealand has integrated more and more environmental responsibility and the principals of sustainability in their practices. That has been very satisfying," he said.

In brief

NIWA's Clean Air Monitoring Station at Baring Head in Wellington. (*Dave Allen*)

Significant result

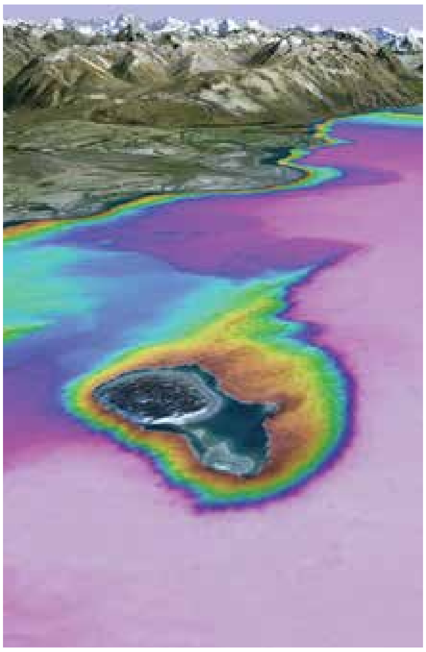
NIWA's Clean Air Monitoring Station at Baring Head recently recorded a significant result, with carbon dioxide readings officially passing 400 parts per million (ppm) – a level last reached over three million years ago.

Carbon dioxide is measured at similar stations around the world. Most emissions occur in the Northern Hemisphere, so the 400ppm threshold has already been passed at stations to the north of New Zealand. The Mauna Loa station in Hawaii passed 400ppm in November, the Australian monitoring station at Cape Grim, Tasmania reached it in the middle of last month, and that level has just been recorded in Antarctica.

NIWA atmospheric scientist Dr Sara Mikaloff-Fletcher says carbon dioxide levels have been steadily increasing for decades.

"This is a path we have been on for a very long time. The 400ppm threshold represents an opportunity for people to recognise this landmark and understand that there is only a small amount of time to accomplish change."

Agriculture is likely the dominant cause of rising global methane concentrations.



Lake Tekapo bathymetry. (*NIWA*)

Enteroctopus zealandicus, the elusive yellow octopus, photographed by NIWA's Deep Towed Imaging System. (*NIWA, Ocean Survey 20/20*)

Climate change breakthrough

Research led by NIWA atmospheric scientist Hinrich Schaefer has provided a major breakthrough in understanding the causes of climate change.

The findings from a study of methane emissions concluded that the rise of methane levels in the atmosphere since 2007 is most likely due to agricultural practices, and not fossil fuel production as previously thought.

NIWA worked with scientists from the University of Colorado and Heidelberg University in Germany who had already been taking measurements in a number of locations across the world.

"We wanted to put all the data together, then calculate the global average for each year and look at how that has changed over time," Dr Schaefer said.

"The data indicates that the source of the increase since 2007 was methane produced by bacteria, of which the most likely sources are natural, such as wetlands, or agriculture, for example, from rice paddies or livestock."

Still waters run deep

NIWA scientists have completed their first ever mapping of Lake Tekapo using state-of-the-art sonar equipment to collect bathymetric data.

The team, led by NIWA marine geologist Dr Joshu Mountjoy, first mapped the lake and then used seismic reflection survey equipment to get images of the sediment beneath the lake floor.

The seismic surveying gave scientists images more than 100m under the lake floor that reveal the long history of landslides in the lake.

Dr Mountjoy said the data revealed an unexpectedly dynamic lake bed with a range of processes influencing its shape.

"Lake Tekapo was created by large glaciers that bulldozed sediment down the valley 15,000 years ago – as far as where Tekapo is today. We can now see that about half of the 83 square kilometre lake floor is covered in landslide deposits, some spreading more than a kilometre across the lake bed."

The research is part of a two-year study funded by the Natural Hazards Research Platform.

Quite the catch

Scientists heading to the Auckland Islands to conduct a prey survey of the New Zealand sea lion will have a task on their hands catching the elusive yellow octopus.

A key prey species for the endangered sea lion, NIWA fisheries scientist Dr Jim Roberts says the octopuses are large and probably abundant, but very little is known about them.

"Sea lions eat about one million octopuses a year at the Auckland Islands alone, yet only about 50 specimens have ever been caught by scientists," said Dr Roberts.

"Somehow they evade trawl nets. They either squeeze out of nets or avoid going into them at all."

NIWA technicians have purpose-built 100 yellow octopus pots for the research. The pots, which will be lowered to the sea floor, can catch up to four octopuses at a time.

Underwater cameras will also be used to capture the density, depth and habitats of the octopus and other sea lion prey species.

Dear diary: A pioneer of meteorology

The discovery of diaries of an English missionary living in Northland in the 1800s reveals him as New Zealand's first meteorologist. By Susan Pepperell.

It took Drew Lorrey only a matter of seconds to realise what he'd found.

The NIWA climate scientist was searching the National Register of Archives when the name Richard Davis appeared, with reference to his diaries and two volumes of meticulous meteorological records. These diaries, in fine, looping handwriting, were, Dr Lorrey says, "hiding in plain sight".

Lorrey believes they could be the earliest continuous land-based meteorological measurements made in New Zealand. Regular land-based meteorological observations in New Zealand had been started in the early to mid 1850s by the Royal Engineers in Auckland.

"We've given Richard Davis the title of New Zealand's first meteorologist because of the length and detail of the data he kept – the earliest reported quantitative meteorological account for New Zealand kept over multiple years," says Dr Lorrey.

Rev Richard Davis, circa 1860.
(*National Library of New Zealand – PAColl-7344-97*)

Dr Lorrey and colleague Petra Pearce are part of an international scientific collaboration that digitises historical weather observations.

Richard Davis's inadvertent contribution to this project started more than 175 years ago. He was an English colonial-era missionary, sent from Dorset to Northland by the Church Mission Society, arriving in 1824 aged 34, with his wife Mary and their six children.

A farmer by profession, he established a farm at Waimate North. It was arduous work; suitable land was scarce, and crops failed. Rev. Davis was a prolific correspondent, sending thousands of letters back to friends in England.

In his letters he details the busy comings and goings around the Bay of Islands, his interactions with local Māori and his efforts to grow plants, including fruit trees and vegetables, from seeds sent from England. A vital part of this endeavour required an understanding of the local climate.

Rev. Davis recorded the temperature each day at 9am and again at midday, along with a midday pressure measurement. He also commented on wind flow, wind strength and cloud cover, and made notes about extreme weather events.

The records that survive cover nine years of weather observations in two parts, from 1839 to 1844 and from 1848 to 1851. The intervening gap corresponds to the time he was ordained as a deacon and left Waimate to establish the Kaikohe Mission Station.

Two astounding entries record snow – adding to a total of six historic accounts of snow falling in Auckland and Northland, the latest in 2011.

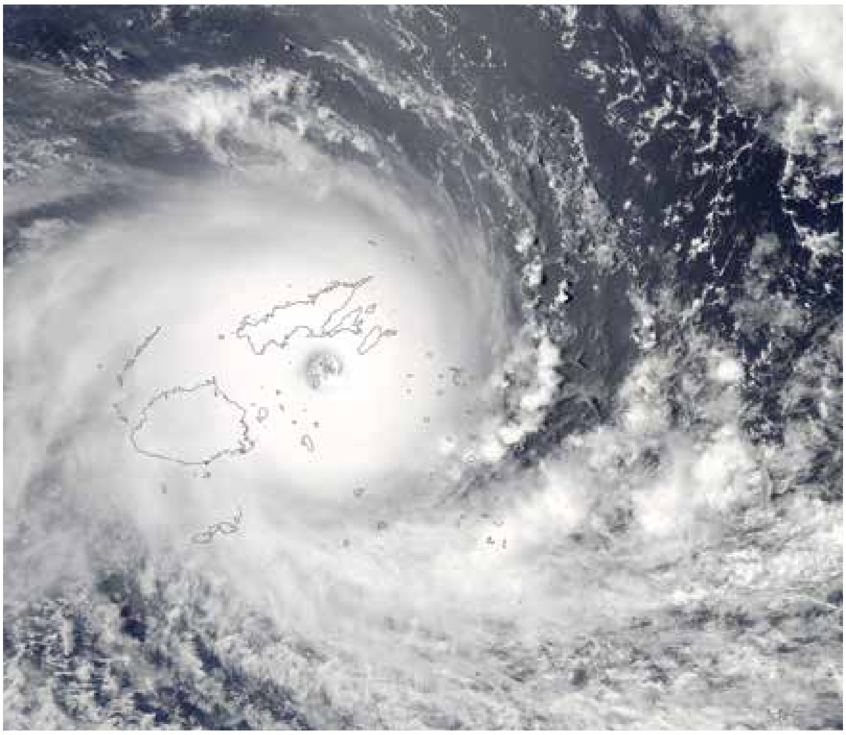
On 30 July 1849, Rev. Davis wrote: "Hail storms. This morning the southern hills and Poutahi covered with snow." And the next day: "This morning the hills were again covered with snow."

The diaries reveal that, on average, winters were colder and summers warmer during Rev. Davis's time, which may be a result of the poor placement of his thermometer.

Dr Lorrey and Mrs Pearce have now had a paper published on the diaries in the international scientific journal Climate of the Past. The Davis diaries will be fed into the 20th Century Reanalysis Project which aims to reconstruct six-hourly snapshots of the weather conditions across the globe.

Rev. Davis died in 1863 and is buried in the cemetery of the Waimate Mission House.

Near-total destruction: The Fiji Meteorological Service quarters in Vanua Balavu. (*Fiji Meteorological Service*)



Cyclone Winston slams into Fiji. (*NASA*)

At the speed of a bullet train

Category 5 Cyclone Winston made landfall in Fiji on 20 February, damaging and destroying thousands of homes and buildings. It left in its wake a death toll of 44 and more than 50,000 people in evacuation centres.

Also enduring the cyclone were numerous weather stations, designed by NIWA and installed over the last decade for the Fiji Meteorological Service (FMS). The stations gather data about Fiji's climate variability that provide information to help reduce the impacts caused by severe weather and climate events.

During the cyclone, some FMS weather stations recorded wind speeds of over 300 kilometres per hour and saw barometric pressures plummet to 930mb.

"Three hundred kilometres per hour is nearing the speed of the Japanese bullet trains (320kmh). A piece of debris in the wind travels just as fast and can cause catastrophic damage to objects in its path," said NIWA Principal Scientist Environmental Monitoring Graham Elley.

The weather stations are located on Fiji's main and outlying islands and are designed to record wind speeds, wind direction, air temperature, humidity, barometric pressure and rainfall. All data collected are sent to a secure central database accessible by FMS and remotely by NIWA. It is used to provide both real-time and historical information, including warnings of inclement weather.

Despite being erected on robust steel poles and protected by steel casings, withstanding these 300 kilometre per hour wind speeds in the cyclone proved too much for some of the stations.

"Our data logger housing is mounted on a 10 metre tubular steel mast and is covered in two layers of steel. At one station, the wind had blown the outer layer right off the main housing, almost like a banana being peeled. Vibrations set up by the wind actually broke a nickel cross arm supporting the wind direction sensor, and we suspect other damage was caused by debris flying at such high speeds," Elley said.

For the stations that survived the cyclone, Elley was impressed they were able to continue transmitting data over the duration of the cyclone.

"By using satellite communications to transmit data from the weather stations, we are able to reduce the 'weak link' caused by damage to land-based communications alternatives. It is also the best way for us to get data back from remote places such as Fiji's outerlying islands where the land-based infrastructure is less common," Elley said.

The data extremes measured at the stations were able to be independently verified using global weather satellite data and imagery from a local Doppler radar. The information made it possible for FMS to analyse the track of the cyclone, estimate the diameter of its eye and the locations of the most intense rain bands in the eye wall.

Panorama: John Morgan

Punching above our weight in the world

New Zealand may be a small nation, but it is making a disproportionate contribution to some of the world's most significant and pressing global science issues. At NIWA, we have many long-established and profound international science linkages, and these connections are increasing both understanding and awareness of global issues in climate and atmosphere, freshwater and marine science. NIWA's leadership and expertise is highly valued and sought after, in recognition of our skills and resources, New Zealand as a unique laboratory and our important role on the global stage.

Our close, collaborative relationship with the United States is highlighted in this issue of Water & Atmosphere. It is a relationship built on mutual respect and the delivery of leading-edge scientific outcomes and the application of that knowledge. Our capabilities, and that collaborative attitude, result in NIWA working alongside many of the world's most respected and advanced science organisations.

But the reasons for the many successful collaborations go much further than world-class science and a collaborative approach. New Zealand's geographical location – and isolation – make it an ideal "laboratory" for international research in the atmosphere, freshwater, and marine environments. Our marine estate is the world's fourth largest and one of the most diverse. And, as a nation, we are trusted scientific and environmental stewards of Antarctica and the Southern Ocean.

We estimate the value of direct research funding from our international partners to NIWA's collaborative research to be more than $50 million over the last decade. These funds have contributed to research voyages of NIWA's state-of-the-art research vessel *Tangaroa*, atmospheric measurement campaigns and Antarctic studies. The total international investment in New Zealand-based collaborative research has been in the $100s of millions, especially those initiatives that have included visits of overseas research vessels and aircraft, and specialist equipment.

The largest global geoscience programme has just confirmed that the ocean-drilling research vessel Joides Resolution will spend a year in New Zealand waters and the Ross Sea. This $80 million series of projects is designed to shed light on earthquake and tsunami risk, and to enhance our understanding of how the oceans and marine life will respond to rapid environmental change.

David Dayton, NIWA Chief Executive John Morgan, Ed Gorecki (NOAA), Nancy Cavallaro (USDA), Tom Hourigan (NOAA), and NIWA GM Research Rob Murdoch at the MOU signing in Washington DC.

Deepwave was the biggest scientific experiment to be carried out in New Zealand for more than 20 years. (*Dave Allen*)

NIWA's Research Station at Lauder is internationally recognised as a centre of excellence in atmospheric science. (*Dave Allen*)

NIWA has been working alongside the Scripps Institution of Oceanography and the University of Washington on one of the world's most ambitious and successful international marine research projects. The Argo project is helping us understand more about the impact of global climate change and how ocean temperatures are affecting climate patterns. Funded by NOAA, the US National Oceanic and Atmospheric Administration, NIWA has deployed a network of more than 1000 floats – more than one-quarter of the total global array of nearly 4000 floats – measuring salinity and temperature in the Pacific and Indian Oceans. According to NOAA Argo Program Manager Steve Piotrowicz, the programme would not exist if NIWA had not contributed to the deployment of the floats.

NIWA's Clean Air Monitoring Station at Baring Head, overlooking Cook Strait, with the longest running continuous atmospheric CO_2 record in the Southern Hemisphere makes significant contributions to the global understanding of greenhouse gases. In June this year the CO_2 levels we recorded at Baring Head passed 400 parts per million – a level last reached more than three million years ago.

NIWA's Research Station at Lauder in Central Otago, which is complemented by our atmospheric measurement site at Arrival Heights in Antarctica, is internationally recognised as a centre of excellence in atmospheric science, and is one of only eight Global Climate Observing System Reference Upper Air Network measurement sites worldwide, and the first and only site in the Southern Hemisphere. Lauder's research is key to advancing global knowledge about the changing composition of the atmosphere, and has provided data under the Montreal Protocol that has contributed to international efforts to reduce the Antarctic ozone hole.

NIWA is also one of an elite group of weather and climate organisations worldwide who collaborate with the UK Met Office as operational users of its internationally renowned and globally used weather forecasting system, the Unified Model. Last year NIWA was appointed a core partner, putting us at the governance table of the model. The UK Met Office also uses world-leading software developed by NIWA – Cylc – to run and manage all the operational systems for its Unified Model. This software is now being implemented by other countries that use the Unified Model.

In 2014 NIWA was a key collaborator in the biggest scientific experiment to be carried out in New Zealand for at least 20 years – the Deepwave (Deep Propagating Gravity Wave Experiment) experiment to study the atmosphere over the Southern Alps – with the ultimate aim of more accurate weather forecasting. Funded by the US National Science Foundation, Deepwave was led by the US National Center for Atmospheric Research and the German Aerospace Centre.

This work typifies the size, scope and importance of the global scientific work NIWA is involved in, and the international collaborations and alliances that are formed to facilitate New Zealand's unique and invaluable role in global science advances. Science has perhaps the most important role in addressing many of the critical issues currently facing our planet, and no single country can address these in isolation. Partnerships are paramount. NIWA's contribution and participation in these global science initiatives is essential if New Zealand is to have the technical capability it needs to credibly and effectively contribute to and influence international agreements and initiatives.

John Morgan is Chief Executive of NIWA.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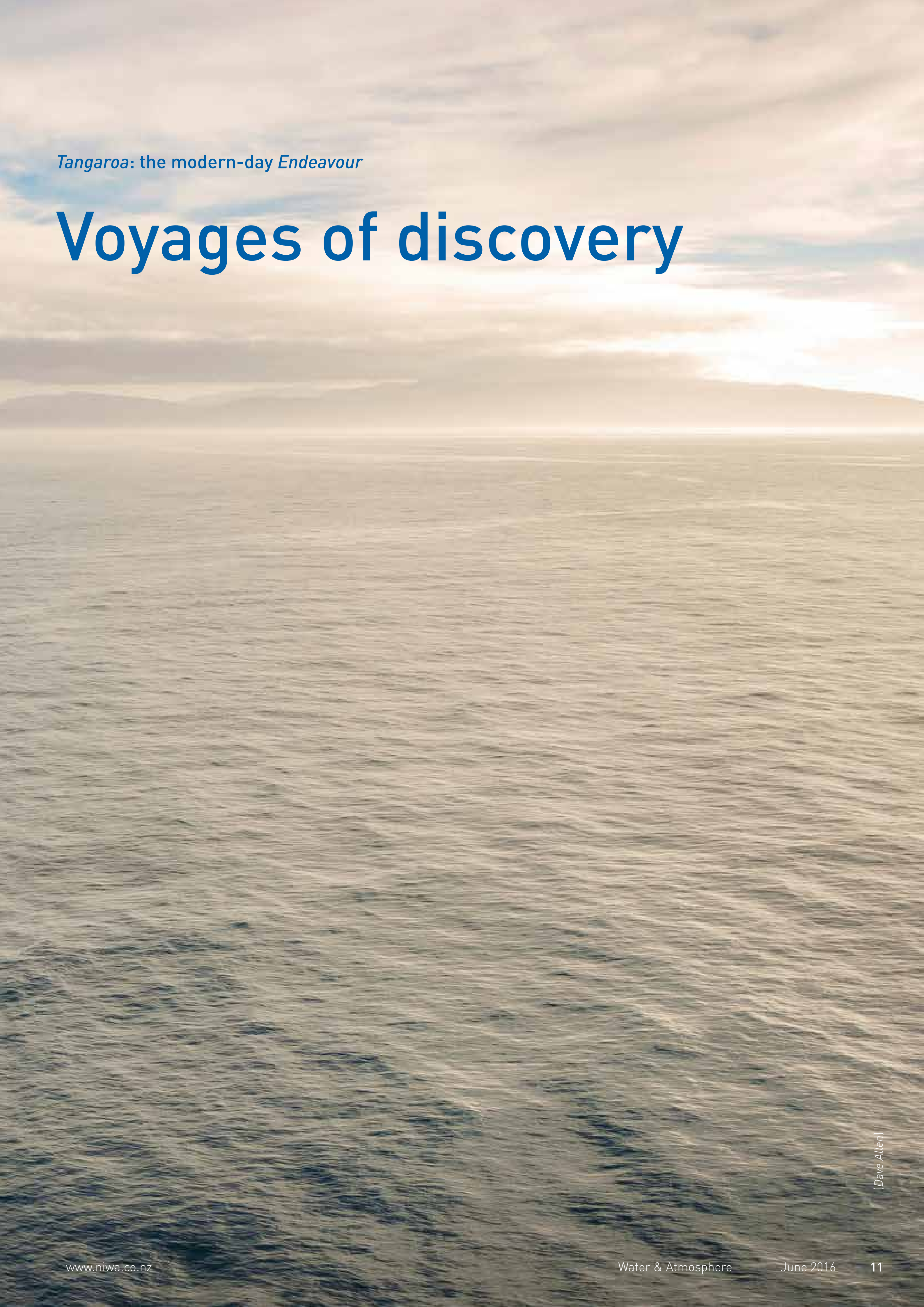
Tangaroa: the modern-day *Endeavour*

Voyages of discovery



[Dave Allen]

NIWA's flagship of New Zealand ocean research – *Tangaroa* – is the modern-day *Endeavour*, venturing into open oceans to conduct work that's proving how science and commercial outcomes go hand-in-hand.

In 1769, having reached Tahiti, Captain James Cook opened sealed orders from the Admiralty detailing the next phase of his Voyage of Discovery.

With the Transit of Venus completed, Cook's 'real' mission was to sail the research vessel HMS Endeavour south in search of *Terra Australis* – the fabled southern continent – and claim its riches for the Crown.

On 6 October 1769, Cook and the *Endeavour* reached the coast of New Zealand, 127 years after Abel Tasman. After mapping the complete New Zealand coastline, proving the country was made up of two main islands, Cook set a course home in March 1770, now all but certain the southern continent did not exist.

On subsequent voyages in 1773 and 1774 Cook crossed the Antarctic Circle, but it wasn't until 1820 that Antarctica was finally sighted in the hypothetical area of *Terra Australis*.

While Cook failed in his quest to claim the purported riches of the southern continent, he set the stage for amazing discoveries to come – discoveries that NIWA's state-of-the-art marine research platform *Tangaroa* continues to make possible today.

As well as increasing knowledge and understanding of the world around us, *Tangaroa* is playing a leading role in identifying, documenting and enhancing the value of New Zealand's extensive marine resources, demonstrating that good science and good commerce are not mutually exclusive, but mutually beneficial.

Jewel in the crown

Tangaroa is New Zealand's only deepwater research vessel. Design and construction began in 1989 in Norway in consultation with staff from the former MAF Fisheries Research Centre.

Fifteen months later, in April 1991, *Tangaroa* was ready for launch, replacing the outmoded GRV *James Cook*.

With a trawler design, *Tangaroa*'s primary role initially was fisheries research. After significant upgrades and improvements over the past two decades, however, *Tangaroa* is now a highly capable, multi-role, oceanographic research vessel.

NIWA owns and operates *Tangaroa* on behalf of the Crown, along with its other important research vessels – *Kaharoa*, a multipurpose research vessel notably involved in the Argo

First Mate Ian Popenhagen guides *Tangaroa* through the icy waters of Terra Nova Bay, Antarctica. (*Dave Allen*) project, the world's largest single science collaboration to deploy profiling floats in all of the world's oceans, and *Ikatere*, a survey launch designed primarily for coastal surveys using multibeam transducers to map the seabed.

All three vessels fulfil critical roles for a maritime nation, but *Tangaroa* is the jewel in NIWA's crown.

In 25 years the vessel has travelled more than one million nautical miles – equivalent to circumnavigating the globe 50 times – conducting much of New Zealand's most important and valuable scientific work in some of the most remote and inhospitable places on the planet.

The role it was originally designed and used for is now just one of many, says NIWA Vessel Operations General Manager Greg Foothead.

"*Tangaroa* was doing about 200 days a year of fisheries research. That's predominantly what it did – fisheries stock assessment, with some scientific voyages as well.

"Progressively over the years, and in response to changing needs and requirements, *Tangaroa*'s role has evolved into what we now have – a sophisticated, multi-role, multi-disciplinary scientific platform."

Tangaroa is now at the heart of about one-third of all marine research work undertaken by NIWA.

"Today we're doing about 60 to 70 days a year of fisheries research and the rest is primarily oceanography, marine biology and geology work.

"That changes depending on what the focus of interest is at the time, whether it's looking at climate change, for example, or mapping the ocean floor to understand more about what lies beneath."

The vessel's busy schedule now sees it at sea for about 300 days a year. And, thanks to continued strategic investment in upgrading equipment and capabilities, NIWA has ensured *Tangaroa* remains New Zealand's single most substantial piece of scientific equipment.

High-tech on the high seas

Tangaroa is the country's only ice-strengthened research vessel, opening up Antarctic and Southern Ocean waters. Last year, *Tangaroa* made its tenth voyage to Antarctica, collecting data and observations on ecosystems and species – including toothfish, and humpback and blue whales – in Antarctic waters.

A $24 million upgrade in 2010 included the addition of a dynamic positioning system to *Tangaroa*'s growing list of capabilities.

The system, DP2, uses three thrusters, the main propulsion propeller and computerised controls to keep the vessel within a specific area or on track. The individual thrusters are engaged when required.

Tangaroa is the only New Zealand-based vessel with the technology, which allows it to stay in one place (within a few metres) or, if required, move unerringly along a path. This vastly improves its ability to deploy and precisely locate gear such as seabed samplers, soil and rock testing equipment, seabed drill rigs, and remotely operated vehicles.

The system is often employed to keep the vessel stationary in waters too deep to anchor, but also in the case of specialist surveying to track in straight lines or follow underwater vehicles.

The system is vital to NIWA's open water research work, says Foothead.

"The DP2 capabilities are especially essential in the case of many new technologies which require vessels to hold a steady position. These technologies include the use of remotely operated vehicles, autonomous underwater vehicles, manned submarines, seafloor observatories and other equipment that is temporarily fixed to the seabed.

"The DP2 takes the human factor out of controlling the ship's position. The system is intuitive and compensates for changes in environmental conditions."

Another piece of crucial research equipment is *Tangaroa*'s hull-mounted multibeam echosounder.

The Kongsberg EM300 multibeam system was installed in 2000 and upgraded in 2010 to a Kongsberg EM302. The upgrade involved installing new transducers, transceiver, computers and associated software, allowing for detailed scanning of the seabed up to 7000m beneath the surface of the water.

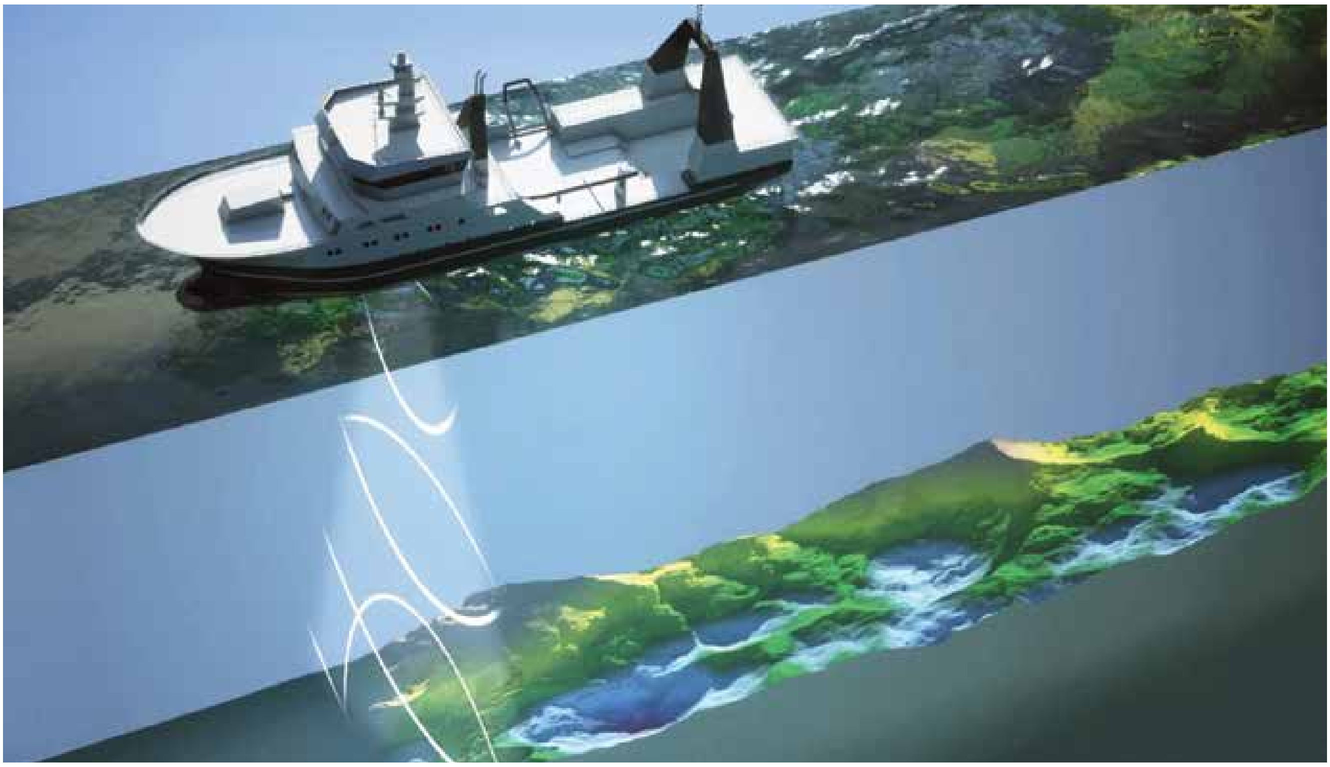
Depending on depth, the multibeam echosounder maps the seabed in a swath up to eight kilometres wide and, with 864 soundings per ping, it provides incredibly high-resolution imagery.

It's a far cry from the bathymetric 'technology' employed by Cook onboard the *Endeavour* – a lead weight on the end of a rope. Cook could not have imagined that beneath the surface of the water was a rich seascape of ridges, valleys, plateaus, canyons and seamounts, as well as extraordinary flora and fauna.

Thanks to the technology on *Tangaroa*, we know more about our vast undersea realm than ever. But, for all that, only about 1.5 million square kilometres – or 15 per cent – of New Zealand's massive marine realm has been accurately mapped to date.

While bathymetric data reveal the shape and depth of the ocean floor, imagery data use the strength of the return signal (backscatter) to indicate sediment features and habitats, says marine geologist Helen Neil of NIWA's bathymetric data-gathering.

The system also records water column information which is used to identify seeps, plumes and other features not normally imaged in the bathymetry data.



Tangaroa's multibeam echosounder produces a 'sound-fan' of 288 acoustic beams which reveals a very detailed picture of the seabed up to 7 kilometres below the surface. (*NIWA*)

As well as the enormous scientific knowledge and deeper understanding of what lies beneath the ocean surface delivered by the technology on *Tangaroa*; the DP2, multibeam echosounder and the recently installed Kongsberg TOPAS PS18 sub-bottom profiler systems also provide capability important to industry, notably in fisheries, mining and oil and gas exploration.

Riches from the deep

New Zealand possesses vast potential wealth in energy and minerals. Much of that wealth lies offshore, however, either on the seabed or locked beneath it.

NIWA is playing a pivotal role in the growth and development of New Zealand's valuable oil and gas sector. It has also provided surveying, habitat mapping and expertise related to the exploration of offshore mineral resources for nearly three decades.

Tangaroa is a critical piece of equipment in this ocean exploration. The TOPAS sub-bottom profiler characterises marine sediments and strata up to 200m below the seabed. This helps identify subsurface gas hydrates, which on the surface of the seabed can also be indicated by carbonate accumulations, hydrocarbon or methane-based seeps and gas chimneys.

The multibeam echosounder can detect plumes of escaping methane or hydrocarbon-based gas seeps in the water column, while the DP2 capability means *Tangaroa* can hone in and survey specific locations of interest.

But energy and mineral exploration poses questions about the viability of resource extraction and potential environmental impacts.

NIWA's environmental expertise is a core part of its exploration brief, with environmental data collected and seafloor habitats identified, such as the discovery of unique chemosynthetic communities.

Chemosynthetic ecosystems are fuelled by chemicals, such as methane gas, rather than sunlight. They occur at cold seeps, hydrothermal vents, sunken whale carcasses and bones, and sunken wood.

New Zealand is one of the few places in the world where several chemosynthetic habitats occur in close proximity, allowing scientists to address key questions about their unique ecology and biodiversity.

NIWA's DTIS (Deep Towed Imaging System) camera, deployed from *Tangaroa*, has not only captured footage of live seeps, such as methane bubbling from the seafloor and other direct hydrocarbon indicators, but also ecological characteristics and biodiversity hotspots.

"In order to manage something, you need to know what's there, and that's everything from base bathymetry through to what is living in and on it," says Dr Neil.

"In oil and gas exploration, for example, direct hydrocarbon indicators, things like carbonate blocks – hard grounds – that will give us a high backscatter return, can have specific faunas that grow around these seeps, like Calyptogena valves and tube worms.

"Then, of course, they (explorers) are also looking for the seeps being active within the water column."

Once resource potential has been established, research turns to establishing baseline surveys, habitat assessments and oceanography to better understand the ecology, chemistry and ocean physics of the target areas. This holistic ecosystem management approach ensures NIWA is at the forefront of the science required to provide decision makers and managers with the information required for sustainable marine resource use.

In terms of good science, NIWA's collaboration with industry is a win-win.

"New Zealand Inc. gets more data, but, as part of this process, environmental monitoring is also occurring," says Dr Neil.

"We get more bathymetric data, backscatter data, water column data. We are taking environmental samples and DTIS video.

"We are gaining information from the deep sea about biologic communities and ecosystems when there's a global paucity of information about the deep sea.

"It's a balancing act that all countries have to make between management, use, sustainability, conservation, tourism and knowledge to make wise decisions."

The symbiosis between NIWA's scientific excellence and work with industry led to the appointment of Rob Christie as Commercial Manager of Marine Business Services in 2013.

A chartered water and environmental manager and scientist with more than 20 years' international experience, part of Rob's role is to coordinate NIWA's maritime operations, most of which are conducted using its research fleet.

While the Ministry of Business, Innovation and Employment and the Ministry for Primary Industries provide key government support for *Tangaroa*, the use of NIWA's vessel-based expertise by overseas research organisations and private sector clients has become increasingly important in maintaining a high level of vessel utilisation each year.

Non-government charters of *Tangaroa* average about 70 days each year, mostly in international ocean science initiatives and industry-based marine habitat and resource exploration.

"Maximising the utilisation of *Tangaroa* is imperative," Rob says. "The more days it is working the better our control of operational and maintenance costs, which also maximises our use of the vessel for scientific opportunities.

Images of a black smoker on Brothers Seamount and a gorgonean coral taken by NIWA's multipurpose camera ensemble DTIS, shown being deployed (top right). (*Helen Kettles*)

Voyages of discovery

"It's a careful juggling act, scheduling scientific voyages with time-bound fisheries stock assessments and private sector contracts with fixed delivery dates.

"This is, after all, a national marine facility, and it is NIWA's role to secure the resources needed to effectively operate and maintain it.

"We've been successful at finding 300 or so days of work for the vessel each year, but it takes negotiation across multiple stakeholders with differing needs to get there.

"The result is a vessel platform that's cost-effective for all our users, both government and non-government alike.

"To achieve the level of vessel utilisation required, we've also established good working relationships with the other Crown Research Institutes, overseas research organisations similar to ourselves that see the value in research science and collaboration and industry operators throughout the Asia Pacific region.

"The recent spike in exploration work over the past five years has helped us develop our international reputation and helped showcase our vessel capability, not only from a technical point of view, but also for the scientific expertise involved, particularly around environmental impact assessments."

NIWA is highly regarded internationally as a pre-eminent ocean science organisation, and continues to invest significantly in upgrading scientific and operational expertise to maintain this position. Its scientists and services are highly sought after in a range of sectors.

For example, NIWA is often selected as a research organisation for international oil and gas company OMV in its exploration work.

"They (NIWA) understand and are willing to meet the high operating standards we have in the oil industry, and we benefit from local experts who have deep experience in the area – they don't have to learn," says OMV New Zealand Exploration Manager Simon Lange.

"They know the environment and how to operate safely in New Zealand waters."

OMV New Zealand's use of *Tangaroa* helps support the excellent scientific work NIWA does for New Zealand, Lange says.

"Engaging NIWA in our commercial activities is a real win-win situation. But it's important to note that NIWA's role is strictly delivering scientific information. They don't play any part in making decisions about hydrocarbon exploration. There is an absolute separation of the two.

Long time-series of trawl or acoustic surveys enable reliable abundance estimates for key fish species. (*Dave Allen*)

Tangaroa made New Zealand bigger

In 2008, New Zealand experienced a massive growth spurt – gaining an area of control the size of Libya.

Approved by the United Nations Commission on the Limits of the Continental Shelf, New Zealand was made sovereign over 1.7 million square kilometres of seafloor in addition to its control of the Territorial Zone and Exclusive Economic Zone.

These areas combined, including the Ross Dependency and the area of search and rescue responsibilities, mean New Zealand governs one of the largest maritime estates in the world, accounting for nearly 10 per cent of the world's oceans.

Initiated to clarify rights to oil, gas and mineral resources, the UN approval of New Zealand's proposal gave New Zealand exclusive rights to develop and manage resources in the acquired area. New Zealand was just the fourth country in the world to gain the UN's rubber-stamp of its extended continental boundaries.

The new boundaries were the result of survey and research work that began in 1999 involving the Ministry of Foreign Affairs and Trade, Land Information New Zealand, the Institute of Geological and Nuclear Sciences, and NIWA.

NIWA's flagship research vessel, *Tangaroa*, played a pivotal role in obtaining much of the data and research that went into the successful proposal to the UN.

"*Tangaroa* provided that key information," says NIWA General Manager of Research Dr Rob Murdoch.

"There was a whole bunch of historical information, but *Tangaroa* did the remaining survey work to provide the data that enabled New Zealand to make the claim.

"It grew New Zealand's area of jurisdiction by another 25 per cent, about 1.7 million square kilometres, with rights to manage any resources associated with the seabed only, not the water above it, as we do with the EEZ."

Dr Murdoch said *Tangaroa* had obtained the seismic and multibeam data on multiple voyages, travelling a total of more than 30,000km.

"It was the only vessel that could've done that work – it was data that only we had the equipment and the vessel to gather."

"In the past, *Tangaroa* has done swath bathymetry and seabed sampling for OMV. In our case, much of the data they acquire for us becomes public after five years and available to be used by anyone interested. NIWA actually has some advantages here. They acquired the data, too, so they don't have to reprocess it or make assumptions or guesses about it."

Greg Foothead agrees that NIWA's oil and gas work has tremendous scientific spinoffs. As well as the opportunity to survey vast areas of ocean that would otherwise remain uncharted, the specific requirements of the oil and gas sector have demanded investment in new scientific technology and skills.

"We wouldn't have a lot of the gear we currently do (on our research vessels) unless we were able to make solid business cases for it."

Captain Cook may have failed to discover southern riches, but NIWA and *Tangaroa* are ensuring New Zealand does .

From high seas to estuaries

Kaharoa's multipurpose capabilities are well demonstrated by its deployment of more than one-quarter of the world's 4000 Argo floats from South America to South Africa. (*Dave Allen*)

While *Tangaroa* might be considered its flagship, NIWA's extensive range of maritime work could not be completed without the support vessels *Kaharoa* and *Ikatere*. NIWA's fleet has capabilities exceeding those offered by many international research vessels.

When NIWA's vessels are not at sea, *Tangaroa*, *Kaharoa* and *Ikatere* can be spotted on Wellington's waterfront.

Kaharoa (Drift net)

The task of quantifying New Zealand's scampi supply, worth $20 million in annual exports, has been charged to *Kaharoa* and her crew this year.

The project involves a 45-day voyage to the Auckland Islands trawling for scampi to assess abundance. The rough and sub-Antarctic waters are no challenge for *Kaharoa*, which has travelled more than 75,000 nautical miles in her time.

The vessel's trawl depth of 600m makes it perfect for surveying marine life such as scampi, which spend much of their adult life on the muddy sea floor in burrows. While a trawl can give scientists an indication of abundance, *Kaharoa* is also able to deploy underwater cameras to examine the burrows in which scampi live.

Additional to trawl survey work, *Kaharoa* is equipped to support acoustic measurement of fish abundance, provide dive support and complete survey work in biology, ecology, geology and sedimentology. With space for five scientific staff, five crew and an eight-tonne insulated ice hold, *Kaharoa* is proving itself to be much more than just *Tangaroa*'s kid sister.

Ikatere (Grandchild of Tangaroa)

At almost 14m long and fitted with two Hamilton jet engines, *Ikatere* is fast, nimble and versatile.

Built in 2009, the vessel's Dynamic Positioning System allows it to stay on location when completing work such as deploying buoys, moorings, seabed sampling and bathymetric mapping.

In January, *Ikatere* was commissioned to take part in a blue whale study off the Taranaki coastline.

Scientists from Oregon State University and the Department of Conservation were able to deploy hydrophones off the vessel and down to the sea floor to record vocalisation from a congregation of blue whales. The recordings gave the researchers an indication of the location of the whales and assisted in mapping their movement patterns.

From *Ikatere*, they could also photograph whales for identification, launch drones to capture aerial footage and take tissue samples from the whales for isotopic analysis.

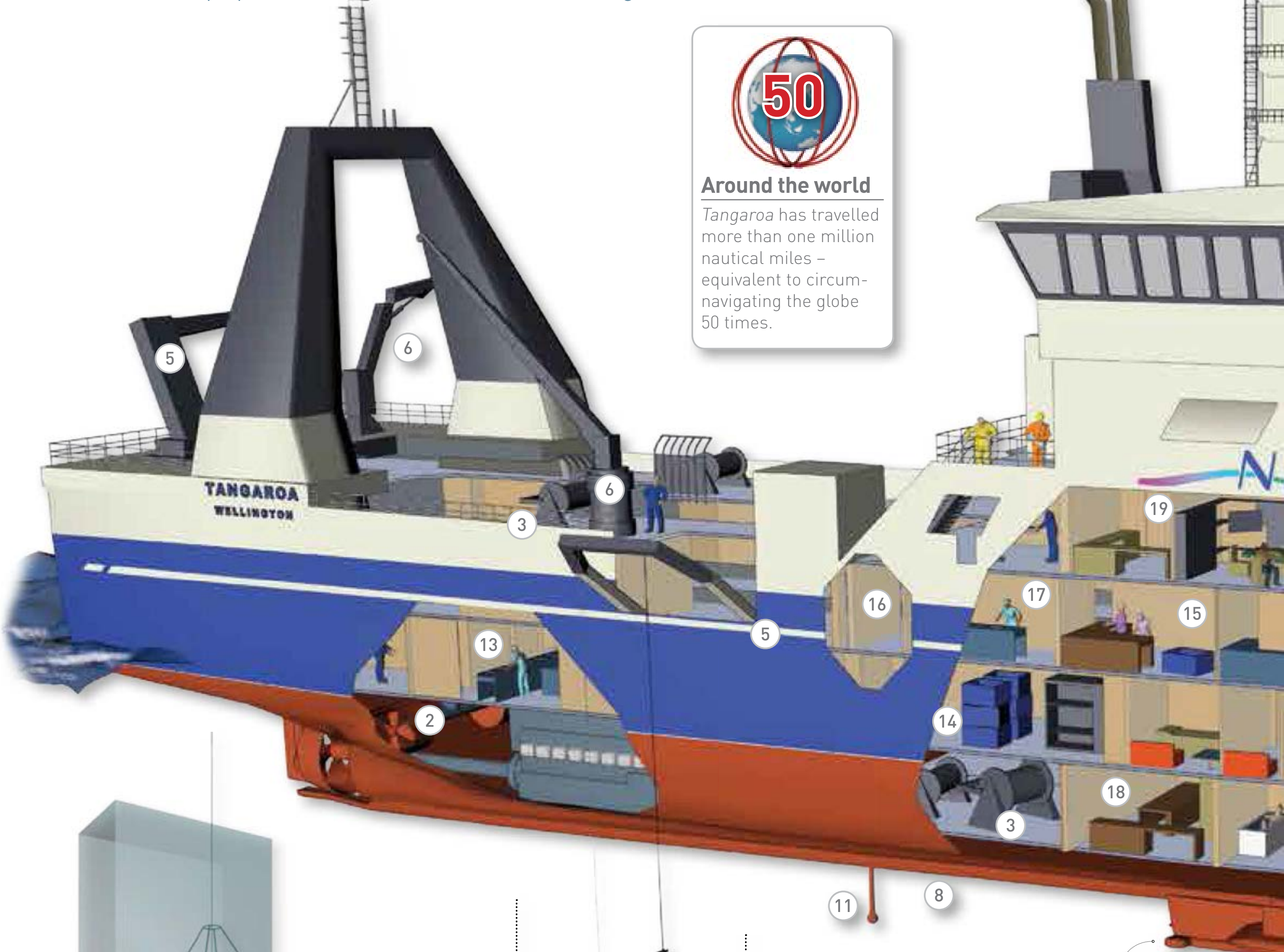
Alongside the larger vessels, NIWA operates about 30 other Maritime New Zealand-certified vessels.

But, while they have some very sophisticated equipment and vessels at hand, NIWA scientists go back to the basics when the job is right – often using small, non-motorised craft such as kayaks, canoes and aluminium dinghies or inflatables to visit remote sites on ponds, lakes, rivers and estuaries.

Ikatere's Dynamic Positioning System allows it to stay on location when deploying buoys, sampling the seabed or mapping the bathymetry. (*Dave Allen*)

High-tech on the high seas

Science equipment onboard NIWA's RV *Tangaroa*



Around the world

Tangaroa has travelled more than one million nautical miles – equivalent to circum-navigating the globe 50 times.

Seabed grab

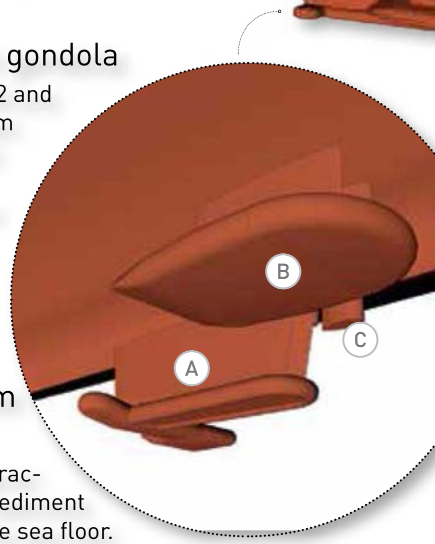
Large metal jaws designed to take a sample of sediment out of the surface layer of the seabed.

A. Multibeam gondola

Houses the EM302 and EM2040 Multibeam Echosounders for measuring topography of the sea floor, measuring backscatter and collecting water column data.

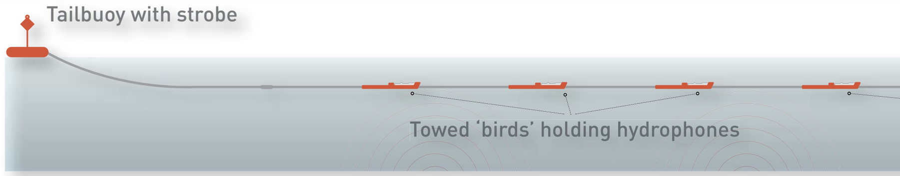
B. Sub-bottom profiler pod

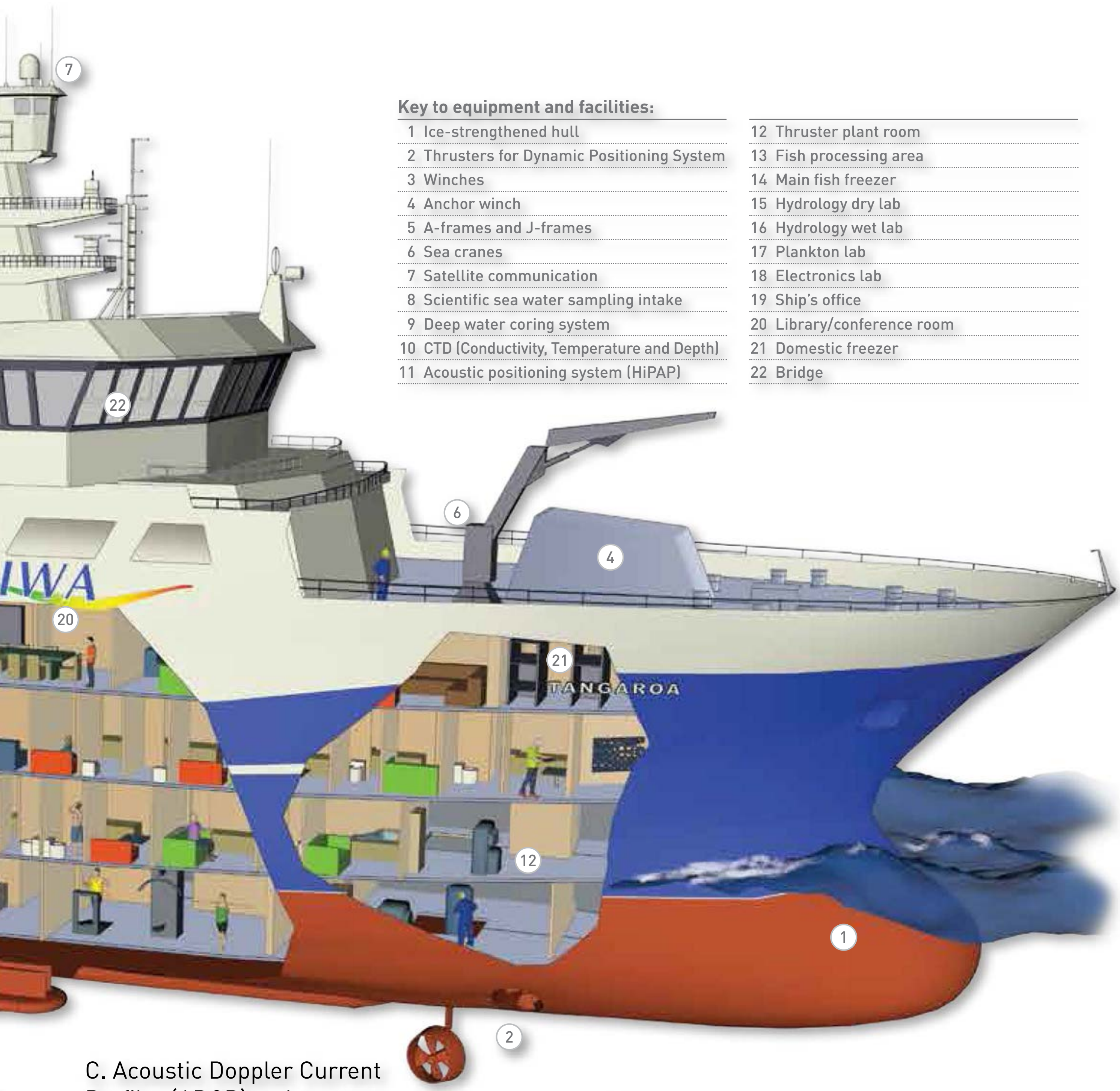
Identifies and charac-terises layers of sediment and rock under the sea floor.



Multichannel seismic system

A system which uses a sound source (air guns), hydrophones and acquisition software to identify geological structures and sediments beneath the sea floor.





Key to equipment and facilities:

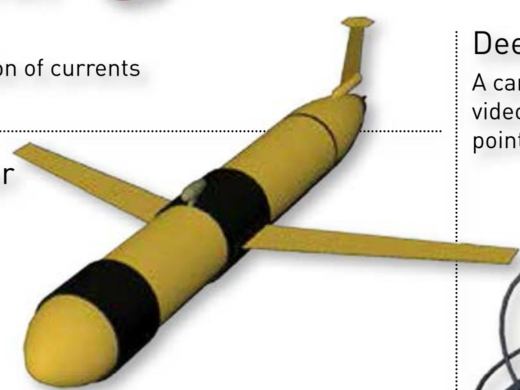
1 Ice-strengthened hull	12 Thruster plant room
2 Thrusters for Dynamic Positioning System	13 Fish processing area
3 Winches	14 Main fish freezer
4 Anchor winch	15 Hydrology dry lab
5 A-frames and J-frames	16 Hydrology wet lab
6 Sea cranes	17 Plankton lab
7 Satellite communication	18 Electronics lab
8 Scientific sea water sampling intake	19 Ship's office
9 Deep water coring system	20 Library/conference room
10 CTD (Conductivity, Temperature and Depth)	21 Domestic freezer
11 Acoustic positioning system (HiPAP)	22 Bridge

C. Acoustic Doppler Current Profiler (ADCP) pod

Measures the speed and direction of currents under the vessel.

Autonomous Underwater Vehicle (AUV)

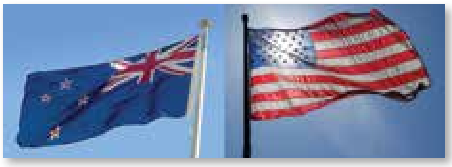
A programmable vehicle that can drift, drive or glide through the water on a pre-programmed mission without real-time control.



Deep Towed Imaging System (DTIS)

A camera system with high definition still and video cameras, lights, strobes and laser pointers mounted on its frame.

Source: NIWA. Text: Nicky Barton. Graphic: Arie Ketel, redVilla



Our American friends

The friendship between New Zealand and the United States continues to grow and evolve, and science is helping forge a new path for the two nations.

Helen Clark once described New Zealand and the United States as old friends. She said the relationship was a very important one because of the two nations' "strong economic, scientific, education, and people-to-people ties."

The relationship is certainly historic. America established consular representation in Russell in 1938. It flourished after World War II, during which hundreds of thousands of Marines passed through the country on the way to fight in the Pacific.

Sixty years later, Prime Minister John Key says further building the relationship with the US "is a core focus of this Government's foreign policy."

Science can help. New Zealand's Crown Research Institutes have international science diplomacy built into their operating principles.

NIWA's strong and enduring relationship with two major US research organisations, the National Oceanic and Atmospheric Administration (NOAA) and the US Geological Survey (USGS), is a cornerstone of the New Zealand-US science partnership. Its relationship with these organisations has been formalised through MOUs, and is driving collaboration in freshwater, marine and atmospheric science.

NIWA's Chief Executive John Morgan signed the MOU in Washington DC earlier this year on behalf of New Zealand, with NOAA and USGS signing on America's behalf.

NIWA's General Manager Research, Rob Murdoch, says the MOUs are testimony to the regard in which New Zealand's freshwater, marine and atmospheric science is held internationally.

"The US has recognised that New Zealand is an ideal laboratory equipped with high-quality researchers," he says.

"We're able to deliver at a national level what many other countries can't. Our unique marine location also provides opportunities for research that can't be found elsewhere.

"There are benefits for New Zealand. US research agencies have significant expertise in areas we're interested in. The US is a big player in global environmental management. A lot of our measurements have global significance, so we're an important and valuable contributor – and we're able to access their data.

"They are well funded and have access to some amazing technologies which they are happy to share with us."

The Argo Project

An example of collaboration with US research institutions is the Argo Project. Argo is a global array of more than 3000 free-drifting profiling floats that measure the temperature and salinity of the upper 2000m of the ocean.

Argo data come from these battery-powered autonomous floats that spend most of their life drifting at depth. At about 10-day intervals, they rise to the surface over about six hours while measuring temperature and salinity. When they surface the floats transmit the profile data and their position via satellites. The floats then sink and drift until the cycle is repeated. The floats are designed to make about 150 such cycles.

NIWA Physical Oceanographer Philip Sutton says that Argo dates from the late 1990s, with the first floats launched in 2000. Largely funded by NOAA, NIWA's team works closely with the Scripps Institution of Oceanography and the University of Washington to deploy floats in the Pacific and Indian Oceans.

"The data that's collected is providing a high resolution picture of global heat and salinity content of the oceans, together with information about changes in the currents," Dr Sutton says.

"We are gaining greater understanding of ocean heat content and the effects this has on climate patterns and changes. As well as being able to better predict climate cycles longer term, in the short term these data should be able to help predict such things as the occurrence and intensity of tropical cyclones. Prior to Argo, knowledge of the ocean interior was limited in time and space, based on information captured from surface vessels.

"Before NIWA's involvement, Argo floats were largely confined to the northern hemisphere. There were large knowledge gaps in the southern oceans."

NIWA vessel *Kaharoa* has been ideal for deploying floats. It has sailed from New Zealand to Chile four times, and also across the Indian Ocean to Mauritius twice and Durban once.

The bigger trips have seen up to 100 floats deployed.

NIWA Physical Oceanographer Philip Sutton (centre), Dean Roemmich, Professor of Oceanography (left), and Kyle Grindley, Development Engineer, from Scripps Institution of Oceanography in San Diego, California, with a deep Argo float ready for deployment near the Kermadec Trench. (*Dave Allen*)

Tangaroa has also been used to deploy floats in more rugged Southern Ocean areas.

In addition, NIWA has purchased and deployed two floats every year since 2001.

"We're purchasing and deploying Argo floats in proportion to New Zealand's share of the world's population," Sutton says.

At a February 2016 New Zealand Embassy function to celebrate New Zealand-US collaboration, NOAA Argo Program Manager Dr Steve Piotrowicz formally acknowledged the essential contribution that New Zealand, through NIWA, had made to the Argo programme.

"Argo is arguably one of the most ambitious and successful international marine research programmes ever undertaken. It would not exist if NIWA had not contributed to the deployment of floats, now well over 1000 in the sea today".

"Argo is arguably one of the most ambitious and successful international marine research programmes ever undertaken. It would not exist if NIWA had not contributed to the deployment of floats, now well over 1000 in the sea today".

Dr Steve Piotrowicz, NOAA Argo Program Manager

The Kermadecs

The Kermadecs are the focus for a range of research projects, from deep trench habitats to actively erupting undersea volcanoes. NIWA and other CRIs, such as GNS Science, carry out collaborative science with a number of private companies and research institutes.

NIWA Principal Scientist Fisheries Malcolm Clark says that the seabed mining opportunities come from minerals released from undersea volcanoes, which form where the sea floor on the Pacific tectonic plate is being forced beneath the Australian Plate. The minerals stay in solution under high temperatures and pressure until they're exposed to sea water, at which point they solidify. There are high concentrations of copper, zinc, cobalt, manganese, gold, silver and some rarer minerals known as "rare earth elements".

"Growing interest in 'green technologies' means demand for these minerals is increasing. Some of the deepsea sites along the Kermadec Ridge have higher concentrations than land-based mines," Dr Clark says.

"Potentially there can be less environmental damage with extraction from a smaller seabed area compared with the need to remove large tonnages of overburden on land. However, there is a lot we need to learn about the biodiversity of these ocean habitats, and the likely environmental impacts of human activities such as mining".

Capable of reaching a depth of 6000 metres, Woods Hole's 'Sentry' is readied for deployment from *Tangaroa*. The AUV (Autonomous Underwater Vehicle) uses multibeam and sidescan sonars to map the topography and capture thousands of photographs of the seafloor. (*Rob Stewart*)

US scientists are also interested in such deepsea environments, and potential minerals extraction, leading to close cooperation.

While minerals attention focuses on seamounts, the Kermadec Trench is one of the deepest places in the world, at up to 10km deep. These extremely deep environments are of interest to scientists because of the biodiversity to be found there, Clark says.

"Our studies help us learn about what animals live in these locations, how they are adapted to survive the extreme pressures at such depth, and how they are connected to other deepsea communities in similar trench systems and in the world's deep oceans generally.

"American research institutes are well resourced with high-technology equipment, such as submersible vessels that New Zealand institutes do not have, and are ideal to explore the Kermadec's seamounts and trenches."

Air smoke pollution

Smoke from wood fires is New Zealand's largest source of air pollution. It's also a major contributor to air pollution in the Pacific Northwest states of the US, as well as in upstate New York and Maine.

This is a driver behind joint research being undertaken between NIWA and the Universities of Pittsburgh and Washington. NIWA's international collaboration is also being funded by the Ministry of Business, Innovation and Employment's Catalyst Fund.

Air Quality Scientist Ian Longley says that strong relationships between scientists at NIWA and in the US have been a major contributor to research work in progress.

"New Zealand has a clean and simple environment compared to the US, where airborne pollutants are a complex mix of emissions from local and distant sources. All of our pollution is local and much easier for the sources to be identified and understood. This means we provide opportunities for US researchers to test monitoring equipment and analytical techniques, gaining valuable information for us at the same time."

Jane Clougherty at the University of Pittsburgh has a strong interest in New Zealand after doing some of her postdoctoral research at AUT University in Auckland.

Clougherty has been involved in air monitoring studies in Auckland and Christchurch using small samplers that can

Jane Clougherty (University of Pittsburgh) with NIWA's Ian Longley. (*Dave Allen*) be attached to lampposts. The Christchurch study involved samples being monitored in daytime and at night to see what differences there were, for example from wood fires as well as buses and trucks. Data analysis is being done in partnership with US facilities, and results from these studies are to be published at the end of this year.

"This research is valuable and exciting. Work is currently underway to get a larger study funded," Ian Longley says.

When rivers meet oceans

What happens when rivers meet the oceans is not well understood. As well as freshwater combining with seawater, sediments and farm runoff are mixed in too. The challenge is the river inflow is often only a metre or so thick, floating on the ocean surface. Satellite imaging and traditional computer models only get us so far in understanding the fate of this exchange, NIWA's Principal Scientist Marine Physics Craig Stevens says.

"Rivers meeting oceans is also of interest to US research institutions Oregon State University and the Scripps Institution of Oceanography. They are involved with us in a project at Deep Cove in Fiordland, the exit point for the tailrace from the Manapouri power station," Dr Stevens says.

Manapouri is New Zealand's largest hydroelectric power station and its tailrace is New Zealand's fourth largest source of freshwater into the ocean. It generates flows of several metres per second and creates a sharp interface between freshwater and saltwater, as well as a tightly focused plume structure that persists down the fiord for many kilometres. Generator Meridian varies the freshwater discharge based on its generation needs. This makes for a "natural laboratory" providing valuable information about the nature of freshwater and seawater mixing.

Tyler Hughen from Scripps Institution of Oceanography deploys an autonomous drifting profiler in Doubtful Sound. (*Craig Stevens*)

Craig Stevens prepares a turbulence profiler for deployment in Doubtful Sound. (*Rebecca McPherson*)

"There are similar hydro schemes in North America and Norway, but it is pretty uncommon to have a large freshwater discharge point at the top of the fiord," Stevens says.

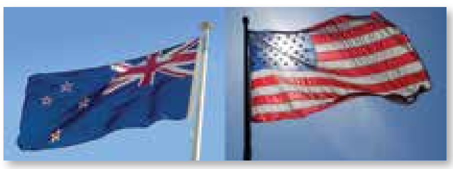
"Our US partners have been blown away by what they've been able to achieve at Deep Cove. Great sampling means great science. We've benefitted from access to the monitoring technologies they've brought with them. Analysis of the data is underway."

NIWA's Deep Cove research has been funded by the Royal Society of New Zealand's Marsden Fund. The Marsden Fund also contributed to work in Antarctica from 2010 to 2012.

"This Antarctic work was similar in lots of ways to what we've been doing at Deep Cove," Stevens says.

"Again we were examining buoyant flow and the mixing of freshwater and saltwater, but now under melting ice sheets. On this project we worked with senior US scientist Miles McPhee who literally wrote the book on turbulence under ice and was the lead author for a recent paper on the collaborative work.

"Freshwater mixing with saltwater is a pretty important area of research. Our understanding of systems and tools is still growing, scientific excitement is high and we're confident we're on a good track with our work. The versatility of New Zealand scientists, combined with opportunities we can provide to work alongside international researchers, particularly those from the US, means we're at the head of the game."



The pearl of New Zealand fishing

The Quota Management System, which some say saved New Zealand fisheries, is 30 years old today. The system is founded on science that studies fish biology, abundance and distribution, and estimates how many can be caught and still keep the population healthy.

In April this year 40 fisheries ministers and officials from Pacific nations came to Wellington to learn about New Zealand's catch-based fisheries management system.

They were here because New Zealand Prime Minister John Key offered the tour at last year's Pacific Islands Forum leaders' summit. The offer was part of a US$34 million fund provided by New Zealand for the region to set up a catch-based system.

Catch-based management means a limit is set on the volume of certain species caught. Commercial fishers are assigned a portion of that volume. The catch volume is set, and adjusted if required, so that the productivity of each species can be maximised. The secret to the success of the system is good science to help inform sustainable management. It is essential to accurately assess how many of the species exist, where they live and move, and how they reproduce and grow. Only then can you confidently set a catch volume that will allow the population to regenerate.

The Pacific leaders were here because New Zealand knows a thing or two about such systems. It manages the nation's commercial wild fish catch of 130 different species, worth $1.3 billion in exports each year.

A local fisher unloads his catch of snapper on Auckland's waterfront in the mid 1970s – long before the Quota Management System came into play. (*Photographer unknown c1975*)

Cook Islands Prime Minister Henry Puna says the New Zealand system is one of the best in the world. He says adopting a similar quota management approach will ensure the sustainability of Pacific fisheries.

"We all share a common objective of making sure that fisheries in the Pacific are sustainable well into the future and we believe that the Quota Management System will deliver that for us."

The visit to learn from New Zealand's expertise illustrates the maturity of a system which turns 30 years old this year.

The pearl anniversary is an opportunity to reflect on a decision in 1986 that effectively saved the industry. In fact, quota management has turned into a saleable advantage for fish exporters. In a world obsessed with sustainability, the fact that New Zealand fish catches come from guaranteed sustainable populations adds marketability and value.

Thirty years on, it's hard to recall exactly how desperate the situation once was.

A former Ministry of Fisheries Deputy Chief Executive, Stan Crothers, describes the period as 'the wild west'.

Like every other country in the 1980s, New Zealand had managed its fisheries using traditional input controls like size limits, gear restrictions, seasons and area closures. And, like many fisheries around the world, our inshore industry was overcapitalised. Too many boats were chasing too few fish.

"By the early 1980s, New Zealand fisheries managers found themselves in a very challenging situation," according to Crothers.

"Deepwater fisheries had recently begun to be developed and we wanted to see that development continued in a way that was economically rational and sustainable. Our inshore fisheries, meanwhile, were on the verge of economic collapse."

Measures such as moratoriums and controlled fisheries failed to work. Something more radical was needed. It was a huge challenge for government and industry to institute a management system that could effectively deal with both the offshore and inshore situations.

Crothers says the QMS was a product of its time, a period of huge government reform and change in New Zealand society.

"Market economics was the flavour of the day, and the QMS incorporated a strong element of this by creating a market in commercial harvesting rights."

A point of difference to other quota systems was the creation of Individual Transferable Quotas (ITQs). These allocated defined tradable shares to fishers, allowing them to catch the fish when it was most economically viable for them. This reduced wasteful competition from a 'race to fish'.

"The idea was that such a market would provide business certainty and encourage investment and efficiency in the fishing sector."

In October 1986, after two years of consultation and planning, the Quota Management System was introduced with widespread industry support.

Initially the fishing industry had to endure lean times. To allow inshore fish populations to rebuild and support larger catches in the future, the initial catches were set very low – less than half the previous catch levels and some as low as 17 per cent. The Government offered compensation for the catch reductions. Yet, in many stocks, the reductions were not enough, forcing the balance of quota to be reduced without compensation.

The seafood industry is now a major champion of the QMS approach, and a constructive contributor to its regular tweaking.

Tim Pankhurst, Chief Executive of Seafood New Zealand, says, in contrast to the 'the boom and bust' period before the QMS, fish stocks are now managed sustainably.

Pankhurst says the accuracy of science about fish is as vital to sustainable fishing as the Quota Management System itself.

"The science tells us that New Zealand's fisheries are performing extremely well, with around 83 per cent of individual fish stocks above the level where sustainability would become a concern."

Scientists from NIWA, and formerly the Ministry for Agriculture and Fisheries, have been involved from the start of the QMS. Over the period, they've taken great steps in improving the accuracy of its fish stock monitoring counts, and assessment of productivity levels.

Rosemary Hurst, NIWA's Chief Scientist Fisheries, says one of the most significant advances in fisheries science in New Zealand over the 30 years has been the development of fishery-independent methods to monitor fish abundance.

"Long time-series of fisheries monitoring allows us to better understand natural and fishing-induced variations in abundance. We are increasingly confident about our estimates of fish abundance, and the impact that fishing has on fish stocks.

"For example, we've created 25-year-long time-series of trawl and acoustic surveys, using the NIWA research vessels *Tangaroa* and *Kaharoa*. A quarter of a century of these data enables provision of reliable abundance indices for stock assessment of key species, as well as environmental indices for secondary species caught on the surveys."

Also essential to robust stock assessments is the collection of reliable fishery-dependent data. There are a number of data types available as inputs to the assessment models.

Our science underpins the certification for hoki, southern blue whiting, hake, ling and toothfish, says Rosemary Hurst, Chief Scientist – Fisheries. (*Dave Allen*)

"One of these is the fine-scale commercial catch and catch-rate reporting for most of New Zealand's fisheries that is now amongst the best in the world," says Dr Hurst. For the key fisheries, we also have valuable time-series of catch sampling data (verified catch weights, fish size, sex, spawning conditions and age) collected by Ministry observers on offshore 'deepwater' vessels, since the late 1980s, and from landed catches for inshore species.

Model data inputs include all the available reliable data, including commercial catch rates, research abundance indices (from trawl, dredging, potting or acoustic surveys and tagging studies), population age or length structure, growth and age of maturation. For inshore species, recreational catch data may also be included.

Digital advances

Rosemary Hurst says scientists have a lot to be proud of in their contribution to New Zealand's stock monitoring and assessment processes. Particularly noteworthy is development of state-of-the-art analytical software such as NIWA's stock assessment model, CASAL. The NIWA-developed software package is an international standard in the assessment and management of fish stocks, including some of the world's most prized species. It is being used by overseas agencies to assess Patagonian and Antarctic toothfish and broadbill swordfish fisheries.

NIWA fisheries scientist and CASAL development team leader Alistair Dunn says the software has become a universal language of fisheries science. "There are lots of communication barriers in international communities, so this gives us a standard language to use on the topic.

"We have just built a new generalised population modelling package, CASAL2, to extend and replace CASAL, allowing us to model marine mammal and seabird populations as well.

"We are also starting to develop a suite of more complex spatial and ecosystem models that will underpin our science used to understand and manage marine ecosystems.

"In New Zealand, fisheries are typically managed to achieve a target spawning biomass (total mass of breeding fish) of around 40 per cent of its original size fishing. If the biomass level falls below 20 per cent, it's regarded as overfished, and one below 10 per cent is considered collapsed and at risk of not recovering.

"NIWA's population modelling tools allow us to evaluate the potential risks in order to maximise catches without damaging the stock population." Using this science, the state of important fisheries like hoki and orange roughy have improved over the past 10 years, and are now well above target biomasses and support sustainable catches.

Rosemary Hurst points to an emerging need to be able to make stock and risk assessments even in 'data poor' situations.

"Our science underpins the Marine Stewardship Council Certification for hoki, southern blue whiting, hake, ling and toothfish."

How the quota system works

The aim is to conserve major fisheries stocks at sustainable levels and to improve the efficiency and profitability of the New Zealand fishing industry. This is done by managing fisheries at the level of Maximum Sustainable Yield.

The principle of a Maximum Sustainable Yield is used to establish the level at which the sustainable catch is highest. Fish stocks are generally most productive at between about 30 per cent and 45 per cent of their unfished size, because a decrease in population reduces competition for food and results in a younger and faster-growing population.

Since 1986 the Ministry of Fisheries has gradually brought more commercial species under the management of the quota system. In 2014 the number of species reached 100, split into 638 regionally distinct stocks (Quota Management Areas).

Scientists and the industry work together to assess the population of each species and stock in the system. From this, the Ministry for Primary Industries makes recommendations to the Minister to set a Total Allowable Commercial Catch (TACC) for each species in each QMA. Individuals and companies are allocated the right to catch certain quantities of particular species, or 'quotas'. Quotas can be leased, bought, sold or transferred.

In areas where significant non-commercial fishing exists (for example, recreational) this is taken into account and a portion of the total allowable catch is set aside before the TACC is calculated.

In 1986, when the Quota Management System was brought in, quota was allocated to individuals and companies as Individual Transferable Quota (ITQ) on the basis of catch history.

Each ITQ entitles its holder to a certain share of the yearly TACC for a particular fish species in a particular area. ITQ has economic value and can be traded or leased. Asset value of ITQ in 2015 was about $4 billion.

Treaty of Waitangi

About the same time as the fisheries were in stock crisis, Māori claimants were concerned that the Treaty of Waitangi guarantee of "full, exclusive and undisturbed possession ... of their fisheries" had not been honoured. Both the Waitangi Tribunal and the Government agreed that their claims had merit and negotiated a full and final settlement of Māori claims to sea fisheries. They granted to Māori 10 per cent of Individual Transferable Quotas (ITQs), 20 per cent of new species in the QMS, 50 per cent of Sealord Products Ltd, and a method of identifying traditional fishing areas and custom-based regulations.

It is estimated that Māori currently own about 50 per cent of the fishing quota.

A wealthier nation

A study by Statistics New Zealand (2009) revealed that the fisheries asset – the number of fish in the sea and their value – has increased.

The study demonstrated the long-term value of the QMS in what has happened to the original 26 species which started the system. Between 1996 and 2009, their asset value increased 18 per cent, even though their TACC declined by 40 per cent.

The value of all commercial species in the QMS increased by almost 50 per cent between 1996 and 2009. The total asset value of New Zealand's fisheries is currently over $4 billion.

The growth in scientific knowledge has supported new species to be added to the QMS, and their TACCs sustainably managed. This sustainable management has also enabled some key fisheries to obtain Marine Stewardship Certification, which also adds to export value.

In the past 30 years the QMS has proved its value. It would not have been possible without scientists knowing, with a great deal of confidence, how many fish were left in our sea.

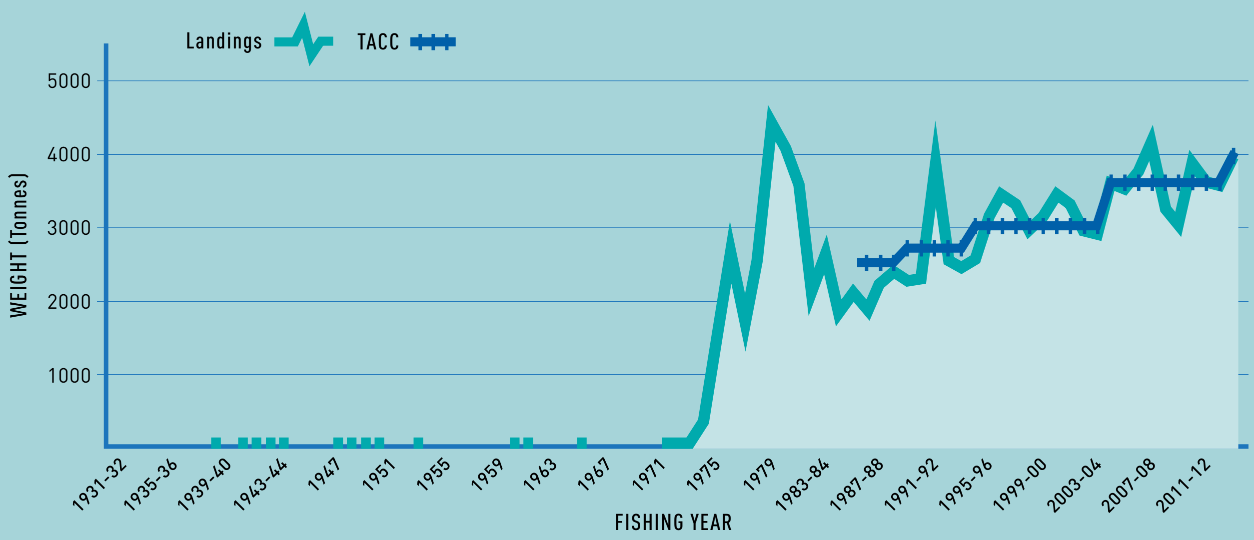
The story of ling

Ling is one of the 'deepwater' fish species that had a short time-series of catches prior to 1986. There was considerable uncertainty about its sustainable levels when TACCs were first established.

Since then fisheries assessment has estimated the population using *Tangaroa* trawl surveys, research and commercial catch-at-age distributions, and commercial catch-per-unit-effort.

The result has been a growing confidence to gradually increase the ling TACC over time. Continued monitoring is showing the increasing TACC to be sustainable.

Reported commercial landings and TACC for the ling LIN stocks, LIN 1 (Southland).



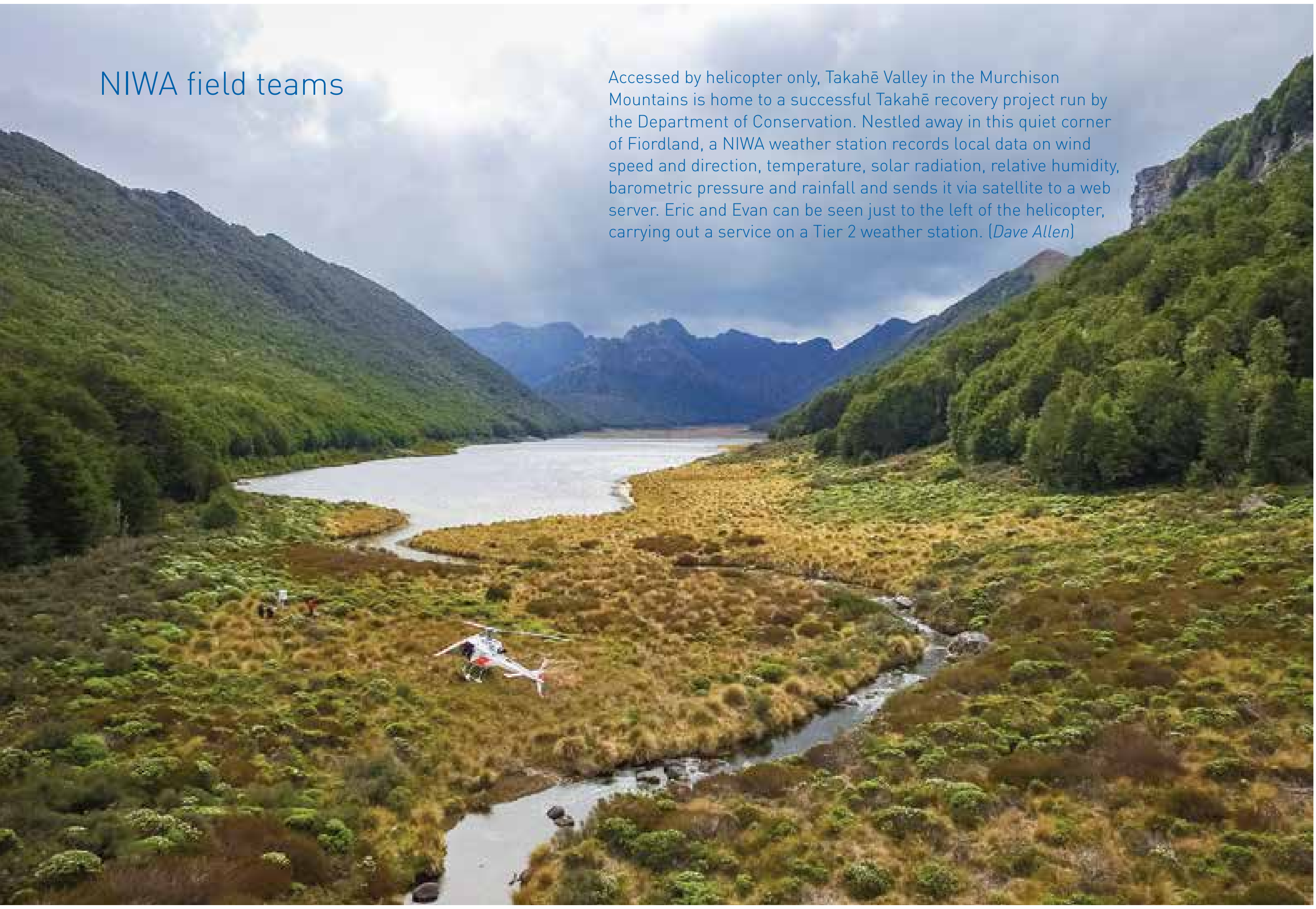
NIWA field teams

NIWA environmental monitoring technicians Evan Baddock and Eric Stevens have ventured deep into Fiordland to monitor river and lake levels in the area. Travelling by jet boat and the occasional helicopter, they get to work in some of New Zealand's most stunning scenery.

Environmental Technicians Eric Stevens (left) and Evan Baddock in transit from Takahē Valley, Fiordland. (*Dave Allen*)

Evan downloads river gauging data from a remote station near Doubtful Sound in Fiordland. Dense bush obscures the Lyvia River, which flows just a few metres away in the background. (*Dave Allen*)

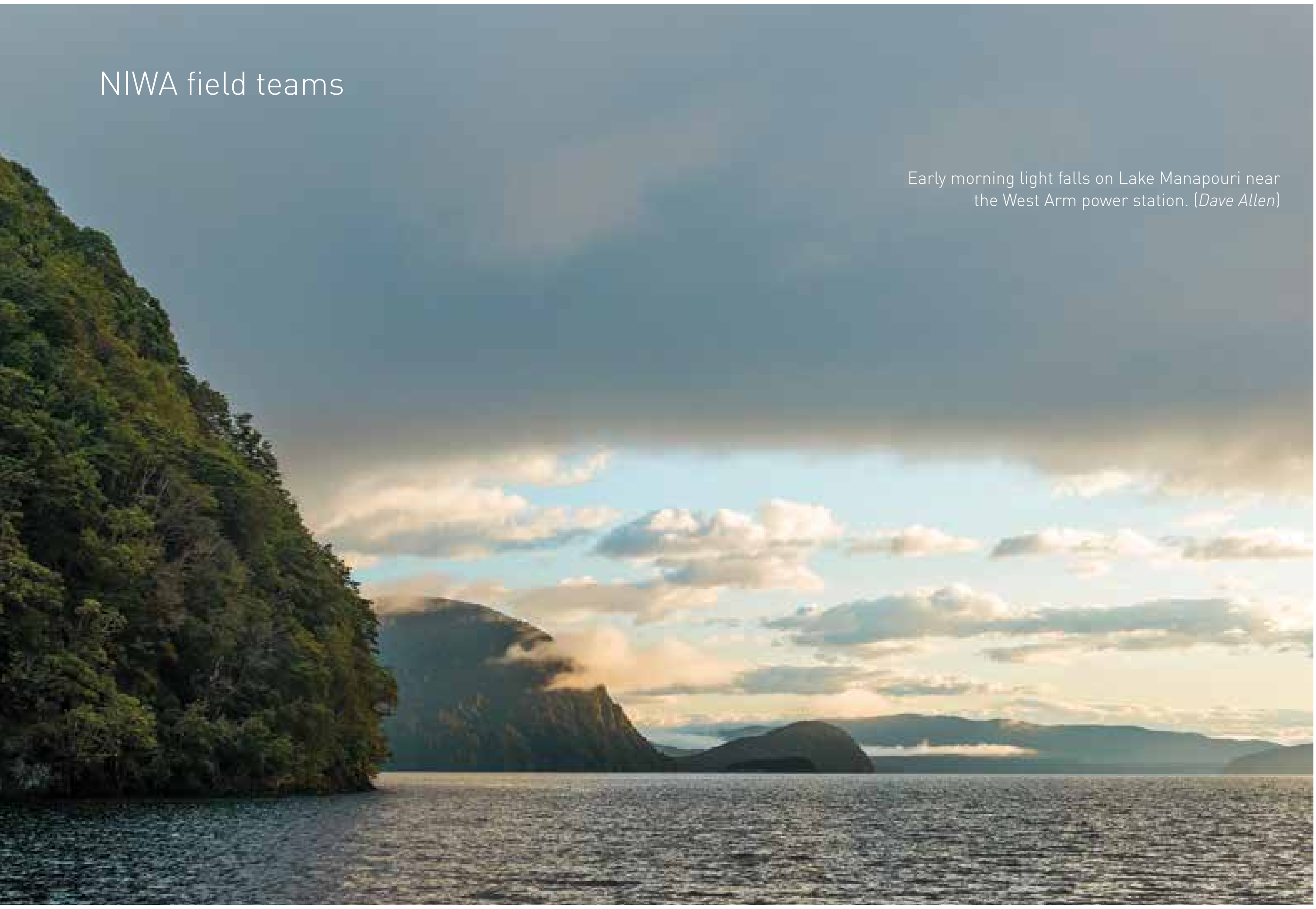
NIWA field teams



Accessed by helicopter only, Takahē Valley in the Murchison Mountains is home to a successful Takahē recovery project run by the Department of Conservation. Nestled away in this quiet corner of Fiordland, a NIWA weather station records local data on wind speed and direction, temperature, solar radiation, relative humidity, barometric pressure and rainfall and sends it via satellite to a web server. Eric and Evan can be seen just to the left of the helicopter, carrying out a service on a Tier 2 weather station. (*Dave Allen*)

Evan records river level and flow data at a site on the Waiau River, Southland. (*Dave Allen*)


Eric and Evan servicing a Tier 2 weather station at Takahē Valley, Fiordland. (*Dave Allen*)



Early morning light falls on Lake Manapouri near the West Arm power station. (*Dave Allen*)

Evan gauging the Mararoa River near Te Anau, Fiordland. (*Dave Allen*)

Eric servicing a lakeside gauge near West Arm power station, Lake Manapouri. (*Dave Allen*)

On the right wicket

As far as names go, MS Srinivasan admits his doesn't exactly roll off the tongue.

For the record, his full name is Mathirimangalam Subramanian Srinivasan – Mathirimangalam being the name of the village in Tamil Nadu, India, where he is from, Subramanian being his father's name, and Srinivasan being what we in New Zealand would consider a 'first' name.

"We don't have a last name, just a name," he says. So MS it is, then.

As well as being easier to say, the NIWA field hydrologist's abbreviated moniker also serves as a handy way of breaking the ice with many of the Canterbury farmers he works closely with as he helps them get the best out of irrigation systems using NIWA's science and services.

"I always joke with them that MS stands for milk solids. It's something farmers are always interested in, so they connect with me right away."

That personal connection is something that MS works hard at developing, given the people he works with in the field are as important to him professionally as he is to them.

"I get the opportunity to talk to a lot of farmers and draw on their experience and knowledge. My first responsibility is to make sure farmers trust me and understand that I'm there to help. But I also have to understand their logic and help them with the tools (developed by NIWA) that are available to them.

"Farmers don't tend to like being told what to do with their water, but I work for NIWA and we are recognised as a leader in freshwater science and knowledge."

MS has focused his expertise on irrigation for the past six to seven years, when dairy farming and conversions began picking up in the Canterbury region.

As farming intensity has increased, so too has the need for smarter thinking in water use, management and efficiency.

Farming depends heavily on irrigation to maintain productivity, but, to make best use of it, farmers need to know the moisture content of their soil, when it's going to rain and how much will fall. For example, irrigating today might be wasteful if it's going to rain tomorrow.

MS has been instrumental in the development of the IrriMet tool, a practical web-based application that helps farmers maximise pasture growth and minimise water and nutrient losses.

A personal connection with farmers is something that MS (right) works hard at developing. (*Dave Allen*)

Mathirimangalam Subramanian Srinivasan ... or just MS to us! (*Dave Allen*)

"It's about being proactive rather than reactive," says MS. "Looking at forecast information is an important component in irrigation; they are able to stay one step ahead."

Equally important is having gumboots on the ground, MS says. Collaboration is vital in MS's line of work, and he's good at it – winning the customer focus award at last year's NIWA Excellence Awards for his work with councils, primary sector agencies and farmers.

"I guess it's quite unique for someone who doesn't even speak English as a first language. I don't really like being stuck behind a desk, and an advantage I have is that I can go and talk to people and share information."

Chatting with cockies in Canterbury is a far cry from growing up in southern India. MS, now 46, was born in a small town called Kumbakonam, hometown of famed Indian mathematician and autodidact Srinivasan Ramanujan.

"It's also a famous town with temples dating back to the ninth and 10th centuries, hence my interest in history and archaeology," MS says.

"The logical reconstruction aspect of the three disciplines – history, archaeology and hydrology – interests me. As a field hydrologist I often set up field studies to measure rainfall, runoff, soil moisture and other hydrological and soil variables.

"I have to learn to read the landscape and relate what I see to what I measure; what could have happened when, say, there was rainfall or a flood in a catchment or river."

MS left India for the United States in 1993, completing graduate degrees at the Pennsylvania State University in Agricultural and Biological Engineering (specialising in hydrology). He then worked with the US Department of Agriculture for five years.

After 12 years stateside, MS decided it was time to head home to India, where his family still lives. Fortunately, a tip-off from a colleague brought him to New Zealand instead.

"A Kiwi friend of mine from my time in the US found an opportunity for me to work with him at AgResearch at Invermay. I started there in December 2005 before joining NIWA in April 2008."

But the opportunity to further develop his scientific career wasn't the only thing that lured MS to New Zealand. Starved of opportunities to enjoy cricket in the US, the shift to Godzone has been a godsend.

"It is one of the reasons I'm here. Like any other Indian kid, I started playing cricket as soon as I was tall enough to cover the stumps when I bat. Cricket is like a religion in India.

"Here I have the chance to do good science, and transfer that knowledge, and enjoy cricket – more watching than playing, though."

Flow-on effects

South Canterbury's landmark Rangitata South Irrigation Scheme (RSIS) is one of the country's most ambitious irrigation water harvesting, storage and distribution projects. When it was first conceived, lead contractor Rooney Earthmoving Ltd (REL) needed specialist help devising the system of automated flow-monitoring and control technologies that is central to the scheme's operation.

REL turned to NIWA's Christchurch-based Instrument Systems team, initially to develop technology that would manage the flow of water from the Rangitata River into the storage facility. A second contract quickly followed, for monitoring and distribution systems across the entire scheme.

Now farmers tapping into the RSIS can gain maximum productive value from their land – some of New Zealand's most drought-prone – without compromising the needs of other river users or local ecosystems.

Harvesting nature's excess

Sustainability is at the heart of the RSIS.

"The Rangitata River's normal flow is insufficient to supply a scheme of this scale continuously," explains NIWA Instrument Systems Group Manager Rod Mckay. "But rain in the headwaters can often boost flow tenfold or more in the space of just a few hours. Typically there's an abrupt peak, then flows return to normal over a day or two.

"RSIS captures a small portion of this floodwater and stores it, so that irrigation water can be delivered to farms when it's really needed, and in more manageable quantities, without affecting the integrity of the river or its ecosystems."

Three hydraulic gates at the scheme's intake begin to open only when river flow (measured two hours upstream) surpasses 110 cubic metres per second. Up to 20 cubic metres per second of floodwater is diverted into an open race supplying a series of seven massive storage ponds – each slightly lower in elevation than the previous.

Collectively, these ponds can hold 16.5 million cubic metres of water – enough to fill about 6,400 Olympic-sized swimming pools. The ponds are filled simultaneously from a ring race, with level control provided as a 'managed cascade' from pond to pond.

NIWA-designed water-level monitoring and control nodes maintain a constant differential in level (known as the 'set-point') between each pond and its downstream neighbour, by controlling the position of hydraulic slide gates between the ponds. Careful management of level differentials in this way minimises the stress on the earthen pond walls.

Rangitata South Irrigation Scheme. (*Rooney Earthmoving Ltd*)

Farmers are served by water from the lowest pond, via an 80km-long network of supply races and more than 45 controlled 'turn-out nodes' designed by NIWA. All told, the RSIS delivers to around 35 farms spread across 14,000ha between the Rangitata and Orari Rivers.

Hands-free management

A key challenge for NIWA was to automate the entire scheme, using a tailored wireless telemetric control system.

"The goal was for a system that can operate unattended 24/7, relieving RSIS staff of time-consuming water-scheduling and supervisory tasks," says Rod Mckay.

The scheme's control nodes transmit flow-rate information wirelessly to a Neon server, or 'hub', located in an office alongside the storage ponds. The hub, in turn, sets and transmits flow-rate or level targets for each node, and checks that flows and levels are within the expected range. Gates at each node are continuously adjusted to keep flows on target – all managed remotely by NIWA's proprietary 'Irrigation Sentinel' software.

This continuous two-way communication ensures the right amount of water is delivered to the right place at the right time and – critically – the system operates efficiently within consented limits.

Firsts for NIWA

Communication uses two wireless networks. Pond control nodes communicate with the hub via a local Wi-Fi network that covers more than 6km, from the intake on the first pond to the outlet on the last. This ensures the intake and pond system can operate autonomously, in the event that commercial networks fail. Operating over a much larger area, the race turn-out nodes and hub communicate using commercial cellular networks, made secure by NIWA's Private Access Point Node on the carrier's network.

"RSIS has demanded some quick thinking on our part to meet its unique challenges," says Rod Mckay. "The scheme involved a number of firsts for NIWA, including installation of the single-customer Neon server on site, the wide-scale local Wi-Fi network, and the machine-to-machine cellular data network.

"We also designed and worked closely with the manufacturer of the farm turn-out flow-control gates. These were built so that they could be installed by REL and manually set to position, ready for outfitting with an electric actuator, data logger and solar power by NIWA.

"RSIS has ably demonstrated our ability to successfully deliver an end-to-end irrigation management solution at the large scheme scale."

NIWA provides ongoing support for RSIS's gate data logger systems, Neon server and Wi-Fi infrastructure.

Fast facts

- The RSIS intake lets in up to 20 cubic metres of water per second, a rate that would fill an Olympic-sized swimming pool in 125 seconds.
- The scheme includes a salmon spawning race, which is fed from the intake. Flow is controlled to provide optimum conditions for spawning.
- If no water is leaving the ponds, it would take more than nine days to fill them from empty.
- When full, the ponds hold approximately 30 days' supply for downstream farmers – when delivered at the race capacity of more than seven cubic metres per second.
- All farms have their own on-farm storage, allowing them to use water when they need it rather than only when it's available in the race at their gate.

More information
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NIWA
enhancing the value of New Zealand's natural resources

NIWA (the National Institute of Water & Atmospheric Research) was established as a Crown Research Institute in 1992. It operates as a stand-alone company with its own Board of Directors, and is wholly owned by the New Zealand Government.

NIWA's expertise is in:

- Aquaculture
- Atmosphere
- Biodiversity and biosecurity
- Climate
- Coasts
- Renewable energy
- Fisheries
- Freshwater and estuaries
- Māori development
- Natural hazards
- Environmental information
- Oceans
- Pacific rim

NIWA employs more than 600 scientists, technicians and support staff.

NIWA owns and operates nationally significant scientific infrastructure, including a fleet of research vessels, a high-performance computing facility and unique environmental monitoring networks, databases and collections.

Back cover:

Orange roughy. (*Neil Bagley*)

NIWA
Taihoro Nukurangi

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