WATER & ATMOSPHERE

June 2015

Weathering the storm

How science serves the stormiest region on earth

Building resilience

Dealing with the growing pains of urbanisation

Cleaning up

Island solutions to pollution

Actions stations on climate

Putting better climate data to good use

WATER&ATMOSPHERE

June 2015

Cover:

Severe Tropical Cyclone Pam at peak strength near Vanuatu on 13 March 2015. (*NASA*)

Water & Atmosphere is published by the National Institute of Water & Atmospheric Research (NIWA).
It is available online at www.niwa.co.nz/pubs/wa

Enquiries to:

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

email: wa-editor@niwa.co.nz

ISSN 1172-1014

Water & Atmosphere team:

Editor: Mark Blackham

Production: NIWA Communications and Marketing Team

Editorial Advisory Board: Geoff Baird, Mark Blackham, Bryce Cooper, Elizabeth Griffin, Barb Hayden, Rob Murdoch

Follow us on:

facebook.com/nzniwa

twitter.com/niwa_nz

google.com/+niwanz

www.niwa.co.nz

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

NIWA
Taihoro Nukurangi

enhancing the benefits of
New Zealand's natural resources

Sensitive souls

Research on the spawning biology of whitebait species shows that populations of the native fish are highly sensitive to a wide range of human-related factors, not just fishing.

While whitebaiters lament declining catches, concerns are also being raised about overfishing. NIWA freshwater ecologist Dr Paul Franklin says recreational fishing is just one human factor influencing populations of whitebait in New Zealand waterways.

He says the species' unusual spawning habit of laying eggs in temporarily submerged plants is a high-risk reproductive technique easily affected by human use of land and water.

Whitebait are the juveniles of five species of native fish that return to freshwater after spending the first few months of their lives at sea. This migration into freshwater is a critical part of their life cycle, as they move upstream to find the habitats where they will feed, grow into adults, mature and then begin the cycle all over again.

Scooped from a net at Neil's Beach, Jackson's Bay. (*Colin Monteath, hedgehoghouse.com*)

After spawning sites of the giant kōkopu (*Galaxias argenteus*) were discovered for the first time in a suburban Hamilton stream in 2013, Dr Franklin set out to understand more about the spawning biology of the five whitebait species.

"All five species deposit their eggs in habitats – vegetation and grasses – only temporarily submerged by high water levels. For inanga (*Galaxias maculatus*), which migrate downstream to estuaries to lay their eggs, this is high spring tides. For the other four species, this is high river flows caused by rainfall.

"It's not clear why they would do this, because it is a high-risk strategy."

An average-sized adult female inanga will lay about 2000–3000 eggs. On average, only about 11 per cent survive to hatch, and once the eggs hatch and the larvae make it to sea, survival is very low. There is no specific information on inanga, but mortality of larval fish in the marine environment has been estimated at 98 per cent.

"Mortality at sea is something we can't control – the only way we can (increase populations) is by improving the number (of larval fish) that gets there in the first place."

Dr Franklin said changing land and water use was influencing spawning.

"The unusual reproductive strategy of whitebait makes them uniquely susceptible to changes to river flows and bankside vegetation. The eggs of inanga, for example, are typically laid within dense grasses that retain moisture and provide shading. These conditions help the eggs survive out of water until they are ready to hatch about three to four weeks later.

"The eggs then hatch when the spawning sites are re-inundated by future high river flows or, in the case of inanga, high spring tides. The larvae are then washed out to sea, where they stay for several months, before finally returning to freshwater as whitebait."

That meant that if the eggs were not re-submerged within a suitable time, they would die.

"As we use waterways in different ways there is a greater impact on the life cycle of the fish. Activities from agriculture to power generation constantly change flow and flooding conditions.

"Riparian management is also a factor. Given that spawning takes place in bankside vegetation, anything that affects this (mowing, clearing or planting) can have an effect. The type of vegetation is also important. For example, fish won't spawn at all in the lower Waikato River where glyceria (an introduced plant) is common."

Dr Franklin said it was clear that many elements determined overall whitebait populations.

"What this emphasises is the susceptibility of the species to changes in habitat, and in all stages of their life cycle there are things that impact them.

"Only by considering all these things together will we get a clearer picture."

Gliding time

A state-of-the-art underwater research glider has been unveiled by NIWA scientists in Wellington.

Coastal oceanographer Joanne O'Callaghan has taken delivery of the 1.5-metre long glider, which can carry a variety of sensors to measure temperature, salinity, light, oxygen and fluorescence under the surface of the ocean.

The Slocum Glider – named *Manaia*, after the representation often carved into the figureheads of sea-going waka to give spiritual direction to the waka's journey – is one of about 500 around the world, but is the first in New Zealand. The gliders are named after Joshua Slocum, the first man to sail alone around the world. The glider is designed to travel the oceans alone, like Captain Slocum, and will be initially deployed off northeast New Zealand.

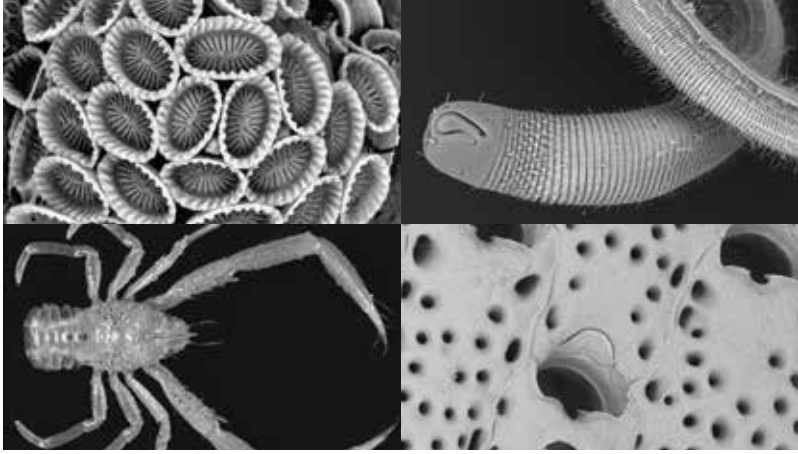
Unlike powered submarines, the glider does not use a propeller to move through the water. It moves by changing its buoyancy to glide up or down in the ocean. Wings on the glider convert vertical displacement into horizontal motion, resulting in a vertical saw-tooth dive pattern down to 200m, at a horizontal speed of about one kilometre per hour. This efficient means of locomotion leaves most of the on-board battery power for operating the scientific instruments it carries. A glider deployment usually lasts about 30 days, during which time the glider will travel about 400km through the ocean.

O'Callaghan says the data, transmitted via a phone call made during occasional surfacing, will be valuable for understanding the coastal shelf seas around New Zealand.

Satellites have collected measurements about the ocean's surface for more than 30 years, but, just as the weather is constantly changing above us, so is the ocean below us. We have very limited information on sub-surface variations in temperature, salinity, oxygen and biological parameters in water shallower than a few hundred metres – what we consider to be the Continental Shelf.

Manaia will help gather more data on the part of the ocean closest to where we live, and those data will be accessible from a computer almost instantly each time the glider surfaces and dials home.

Joanne O'Callaghan with *Manaia*. (*Dave Allen*)



NIWA discovers 141 new creatures

NIWA biologists have discovered 141 new marine creatures in the past three years, an important contribution to the worldwide register of underwater life.

The World Register of Marine Species (WoRMS), published in Ostend, Belgium, has almost completed logging all the world's known marine species. The list relies on contributions from marine biologists around the world.

More than 1000 new-to-science marine fish species have been described globally since 2008 – an average of more than 10 per month – according to the scientists completing the consolidated inventory of all known ocean life.

Among new fish species worldwide are 122 new sharks and rays, 131 new members of the goby family, and a new barracuda found in the Mediterranean.

A recent NIWA-led inventory of New Zealand's marine species counted close to 12,500 named marine species for the WoRMS. At least 3000 more species are in New Zealand museum collections awaiting formal naming and description.

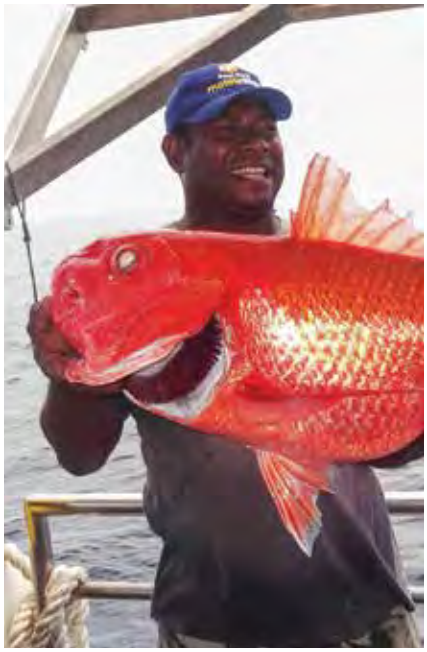
NIWA's Dr Dennis Gordon, who led New Zealand's marine species inventory, and two other NIWA biologists, are part of an editorial group that determines which species should be in the WoRMS. Dr Gordon also helped shape the higher-level management classification of life used by the WoRMS. The latest version of this classification is about to be published.

Dr Gordon says New Zealand is still in the discovery phase when it comes to marine life. "Marine BioBlitzes in recent years have discovered new species on Wellington's seashores, and NIWA's studies investigating vulnerable deepwater ecosystems have uncovered lots of new species," he says.

In the past three years, NIWA biologists, assisted by visiting specialists from overseas, have discovered 141 new marine animals in the 60-year-old NIWA Invertebrate Collection, including specimens from recent research cruises.

These comprised sponges, corals, sea anemones, bryozoans, round worms, sand hoppers, comma shrimps, seed shrimps, squat lobsters and sea squirts. Several new seaweed and phytoplankton species have also been discovered and named. Having named species enhances the data quality of scientific research on marine ecosystems.

In brief



Deepwater snapper. (*SPC*)

Domestic heating is a major source of air pollution. (*Dave Allen*)

Algal ecologist Karl Sofi with his winning homebrew. (*Dave Allen*)

Fishing Tonga

Fisheries scientists from NIWA are helping Tonga maximise the economic benefits of commercial fishing.

As part of a $2.7 million New Zealand Government-funded project launched last year, NIWA will work with the Secretariat of the Pacific Community, the Tongan government and the local fishing industry to develop a sustainable line fishery for deepwater fish in Tonga's Exclusive Economic Zone.

Project leader and NIWA fisheries scientist Dr Stuart Hanchet said the project will also explore ways to maximise economic returns and develop new market opportunities.

An initial phase of the programme will involve training Tongan fisheries staff in the analysis of fisheries data to complement research into the biology, abundance and management of the deepwater snapper fishery.

South Island pollution

Eight out of the 10 most polluted places in the country are in the South Island, according to a report released by the Ministry for the Environment.

The pollution hot spots included Otago, Timaru, Reefton, Invercargill, Christchurch, Richmond, Kaiapoi and Rangiora.

Guy Coulson, NIWA Group Manager, Air Quality Research, says two factors 'gang up' on the South Island.

"In winter it is cold and still. Then people start using their fires or log burners."

Inversion layers trapped polluted air on cold, still nights.

Geography also played a part, "particularly in areas with a basin surrounded by hills trapping air".

Domestic heating was the major source of air pollution, followed by transport emissions. High pollution levels have been shown to lead to more deaths, hospital admissions and emergency department visits.

Rotorua and Tokoroa are the only North Island towns to feature in the top 10. The least polluted areas include Wellington and Kumeu.

NIWA scientist takes out top beer prize

NIWA microbial ecologist Karl Safi took out the title of champion brewer in a Society of Beer Advocates competition late last year.

He entered 16 beers in the national home brew competition, winning 12 medals.

Mr Safi says his microbiology background means he understands the importance of keeping things sterile and clean.

"Applying good microbiological practices to my beer means I can make it consistently and make it well.

"Going to tastings and listening to judges at competitions, and even standing around trying each other's beers, help you realise what was meant by the faults the judges picked up. The feedback you get from competitions is really important. You get to understand what makes a good beer and the kind of faults that are quite common."

As the champion brewer, Mr Safi receives a brewing scholarship and will spend time at a microbrewery turning one of his beers into a commercial product.

Many invertebrates attach their eggs to stream rocks in a jelly-coated mass. (*Richard Storey*)

A bug's life

A NIWA team in the Waikato is looking at insect laying in freshwater streams, to build a fuller picture of stream health.

Freshwater ecologists Dr Richard Storey and Brian Smith, and interns Maurice de Wit and Neils Groot built controlled pools of flowing freshwater in which to watch insect activity.

Some of the pools had rocks in them, part of which were above the waterline, where insects could land. In the control pools all the rocks were below the waterline.

The team were monitoring whether insects preferred streams with opportunities to land and lay eggs. In a second experiment, rock surfaces above water were coated in a sticky paste to catch the insects, so the team could see which species were visiting the rocks.

Brian Smith said insect life was an important indicator of stream health, and they also provided food for other organisms living in and around the stream.

Antarctic New Zealand technician Kate McKenzie operating the new Bruker 125HR instrument at Arrival Heights. (*John Robinson*)

New Antarctic spectrometer

NIWA researchers received an early Christmas present as a new Fourier Transform Spectrometer (FTS) headed south to Ross Island in Antarctica in December.

The FTS takes high-precision measurements of greenhouse gases, ozone and ozone-depleting gases in the atmosphere. Weighing about 300kg and costing $500,000, it replaces an outdated machine.

NIWA's measurements began in 1992, making them the longest running time series of their type in Antarctica. It's also the only FTS on the continent – and one of only five in the southern hemisphere – that feeds into the Network for the Detection of Atmospheric Composition Change.

The FTS travelled to Antarctica in six boxes from NIWA's Lauder Atmospheric Research Station in Central Otago. It was installed by NIWA researchers John Robinson and Dave Pollard.

Riverton.
(*Google Earth: ©2015 TerraMetrics, CNES / Astrium*)

Dirty fingerprints

A technique known as 'sedimentary fingerprinting' has been used to isolate the source of pollution in Southland estuaries.

NIWA water quality scientist Max Gibbs took sediment samples from the Jacobs River Estuary, and used a forensic compound-specific stable isotope to identify a 'fingerprint' in the estuary's sediment and match it to a source upstream.

Teaming up with AgResearch, Environment Southland and DairyNZ, the NIWA study indicated that 90 per cent of the sediments at the four Jacobs River estuarine monitoring sites were not a direct result of farm animals. They were actually made up of sediments from urban waterways or coastal sediments that had made their way into the estuary.

Sheep pasture contributed to three per cent of the sediment, and dairy and deer pasture contributed only about one per cent.

Science helps out in the Pacific

When Cyclone Pam slammed into Vanuatu in May the vulnerability of Pacific's island nations to extreme weather was again laid bare.

The loss of life and destruction of homes and key infrastructure captured our attention. The Pacific Division of the Ministry of Foreign Affairs and Trade (MFAT) coordinates an Emergency Task Force that responded immediately. New Zealanders mounted fundraising campaigns to help those trying to survive and clean-up. The first priority was ensuring the people of Vanuatu had access to water and sanitation. The infrastructure rebuild will come later.

When there's a problem in the Pacific, it's "our" problem. When there's work to be done, we help.

But all is not well in our relationship with the Pacific. Head of the Secretariat of the Pacific Community (SPC) Colin Tukuitonga recently told local media that the region is turning elsewhere for the funds it needs. Tukuitonga said the region's leaders "want to look elsewhere, we can't just simply continue to rely on Wellington."

This is a great challenge for New Zealand. We can't compete with the deeper pockets of those nations the Pacific is now courting for cash. For example, New Zealand contributes 4.45% of the SPC's budget; 50% of it comes from the European Union. Even doubling our direct monetary aid across the Pacific would barely attract notice.

But the challenges the island nations face will not be solved by money alone. Our relationship is not based on cash. It is much deeper than that; it has as its foundation help, advice, guidance – transfer of knowledge and experience.

The Pacific looks to us because we have learned the art of collaboration. We work with others, across many teams, and with the people who are most affected. We are more multi-skilled and less specialised than many other nations – it comes naturally to us to train non-experts to be part of the solution.

MFAT's focus for the Pacific is to build sustainable economic development. That means work that helps Pacific nations build their own economies and capabilities, decreasing their long-term reliance on international cash.

The NZAid programme directs hundreds of millions of dollars at the Pacific each year. Some of this pays for Pacific nations to use organisations such as NIWA to build the technology, skills and capabilities they need to start doing things themselves.

Fronting this approach is New Zealand's first economic ambassador to the Pacific, Shane Jones. He is identifying ways New Zealand can help Pacific nations build their economic capability. His first priority, for example, is helping the region learn from New Zealand's experience to safeguard and manage its $US2 billion ($NZ2.7 billion) fisheries resource. NIWA's work assessing deepwater fish stocks in Tonga is the sort of expertise the Pacific is seeking.

NIWA works in the Pacific on a wide range of science-based projects – climate change and variability, weather forecasting, natural hazards and tsunami modelling, hydrology and water quality, sanitation, fisheries and deepsea mineral development.

Our approach is to adapt our science to the needs of Pacific communities, to build long-term solutions, and to encourage the whole community to be part of the solution.

MFAT's coordination of the New Zealand Government response to Pacific natural disasters has adopted this view. We've learned that replacing infrastructure destroyed by a storm is of limited use if it is in the same place, facing the same fate, as the original assets. Upgrading to the latest technology is of limited use if the locals don't know how to, and can't afford to, use and maintain it. Upgrades are of even less use if the locals don't change unsustainable patterns of work and living.

The New Zealand lesson is to adjust to weather, not to fight it. Science can tell you what to expect from natural hazards in the future, and how to adapt to reduce the impact. That means that rather than putting up expensive walls against the sea, you move the things that are in danger. You move infrastructure that is most vulnerable to floods, winds and sea inundation.

Our climate work in the Pacific – such as upgrading weather forecasting and early warning systems – is not simply to help the island nations forecast storms and better understand their climate. It is aimed at creating the capability that helps ensure water security or enhance agriculture production, for example through climate-informed decision making.

We understand that science has a cultural context – it can only be as useful as the community wants it to be. That's why NIWA's science centres are based on an approach that

Dave Hunt-Pool/Getty Images

many other nations are unfamiliar with – collaborating with Pacific nations and teaching and equipping them, so they can help themselves; build their own capability. We work in partnership with local and regional organisations to provide applied science-based assistance, training, capacity building and awareness activities. Many of our staff have lived in the Pacific or Asia regions and have an intimate knowledge of the biophysical and cultural environments.

As this issue of *Water & Atmosphere* demonstrates, we are doing a huge amount of work supporting the sustainable management of marine and freshwater resources and environments, increasing commercial and economic resilience to natural hazards, and adapting to or mitigating the impact of climate change in the Pacific.

We do this for good reasons. Pacific island nations are our neighbours and friends, and we have the scientific expertise to produce real, tangible, sustainable results.

Ultimately, what's good for the Pacific is good for New Zealand and good for NIWA – because good science means good deeds, good relations and good environmental, social and economic outcomes.

John Morgan is Chief Executive of NIWA.

Building resilience

Cyclone Pam's furious flight path across the South Pacific in March this year illustrated the danger natural hazards pose to life, livelihoods and infrastructural development in the region. Science is helping these rapidly urbanising nations plan for future development that is more resilient to weather extremes.

Uwen Garae stands in his destroyed house on 16 March 2015 in Port Vila, Vanuatu. Cyclone Pam has hit South Pacific islands on Saturday with hurricane force winds, huge ocean swells and flash flooding and has caused severe damage to housing. Aid agencies say it could be one of the worst disasters ever to hit the region. (*Dave Hunt-Pool/Getty Images*)

Reporting from **Mark Blackham** (New Zealand), **Helen Greig** and **Rachel Reeves** (Cook Islands).

In the Pacific there are few places to hide from the extremes of nature.

Almost everywhere in the Pacific is exposed to sea, weather and geology: where people live, and where their food, transport and businesses are located.

Cyclone Pam was classed as a category 5 cyclone – the most severe – when it hit Vanuatu on 14 March. Winds gusted up to 320km/h.

Although those in the path of Cyclone Pam had four days' warning, nothing could prepare their homes and community buildings for the power of the winds.

A police officer on Vanuatu's Tanna Island told Australian Associated Press that police were handing out emergency rations right up until the moment Pam hit.

Officer Eddy Are said they took cover, along with many others, in the few strong buildings on the island. "We just sat there for hours, listening to this bad, dark sound. All of us are homeless now."

The World Meteorological Organization says the Pacific is the region most prone to natural hazards. Seventy-five per cent of disasters are hydro-meteorological related, with tropical cyclones posing the highest threat and costs in the region.

A 2012 World Bank report found that, of the 20 countries in the world with the highest average annual disaster losses scaled by gross domestic product, eight are Pacific Island countries: Vanuatu, Niue, Tonga, the Federated States of Micronesia, the Solomon Islands, Fiji, Marshall Islands, and the Cook Islands.

The magnitude of these losses is being driven by high population increases and rapid urbanisation in all Pacific Island countries. The total population of the Pacific has trebled since 1960, and the urban population has increased more than five times.

A 2012 Asian Development Bank report on the state of Pacific towns and cities identified that five Pacific Island countries were predominantly urban, with seven having urban populations greater than 40 per cent. Population densities in places such as Betio and Bairiki villages in South Tarawa, Ebeye in the Marshall Islands, and parts of Port Vila and Suva now rival those of Asian cities.

Urban areas in the Pacific have typically developed from colonial centres that have expanded to incorporate surrounding traditional villages. This has led to a mix of planned and unplanned urban development, and a blend of formal and traditional forms of governance. But as rural to urban migration has accelerated, a burgeoning and permanent characteristic of most urban areas is growing squatter and informal settlements (settlements on customary land where land tenure arrangements have been agreed with customary landowners).

Sarah Mecartney, Pacific Programme Manager with UN-Habitat, says up to a third of households in some towns and cities are forced by lack of affordable land to create informal communities in environmentally sensitive areas.

"They live where they can – on low-lying coastal areas and among mangroves, or on steep slopes and on river edges.

"Not only are their houses easily damaged due to materials and construction, the settlements don't usually have protection such as drainage and earthworks, nor facilities like sewage and power," Sarah says.

Mecartney says UN-Habitat is seeing improvement from its work helping urban planners undertake vulnerability assessments, risk modelling, and learning from science agencies.

"There is a growing appreciation of the cost-benefits of planning. Risk considerations are now being built into by-laws and regulations, to create more resilient cities," she says.

Development planning can't come soon enough. In April last year, heavy rain due to Tropical Cyclone Ita caused some of the worst flash flooding ever experienced in the capital, Honiara, and villages on Guadalcanal. The flooding resulted in 22 people killed, 50,000 affected and an estimated US$107.8 million in damage and losses.

A report by the government of the Solomon Islands identified unregulated urbanisation as a major component of the disaster. About 3000 households, 35 per cent of Honiara's population, live in informal settlements within and around the city boundary.

Of the 243 houses completely destroyed by the floods in Honiara, most were located on the banks of the Mataniko River. They were largely traditionally built, low-cost, temporary structures on land that had not been subdivided for residential use.

The urbanisation problem is not confined to the Solomon Islands. A 2014 international comparison showed the exposure of urban populations is 40 per cent higher for cyclones than rural populations. In Fiji, for example, the study estimates that risk of floods is 17 per cent worse for urban areas.

After long considering themselves a rural and semi-rural population, Pacific nations now have to work out how to manage urban development. They are planning where to live and build modern infrastructure, how to incorporate formal land-use planning with traditional land ownership mechanisms, and how to design and build to handle their unique environmental conditions.

A major component of the urbanisation challenge is how to develop modern urban economies and societies in the face of extreme hazards, and with very limited resources. Science

is a starting point. NIWA has been providing hazard and risk maps to help facilitate stakeholder discussion and long-term planning, and developing tools to enable hazard and climate change considerations to be incorporated into infrastructure design. Armed with this information, island nations are developing more resilient communities, identifying locations where development needs to be avoided or where it can be relocated, and identifying conditions their infrastructure will need to tolerate.

Where and how to build

The Pacific is not on its own in planning urban growth and new infrastructure. International governments and development agencies (such as Australia, the European Union, China, Japan, New Zealand, the World Bank, the Asian Development Bank and United Nation agencies) are directing billions of dollars into the region every year. This assistance has a strong focus on development of basic infrastructure through coordinating mechanisms such as the Pacific Region Infrastructure Facility.

Provision of basic infrastructure is essential, but NIWA's Manager for the Pacific, Doug Ramsay, also suggests that it can play a critical role in developing community and urban resilience to weather-related natural hazards and the effects of climate change.

"In the face of climate change and the impact of natural hazards on island nations, there is a fundamental need for a rethink on where we build and how we build.

"Strategically located infrastructure can play a major role in this rethink – directing where future development happens and helping facilitate relocation of existing development in highly exposed areas."

Ramsay is concerned that many infrastructure development and adaptation projects in the region are being implemented with inadequate understanding of the present day weather and climate hazard risks and how these risks may change under future climate change.

He says there is still a large gap in translating climate change science into what it means at a local level for specific infrastructure design conditions.

"There's potential for under-designed infrastructure, maladaptation and inappropriate strategies being implemented without such information.

"It is critical to ensure natural hazard and climate change considerations are incorporated into decision making because major infrastructure has a long lifespan. It is difficult and costly to 'climate-retrofit' once such infrastructure is in place."

NIWA is developing risk-based information to assist planning, and developing tools to provide information required for infrastructure design.

A series of 'calculator' tools have been developed to support infrastructure design. These started in Kiribati in 2008, under phase two of the Kiribati Adaptation Project, and more recently in Fiji and the Cook Islands.

Calculators have been developed to provide extreme rainfall intensity design information for flooding, stormwater and drainage design; drought assessment to aid water resource management; and sea-level and wave assessment for coastal engineering design and coastal hazard planning.

Ramsay says the key was to develop easily applied, pragmatic but scientifically robust tools.

"The calculators are based on the ubiquitous Excel spreadsheet, which makes it easy to install, use and adapt.

"They have been developed around a common format, but are customised for the particular need."

To make it even easier for users, an interface has been built for the spreadsheet. Users make choices related to the type of project and the sort of guidance they need, and input data such as measurements specific to the location.

With the click of a button, the spreadsheet produces a range of design extreme conditions typically required by engineers, with the potential changes in these conditions over the design's potential lifetime due to climate change clearly defined.

Ramsay says the spreadsheet format means the calculators can be effortlessly modified to new uses.

"It's easy to pick up how these calculators work and local engineers have quickly grasped their use and application."

Climate-proofing Mangaia

The calculator proved its worth in assisting the island of Mangaia in the Cook Islands to incorporate climate resilience into future development planning for the main village of Oneroa and strengthening of Avarua Harbour.

Mangaia is the southern-most island in the Cook Islands, 206km southeast of Rarotonga and home to almost 600 people.

A coastal version of the calculator was specifically developed as part of the Mangaia component of the Pacific Adaptation to Climate Change (PACC) project launched in 2009. This was an effort by 14 countries, with coordination from the Secretariat of the Pacific Regional Environment Programme (SPREP) to enhance the capacity to increase resilience and reduce vulnerability to the adverse effects of climate change. The Cook Islands was one of four PACC members to identify coastal zone management as a priority.

Infrastructure Cook Islands Acting Director of Civil Works, civil engineer Paul Maoate, was appointed to manage the project.

Maoate believes the Cook Islands Coastal Calculator has revolutionised the country's ability to build infrastructure along its coastlines that is resilient to the impacts of climate change.

"We now have a tool that can incorporate sea-level rise projections over time, takes into account possible changes in cyclone intensity, storm surges and waves, and delivers the coastal extreme water levels and wave conditions we need to design coastal infrastructure," he says.

In February 2005, Mangaia was blasted by four cyclones that caused extensive coastal damage, and delayed shipping to the island.

Cyclone waves overtopped the harbour, filled more than 4km of coastline with debris, damaging roads, the main village of Oneroa, and the western half of the airport. After the harbour was damaged, many locals had to resort to airfreighting their cargo. Building a more resilient harbour facility was a priority for the Mangaia community.

The first step was to gather coastal-related data on Mangaia's coastline. The government worked with NIWA and the Secretariat of the Pacific Community's Oceans and Islands Programme in the Applied Geoscience and Technology (SPC-SOPAC) Division.

"A detailed survey of the harbour, airport, and town area mapped the terrain, with some tide and wave data also collected," says Maoate.

"The calculator was developed in spreadsheet form, making it easy for us to use and update. It incorporates extreme wave and sea-level data and factors in the predicted climate changes of sea-level rise, swells and an increase in the intensity or number of future cyclones for Mangaia."

Different scenarios were developed to assess how changes in climate and sea level would change extreme wave and water levels affecting the harbour so this could be incorporated into the rebuilding activities. NIWA also looked at how the frequency, magnitude and extent of coastal inundation in Oneroa village may change over the next one to two generations.

NIWA's Doug Ramsay and coastal scientist Dr Scott Stephens assisted with the calculator, training in its use, and translating the information.

Ramsay says the close relationship with Cook Islands engineers and the community on Mangaia was essential to the success of the project.

"We spent a couple of days training the engineers in the use and application of the calculator, and a few more with the engineers and Mangaia community working through the calculator's results and implications. This provided many ideas on how the tool could be improved, which we incorporated.

"Establishing credibility of the calculator with the Mangaia community was vital. With community members, we mapped where waves reached in the village during the three most severe cyclones that were experienced in living memory. Using the calculator, we estimated how far into the village waves would reach for these cyclones. There was a very good match between what had been observed by the community and what the calculator suggested.

"We then explored with the community where damage could occur in the village under future cyclone events exacerbated by sea-level rise and climate change impacts. Very quickly we could see which parts of the village, which community assets and buildings, could be impacted."

Ramsay says the information meant the Oneroa community could decide what they needed to move, strengthen or accept could be damaged over the next 50 years.

"Armed with information, the decisions are in their hands. They decided on the time frame over which they felt they could make adjustments, what their priorities were, and what assets they needed to protect. Over the next few generations they plan to gradually adjust their village to adapt to the increased potential of wave damage due to future cyclones."

Maoate says the projections from NIWA's hazard calculator, and the decisions of the Mangaia Council, fed into the project to build a new wharf.

"The island has no natural harbours or lagoons, and the energy of waves along the coast is quite strong because the geology of the reef is very steep. The Coastal Calculator told us the design conditions to enable us to increase the wharf's concrete slab thickness in order to prevent it from being damaged by future storm waves. We also increased the reinforcing and constructed it using isolated pads to mitigate future damage."

Building resilience

The new slipway, made of thicker reinforced concrete, was relocated to a sheltered area away from the harbour entrance to enable fishermen and the cargo barge to safely launch and land. The harbour channel was also widened to 30m and the depth of the entrance increased to 4m.

Maoate says the structural changes have made the harbour entrance safer to navigate, by reducing the wave set-up in the channel, and increased the overall strength and durability of the port area.

Mangaia's Mayor Tere Atariki says shipping is now safer and there are fewer delays.

"There have been real benefits in terms of freight shipped from Rarotonga. It's sheltered now. Previously, it was more open to the elements. In the past, cargo was often damaged before it was landed, and this was a frustrating loss for importers.

"Fishermen have been quite happy with the changes too, especially the new slipway. Strong currents at the old slipway site made it very dangerous to use at times," he says.

Atariki says initial designs never considered making the harbour climate resilient.

"The first design was lacking – there was nothing to prevent it from being destroyed all over again. The data gathered by the scientists and engineers through the PACC project helped us make the right improvements."

Oneroa shop owner Babe Pokino says he's been impressed with the upgrade, including the new sections of seawall on either side that allow better protection from waves.

"We get a ship in twice a month on average, and we don't have to worry so much about it waiting for days outside the harbour or turning away because of rough seas. The wharf is more spacious and cargo can be offloaded much faster from the barge."

In addition, the project has led to the development of an integrated coastal management policy framework and implementation plan for Mangaia.

Maoate says a cost-benefit analysis carried out late in the project highlighted that strengthening harbour structures to cyclone forces is more efficient when it is designed and built from scratch, rather than a retrofit.

"With retrofits there are always some unknowns that may pose a risk to the overall strength of the structure."

Since the project's completion, the government has adopted a policy that all new coastal infrastructure projects be climate-proofed.

The calculator was not just developed for Mangaia; it can be applied to any of the 15 islands in the Cook group.

"We are already finding new applications for the Coastal Calculator. It will be adapted for use in the upgrades to harbours in the northern group islands of Manihiki, Rakahanga and Penrhyn due to begin this year," says Maoate.

The cost of natural hazards

Since 1950, natural disasters have directly affected more than 3.4 million people and led to more than 1,700 reported deaths in the region (outside of Papua New Guinea).

Ten of the 15 most extreme events in the region reported over the past half-century occurred in the last 15 years.

The number of hurricane-strength cyclones has increased in the southwest Pacific in the past 50 years, with an average of four events now occurring each year.

The cycle of natural disasters seriously retards economic development of the South Pacific. Exactly how much the Pacific is set back is largely unknown, because there are few resources to assess economic impacts of each disasters.

A SOPAC statistical summary of hydro-meteorological disasters in the Pacific (February 2014) found that, while the cost was estimated at NZ$5.2 billion, "the cost of these disasters is massively understated". It said 44 per cent of all recorded disasters have no value costs recorded with them.

The damage and losses from the 2014 Honiara floods were equivalent to 9.2 per cent of gross domestic product (GDP) for the nation. The sectors most damaged were urban and infrastructural: housing and transport, accounting for 56 per cent and 23 per cent of damage, respectively. Economic losses were highest for the mining sector (50 per cent of all losses) and agriculture (31 per cent). As a result, the Solomon Islands Government expected growth to be negative 1.1 per cent that year.

Fiji is the most prone in the region to hydro-meteorological disasters. The costs of these over the 30 years to 2012 was NZ$1.6 billion.

The Fiji floods in 2009 caused about NZ$5 million in humanitarian costs – the impact on people. But the greatest costs – NZ$24 million – were incurred by the nation's sugar industry. The floods were debilitating; 150,000 tonnes of production were lost. Repair was needed to fields, buildings, equipment and roads. This takes time and money, which lowers production over the medium term and sets back long-term industry development.

Fiji floods

Fiji is one of the most urbanised nations in the South Pacific – 52 per cent of the population live in urban areas. This is growing by 1.5 per cent every year.

In January 2009, Fiji was hit by devastating floods. The water claimed 11 lives, left 12,000 people temporarily homeless and caused more than NZ$70 million of damage.

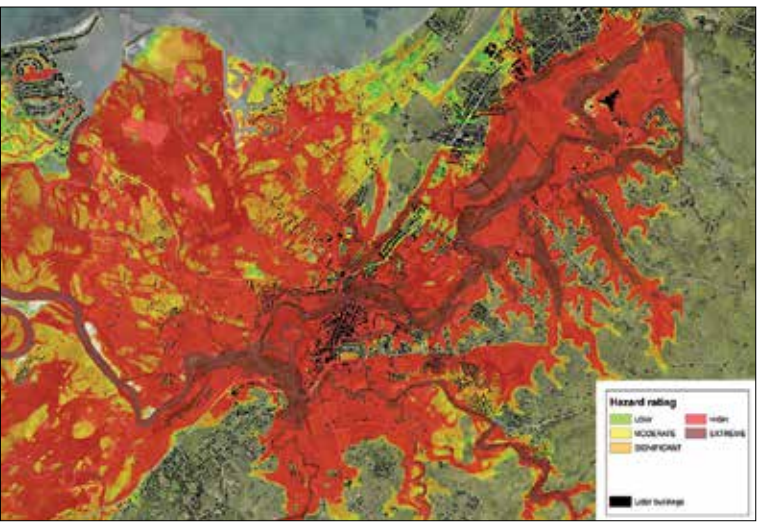
In March 2012, torrential rain again caused flooding that affected more than 150,000 people, with four deaths.

One of the areas most at risk is Nadi, the main gateway to the country for tourists. The high rate of urbanisation, as people move from rural areas in search of jobs in the tourism industry, has collided head-on with the region's climate. Development pressures, particularly informal settlements in the peri-urban areas surrounding the town, are pushing people into evermore flood exposed locations. A UN-Habitat report in 2012 said, "Floods are the principal hazard as a result of the town's topography, mangrove deforestation, and up-river agricultural and catchment management practices."

In recent years the nation has come to grips with the flood risk and development challenges facing Nadi, with a number of inter-related projects aimed at reducing the impacts. NIWA has been part of this effort on a number of fronts, including recently completing the Nadi River Flood Risk Project with the Applied Geoscience and Technology Division (SOPAC) of the Secretariat of the Pacific Community (SPC), with funding by the World Bank.

NIWA Christchurch Regional Manager Charles Pearson says they used computer modelling to assess flood events in the Nadi river catchment, including simulating the 2012 flood.

He says increasing development of land within flood plain areas exacerbated the risk of flood disasters. So NIWA simulated flood events to help Fiji plan flood mitigation measures.



Computer modelling indicates that if a 100-year flood event were to occur, most of the Nadi River basin would be underwater and there would be significant loss of life. (*NIWA*)

Pearson's team used topographic data from high-resolution LiDAR (airborne laser scanning), hydraulic inundation models (computer flow simulations) and risk models (combining hazards and assets). Flood inundation maps were developed, from which economic damages and human losses for the Nadi flood plain area were calculated.

"The model has been able to create maps showing the impact of large flood events on the flood plain," says Mr Pearson. "As well as being able to assess flood warning and evacuation procedures, the modelling helps manage urban development planning."

The study showed that under most flood events, the delta from Nadi township to the ocean would be under water. There would be significant loss of life and damage to infrastructure. Initial assessment of potential mitigation options, such as a flood diversion channel, indicated that, while some of the flood exposure could be reduced during large floods, it would not solve the flooding problem.

The flood model information is now being used in a subsequent NIWA-led project working with Nadi Town Council and the Department of Town and Country Planning within the Fiji Ministry of Local Government, Housing and Environment. The town is one of two demonstration studies in a regional project funded by the Asian Development Bank to develop tools and processes to better incorporate flood hazard considerations into urban and infrastructure planning.

The work builds on earlier support NIWA provided as part of the Nadi component of the regional Integrated Water Resource Management (IWRM) project, coordinated by SOPAC (now SPC). This established a network of rain gauges and river flow monitoring stations in the Nadi catchment that transmit data back to Fiji Meteorological Service to form part of an early warning system.

Pacific IWRM project manager Vinesh Kumar said NIWA's approach to its involvement in the Nadi project has made a difference.

With a large upper catchment of 500km² posing a major flood risk for the downriver Nadi township, an effective early warning system was vital to protect life and property.

"We wanted to see how best we could get that [flood] information to see how we could improve the warning system," says Mr Kumar.

"We didn't want to bring in something that was a one-off, and we didn't want to bring in consultants just to put in one thing but not to the level of the local capacity.

"The way we wanted to approach this issue was to have a component of sustainability and process throughout. We were looking long term, as well, so if the system becomes obsolete we can see how to upgrade it."

Mr Kumar said NIWA was the perfect partner.

"When we engaged with a few companies and went through the process, we found that NIWA had the best options. NIWA also had a good reputation among other stakeholders."

Hydrology technicians Iosefo Erenio (*left*) and Tomasi Naborisi from Fiji Meteorological Service operate new ADV (Area Depth Velocity) equipment recently supplied by NIWA to gauge river flow in the upper Nadi River catchment. Training in the use of the equipment was also carried out by NIWA. Information gathered will be used to assist in the provision of advanced flood warning to residents in low-lying areas of the Nadi Basin. (*Dave Allen*)

Resilience pathways

Cyclones, or typhoons as they are known in the northern Pacific, have long played a role in influencing development patterns.

Over 600 years ago, the islanders of Kosrae, the eastern-most island in the Federated States of Micronesia, commenced construction of Lelu, which was to become the centre of settlement for the rulers of Kosrae for the next 400 years.

The settlement consisted of 100 prismatic basalt walled components reclaiming an intertidal area of reef some 20ha in size. A typhoon sometime in the AD1400s that deposited sand and coral rubble is thought to have created the base for the development at Lelu. Another in the 1790s damaged Lelu, starting its demise as a settlement.

The majority of the population traditionally lived on the lower slopes of the volcanic parts of the island, but above areas impacted by coastal flooding or erosion. Since the mid-1850s, the main villages and all Kosrae's infrastructure have developed on a narrow strip of land around the coastline, built up by cyclone and storm deposits.

The last typhoon to devastate Kosrae was in 1905. However, warnings of the vulnerability of Kosrae's development occur on a frequent basis. Significant high tide flooding and wave overwash of where people live now happen almost annually.

Almost 90 per cent of locals report having experienced coastal erosion, and over half of them have lost property and income due to extreme inundation.

Kosrae has realised that, in the face of climate change, the present development pathway is unsustainable. Kosrae's Governor the Honourable Lyndon Jackson said, "We acknowledge that many of the approaches we presently use to manage the impacts of these hazards on development and our communities will be increasingly ineffective or unaffordable as sea levels rise."

So Kosrae, with support from NIWA, has set out an adaptation plan for the next two generations. Called the Kosrae Shoreline Management Plan, it develops a range of inter-related adaptation activities.

Fundamental to the plan is strategic relocation of infrastructure over the next one to two generations. This will act as a guiding mechanism to assist the gradual relocation of people currently living in areas highly exposed to coastal hazards, back to the locations on the lower parts of the volcanic part of the island where their ancestors had originally settled.

Ramsay says infrastructure can create an enabling environment.

"Communities generally develop around where infrastructure is located. By starting the process now and implementing over generational time frames, relocating infrastructure can be done in an affordable and manageable way, without people feeling threatened by the thought of relocation. As people build new properties, businesses and assets, development on safer, less exposed areas can happen gradually.

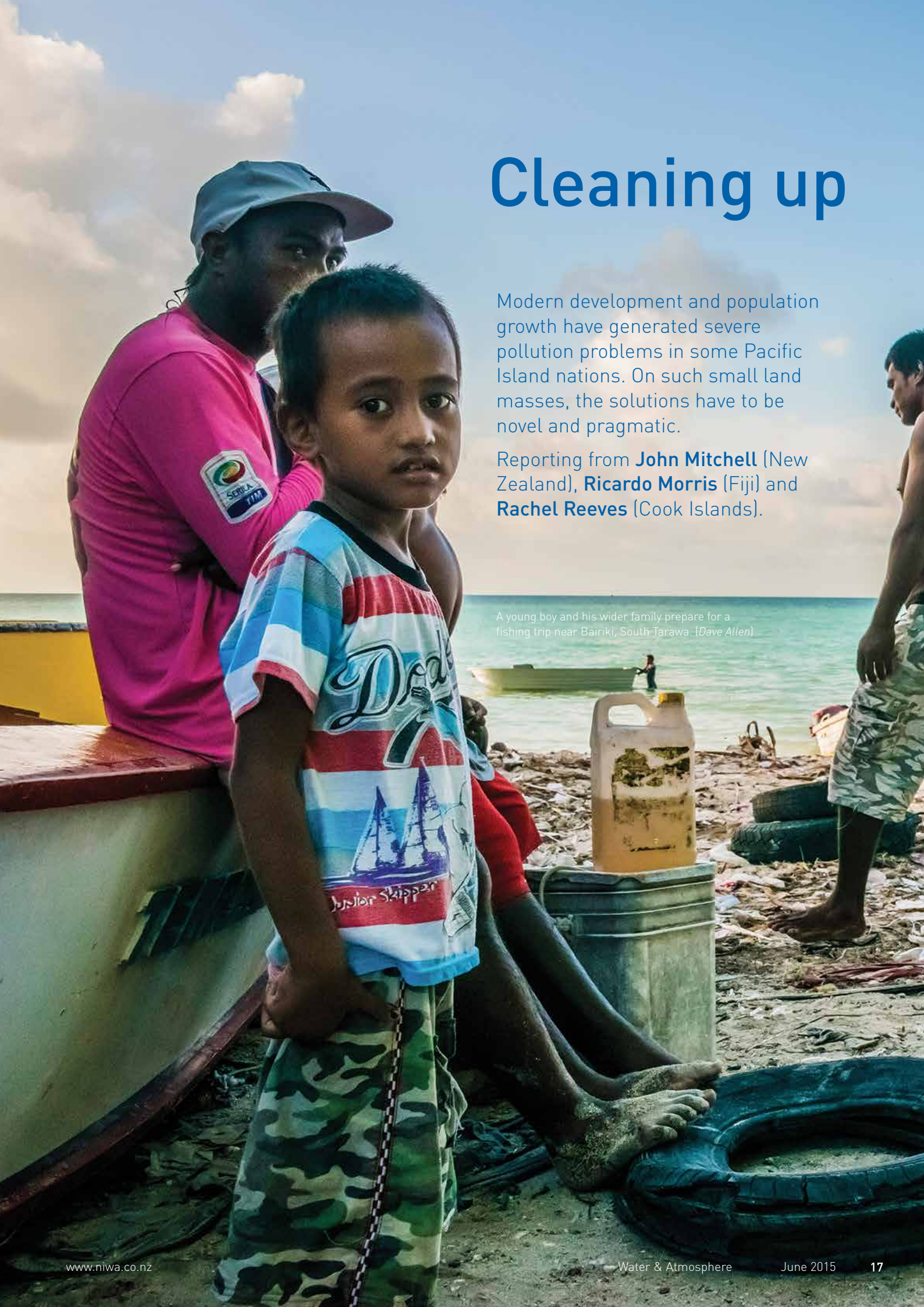
"Relocation is always a difficult thing to discuss, particularly in the Pacific where land has such cultural standing. The important thing is to let people take control by starting the conversation, offer hope, creating an enabling environment, expanding their comfort zone and providing time.

"The hope is that Kosrae's communities can build resilience through a different development pathway, rather than being forced by a severe typhoon striking the island, as their chiefs were on Lelu in the late 1800s, or as the consequences of climate change and sea-level rise really begin to bite."

Cleaning up

Modern development and population growth have generated severe pollution problems in some Pacific Island nations. On such small land masses, the solutions have to be novel and pragmatic.

Reporting from **John Mitchell** (New Zealand), **Ricardo Morris** (Fiji) and **Rachel Reeves** (Cook Islands).



A young boy and his wider family prepare for a fishing trip near Bairiki, South Tarawa. (*Dave Allen*)

Rarotonga is surrounded by a lagoon, which extends to a reef before sloping away to the deeper waters of the Pacific Ocean. It is home to some 13,000 people out of the Cooks' total population of approximately 18,000.

It is a playground for holidaymakers seeking an idyllic tropical paradise. That's seen tourist operations pop up all over the island.

That is why some locals, such as Mike Tavioni, a carver, artist and canoe builder, see tourism development as the cause of the island's pollution problems.

He recalls fishing off Muri Beach on the southeast of the island, long before resort hotels and beachfront homes began to spring up on the shoreline.

Once a pristine stretch of sand, Muri Beach is now smelly and polluted, and development is the cause of the problem, Tavioni says.

"You go to Muri Beach when it is low tide and you scrape the sand where the water meets it. It's black and it stinks. Everybody is blaming the [farmers who keep their] pigs next to the river inland, but we had the pigs inland for 100 years.

"They are diverting people's attention from the real cause. What do we get from tourism? Foreign businesses get money and we get a sick beach.

"It didn't used to be like that."

There are a number of reasons why Rarotonga – like almost every populated island nation on the Pacific – is wrestling with the issue of pollution.

At the core of all these reasons is people. Pollution is a people problem. Tourism is only one symptom of modern development and growth that have outpaced waste and water infrastructure and traditional patterns of living.

Collaborative approaches between aid, development and environmental science agencies are addressing pollution problems affecting all Pacific Island nations by giving people the tools and expertise they need to find workable, long-term solutions.

Nowhere to hide

While the developed world worries about large scale, but still largely unseen, pollution issues, Pacific Island nations are dealing with the everyday realities of pollution.

In New Zealand we are accustomed to turning on a tap to get clean water. Sanitation infrastructure takes care of wastewater. Our rubbish is collected and disposed of. Our large land area and geographic make-up means we have access to regular sources of water and places where we can store it.

Most Pacific Island countries, however, do not have these natural advantages. Together with a lack of economic grunt to invest in infrastructure, limited local expert knowledge and, in some cases, exploding population growth, the need for workable solutions to the problems is now desperate.

The combination of pollution factors unique to each island means solutions have to be highly tailored and tackled project by project. But, where solutions are being found to work, they are being copied and adapted throughout the region.

NIWA regional manager and marine and freshwater biologist Dr Julie Hall says the ultimate success of projects and initiatives to combat pollution throughout the Pacific relies on empowering island populations to better manage the problems themselves.

"It's not enough to give them equipment, show them how to use it and then leave them to it.

"The key to making real change is to upskill the people, to build their knowledge and understanding. That's quite an iterative process, and one that takes time."

Dr Hall has first-hand experience of the pollution challenges facing the Pacific as a result of her work on Kiribati. She says that, while some pollution issues are out of the control of Pacific nations, others are theirs alone.

"Part of what we're working on is behavioural change. For instance, one of the major problems in Kiribati is patterns of open defecation on the beaches.

"Even though there are, in some cases, public facilities available, many prefer to do it that way because it's what they've always done. It's a behaviour we're trying to change by showing them how much of an impact it's having on water quality."

For people that depend on the sea as a food source, as well as for swimming and bathing, a clean marine environment is critical.

Something in the water

The integrity of water, both on the land and offshore, is critical to the island way of life.

Increasingly limited freshwater resources in low-lying islands in particular are under extreme pressure from population growth and poor management, as well as rising sea levels and other impacts of climate change resulting in unpredictable rainfall patterns.

The incidence of diarrhoeal diseases is high, due to poor hygiene, lack of adequate sanitation treatment systems and high levels of poor quality drinking water.

Agriculture is also having a major impact, with animal waste, fertiliser and pesticide runoff making its way into freshwater supplies and coastal waters.

Cleaning up

In Kiribati, getting a handle on the size and scope of the problem of water quality was the top priority, says Dr Hall.

NIWA is leading a two-year project to establish baseline water quality reporting in the republic, which has resulted in a colour-coded report card aimed at providing key information to inform and prioritise water- and sanitation-related infrastructure investment decisions.

The baseline data are being used to evaluate the longer-term impacts and effectiveness of water and sanitation infrastructure interventions in dealing with water quality risks and marine ecosystem health.

The data provide information for public health warnings and advisories. The information also feeds into decisions about management of sustainable food sources such as shellfish and other natural marine resources that the subsistence economy of Kiribati depends on.

In Fiji, NIWA has led two projects installing pragmatic water supply and waste treatment solutions to protect public health and reduce contamination of coastal waters.

The four-year 'Wai Votua' project led by NIWA's Dr Chris Tanner, Principal Scientist – Aquatic Pollution, was launched under the New Zealand Aid Partnerships Fund Programme.

Emerging from this effort, a second project – 'Koro WASH' – was started in 2013 in two other villages. It involves development and testing of smaller scale individual household systems.

Both projects seek sustainable, practical, local solutions to the treatment and disposal of wastewater, as well as the development of water supply and sanitation infrastructure.

The Wai Votua project was focused on Votua, a coastal village of around 300 people on the Coral Coast of the main island of Viti Levu. The villagers lived with untreated wastewater discharges.

In Votua, the wastewater flowing from the village's 57 households (now 65) caused the area to become boggy and smelly, and affected the villagers' health. It also had an impact on the creek that meets the sea beside the village, and on the coral reefs beyond.

Since the water supply and wetlands treatment system was commissioned in October 2010 by NIWA, there has been a notable drop in skin diseases and waterborne illnesses, and the ground around the houses is no longer soggy.

A chief at Votua, Emosi Buravatu, says in the early days villagers had to make do with bathing and washing in the river and using pit toilets along the beachfront. The river mouth, which tests later found to be highly contaminated from the pigpens situated there, also served as a popular play area for children. Houses had no in-house water and women had to cart water for drinking and would wash in the creek.

A water supply and wastewater treatment system, designed in conjunction with Andrew Dakers of Christchurch-based

NIWA scientist Julie Hall with two Kiribati government Environmental Health officers sampling ocean-side water at Tangaru Hospital, South Tarawa. (*Dave Allen*)

NIWA in the Pacific

Working with our Pacific partners

NIWA
Taihoro Nukurangi

Improving water quality

1 Cook Islands
Developing a coastal and lagoon water quality monitoring programme with the Ministry of Marine Resources for pearl and tourist areas.

2 Fiji
Implementing systems and infrastructure for water supply, sanitation and hygiene to rural villages to reduce health risks.

3 Kiribati
Working with the Kiribati Water Quality Committee to implement a coastal water quality monitoring programme to inform sanitation infrastructure investment.

Developing resilient communities

1 Fiji / Samoa
Working with planning agencies to incorporate natural hazard risk considerations in urban planning (with SPC-SOPAC).

2 Fiji
Detailed flood inundation modelling of Nadi town and assessment of economic damage using RiskScape.

3 Vanuatu
Risk management guidance to develop more resilient urban communities in Greater Port Vila and Luganville (with Beca and GNS Science).

Developing resilient communities

4 Wallis & Futuna
Modelling inundation from tsunami sources to support evacuation and development planning.

5 Tokelau
Assessment of inundation hazard from tsunami to support evacuation planning and risk reduction.

6 Federated States of Micronesia / Palau
Working with local and international NGO's to develop a guide to support community understanding of coastal erosion and flooding issues.

Climate services for water and food security

1 Samoa
Developing a climate early warning system with the Samoa Meteorology Division to support Agriculture, Health and Forestry sector decision-making.

2 Fiji
Multi-year collaboration with Fiji Meteorological Service to developing weather, climate and hydrological services.

3 Solomon Islands
Assisting the Solomon Islands Meteorological Service with the meteorological and climate early warning component of Strongem Waka lo Community fo Kaikai project.

4 Regional
Island climate update - working with the Pacific Island meteorological services to improve and deliver seasonal climate forecasts.

Informing infrastructure development

1 Federated States of Micronesia
Developing a multi-generational adaptation pathway to create a more resilient society on Kosrae from the impacts of climate change and sea-level rise.

2 Tokelau
Option and environmental impact assessment of improving cargo and passenger transfer from ship to shoreline (with Spiire NZ Ltd).

3 Cook Islands
Developing decision support tools to inform climate-resilient coastal infrastructure and community development (with SPC-SOPAC).

4 Kiribati
Developing information and tools to support climate risk management.

5 Tuvalu
Review and future needs assessment of the outer islands ship to shore project.

Sustainable economic development

1 Tonga
Developing a sustainable local line fishery for deepwater demersal fish species (with Tongan Ministry of Agriculture and Food, Forests and Fisheries & SPC).

2 Timor-Leste
Assisting the Timor-Leste National Directorate of Fisheries and Aquaculture re-develop its freshwater and marine aquaculture industries (with Worldfish).

3 Papua New Guinea
Multibeam echosounder survey and seabed sampling to assist the development of a submission to the United Nations for extended continental shelf concessions and considerations.

4 New Caledonia
Improving understanding of the movements of tuna and other pelagic fishes (with SPC & IRD)

5 Regional
Development of Pacific ACP States regional guidelines for marine mineral scientific research activities.

company ecoEng, was installed throughout the village. The system comprises separate treatment of toilet wastewater (referred to as black water) and grey water (from washing, bathing and cooking). Pigpens were also moved away from the village and water systems.

The village water is supplied from a dam in the mountains above the village. Water is passed through a new intake filter and settling tanks, and pumped into a new reticulation system in the village. This feeds into a mains water supply supplemented by rainwater collection. To design an appropriate water and wastewater system, water meters were initially used to monitor usage as well as the consequent black and grey water generation.

The new wastewater system treats black water in septic tanks followed by a planted wetland treatment system built in a valley behind the village, while grey water is treated using coconut husks as a pre-filter, followed by soil and sand filtration.

Each house has a septic tank that is connected to pipes that take the overflows to a centralised pumping station. From the pumping station, effluents are transferred up to a wetland constructed behind the village, where it goes through a filtering process through sand and gravel vegetated with wetland plants before the treated water is used to nourish village gardens.

Viliame Jeke, who was the community consultant leading the implementation of the system, says it is imperative that any water supply system built in villages must also consider what to do with the resulting wastewater.

"Water coming in is as important as the water going out – we have to treat that. Otherwise we are just bringing sicknesses into the village because we don't know where they are putting their wastewater, which is far more dangerous than bringing water in," says Mr Jeke.

In Namaqumaqua and Bavu villages, a few kilometres east and west either side of Votua, NIWA's second project is trialling several different designs for sewage treatment systems for individual households.

The treatment systems, involving septic tanks and land application, were installed at Namaqumaqua in 2013. Mr Jeke says they are much more cost-effective and easier to maintain than Votua's more elaborate system.

Ana Lagorei, 48, who works at the nearby resort, says since her sewage treatment system was built in 2014, her family's quality of life has greatly improved.

"With the old system, it would smell and the tank was becoming full. But now we are happy because things have improved. There is no more smell and it is healthier now," says Ms Lagorei, who lives in the house with her husband, two sons and mother-in-law.

"Sometimes I would be confronted with the smell when I came back tired from work, but now I don't. It's a blessing to us. Other generations coming after us will still be able to use this system," she says.

The septic tank system installed at Ms Lagorei's home includes a large dual-chamber tank, and a concrete-covered filtration trench that uses sand and coconut leaves. The treated water then goes into a vegetable gardening area.

Dr Chris Tanner and the team investigate potential sites for a new household wastewater management system to be installed in Namaqumaqua village. (*Dave Allen*)

Chris Tanner discussing sanitation options with members of the Water and Health Committees, Namaqumaqua Village, Fiji. (*Dave Allen*)

The Coral Coast lies in Fiji's typically dry western region where water scarcity in rural areas is often a challenge, so water-less Koro-VIP (ventilated improved pit) toilet systems are also being trialled to eliminate water from the process. As well as not requiring a water supply to operate them, they are much simpler and cheaper for villagers to build.

Dr Tanner says the focus of the project was to work alongside the villagers to find solutions that were effective and practicable.

To be successful, the solution had to be financially viable in a village context, as well as easily manageable. A small-scale solution was developed, integrating infrastructure upgrades with the creation of a wetlands wastewater treatment system.

Villagers are able to use tap water, rather than contaminated water from a nearby creek that was used for everything from drinking and cooking to bathing and sewage disposal.

"Having a proper water supply was a big thing for the people," says Dr Tanner. "The looks on their faces when the water came from their new showers were incredible. They didn't have to bathe in contaminated water, there was no more discharge or smell, and the potential for disease was greatly reduced. It was a big improvement."

The updated reticulation and treatment system has had a major impact, particularly on the health of the villagers.

"Villagers reported a big drop in the incidence of diarrhoea and other illnesses associated with waterborne pathogens," Chris Tanner says.

Makereta Nagauna, 26, of Votua says the changes in the village since the system was commissioned have been dramatic.

"Before they completed this project, especially for children, there would be a lot of skin diseases, but now it has dropped," says Ms Nagauna.

This is not just anecdotal evidence. While completing her university environmental science course, Ms Nagauna decided to survey the impacts on village health and that of the creek and lagoon after the wetlands project was commissioned.

"I interviewed the village nurses and they showed me their diaries – things have really improved compared to the past," Ms Nagauna said.

She added that the well-being of the village in general had improved, with the burden on housewives lightened because of the direct access to clean water in their homes. As well, the marine life in the lagoon has returned.

Ms Nagauna took water samples and compared them with baseline data from the creek and lagoon, and noticed huge improvements in water quality and marine life, which villagers depend on for food and income.

Out with the old, in with the new – a Namaqumaqua villager shows us his old pit toilet before a new latrine is installed on his property. (*Dave Allen*)

Eroni Savou (*left*) and Semi Naqiolevu (right) standing in front of a brand new pit latrine at Namaqumaqua village. (*Ricardo Morris*)

According to Dr Tanner, the NIWA project showed that a simple, elegant, science-based solution tailored to the needs of villagers could get results, especially when designed and delivered in conjunction with the locals themselves.

"It's a village-scale solution that the villagers themselves can manage," says Dr Tanner.

"That's the really important thing; that it can be shared and adapted elsewhere, with practical guidelines also being developed to aid uptake to other villages."

Mr Jeke showed *Water and Atmosphere* his latest pride and joy: a dual-chamber ventilated pit latrine where small additions of soil or mulch are used to quicken the decomposition process of the faecal solids and eliminate odours.

"I've seen compost toilets in Fiji but not a Koro-VIP latrine version with chambers like this one," says Mr Jeke of the toilet installed at Namaqumaqua villager Semi Naqiolevu's place.

"Because of the scarcity of water, this pilot of the improved pit latrine is much cheaper to implement than a septic tank system." Mr Jeke says one chamber will probably take eight years to fill up, before it becomes necessary to use the other chamber.

Naqiolevu, 54, is as proud of the neat corrugated iron and concrete structure, which almost looks like a tiny church, complete with a washbasin fashioned out of a giant clamshell in the small porch at the entrance.

Mr Naqiolevu beams as he describes how happy he and his wife are that they finally have a proper, odour-free toilet facility.

The team working on these projects includes Dr Rebecca Stott, a NIWA environmental health scientist, and Dr Ann Winstanley, a social scientist from New Zealand's Institute of Environmental Science and Research, who assisted with health and hygiene monitoring, and capacity-building with the villages. Making the connection between the health of their families and the state of their water and wastewater systems was the key to engaging women's involvement in the project. Communication and active engagement by local villagers were also significantly aided, and the outreach of the projects extended, by building on local knowledge, networks and input from the University of the South Pacific in Suva, the non-governmental organisation Rustic Pathways and Viliame Jeke.

Blue lagoons

The Cook Islands comprise five major islands spread over more than 2,200,000 square kilometres of ocean, divided into two distinct groups: the Southern Cook Islands and the Northern Cook Islands of coral atolls.

Rarotonga is the Cooks' most populous island and is surrounded by a lagoon bordered by a coral reef.

The lagoon is central to life in Rarotonga. But the infilling of swamps and clearing of foreshore vegetation to build hotels, a history of poor sewage management and the runoff of chemicals used in modern agriculture have taken a toll on its health.

To better understand the problem, the Cook Islands Ministry of Marine Resources (MMR) is supporting an $18 million waste and sanitation project through an agreement to provide water quality testing services over the next four years.

MMR Secretary Ben Ponia says NIWA has played a key role in developing the capacity for lagoon monitoring.

"The involvement of NIWA began with an institutional strengthening project that trained staff in analysing key water quality data and establishing a water quality testing laboratory."

The new agreement with Infrastructure Cook Islands (ICI) to conduct groundwater, stream, and lagoon water quality testing in association with the Sanitation Upgrade Programme (SUP) was signed in December.

The SUP is aimed at delivering improved infrastructure, services, systems, regulation, monitoring and awareness of sanitation and waste management. The project is funded by the Cook Islands Government, the New Zealand Aid Programme, and the European Union.

It follows on from a $3 million waste management initiative from 2011 to June 2014, which resulted in the upgrade of sanitation systems in about 220 homes on Rarotonga's southern coastline.

According to WATSAN (ICI's water, waste and sanitation unit), residential sources make up 45 per cent of lagoon pollution on Rarotonga. Another 35 per cent is attributed to commercial properties.

Assistance provided by NIWA and the Global Climate Change Alliance: Pacific Small Island States (GCCA: PSIS) project has enabled the MMR to build the capacity needed to provide water quality testing services.

Developing robust water quality datasets against which future changes can be tracked, through ongoing and improved water quality monitoring, is one of the key outcomes of the SUP project.

Ponia says past support from NIWA helped the MMR set up a programme to collect baseline water quality data in the islands of Rarotonga, Aitutaki and Manihiki.

"Having a baseline set of data provides a reference point to compare changes in water quality over time. NIWA expertise was useful in establishing standards to assess what levels could be considered good or poor quality.

"The natural nutrient recycling processes and tropical versus temperate environment mean each location is affected differently by nutrients. For example, in some systems the level of nitrogen may limit the growth of algae in the lagoon, and in other systems it may be phosphate that is the limiting nutrient, which you have to monitor carefully."

Initially the NIWA laboratory was used to test samples that couldn't be processed at the MMR's makeshift chemistry and microbiology lab.

Former MMR Secretary Ian Bertram, now with the Secretariat of the Pacific Community (SPC), says reports in 2004 of an irritant syndrome in the Titikaveka lagoon sparked the MMR's engagement with NIWA.

"Swimmers were reporting sore eyes, rashes, and other symptoms from this one area of the lagoon. We thought it was caused by a harmful algae bloom, but this was never confirmed. There was a lot of speculation in the media about the cause – it could have been soil that was dumped around the nearby college, introduced plants, pollen, all of that. I'd heard of these kind of symptoms being reported in Hawaii and Sydney, but there was little evidence produced on what had caused it."

At the time, the MMR had begun water quality testing for the pearl farming industry in the northern group islands of Manihiki and Penrhyn.

"When the irritant syndrome was reported, we brought equipment from Penrhyn to start researching the cause. At the same time, we needed to learn how to carry out the sampling and testing ourselves. That's when we got in touch with SOPAC [South Pacific Applied Geoscience Commission] and they put us in touch with NIWA. New Zealand was close enough for us to send samples across, and NIWA brought in equipment and staff to help train us and set up an office as a lab."

Ponia says the MMR has come a long way over the past decade.

"We are practically self-sufficient in our water quality monitoring programmes and our ability to conduct testing. We currently use a spectrophotometer for testing, and we are looking at acquiring a nutrient analyser, which will allow faster testing and greatly expand our capacity to monitor sites, and to do so more regularly. Ultimately we will also require a purpose-built laboratory to carry out these tests.

"While we now have the skills and the capacity, the physical infrastructure of the laboratory limits our ability to meet international standards for accreditation. Because it is not sterile, this risks samples being contaminated."

Climate action stations

Climate and weather are central to life in the Pacific. They affect everything, from crops, health and transport, to tourism and social life.

The islands of the Pacific put up little resistance to the great patterns of the region's evolving climate and day-to-day weather. Living there, you are constantly aware of nature's parade passing overhead. When the weather or climate is extreme, the parade can be a deadly spectacle.

Powerful and sudden weather punches are devastating (see Resilient islands, page 10). The region experiences an average of eight to nine tropical cyclones every year. NIWA estimates that in an average season, four cyclones are likely to reach category 4, with mean wind speeds of at least 86 knots or 160 km/h, and one to two reaching category 5, with mean speeds in excess of 107 knots or 200 km/h. In 2012 Cyclone Evan killed 14 people and caused massive property damage in Samoa – and resulted in the loss of one-third of the country's annual economic output.

However, extremes in climate that play out over much longer periods, such as drought, can be just as damaging as cyclones.

In 2011 Tuvalu and Tokelau were severely affected by dry conditions resulting in a state of emergency being declared in Tuvalu in late September. By this stage, subsistence crops were suffering, water was being severely rationed and a number of islands were close to running out of drinking water.

NIWA's Manager for the Pacific Doug Ramsay says, "A key issue was that, although a variety of regional forecast information was available indicating dry conditions, it wasn't being communicated in a way or context that highlighted the growing severity of the drought until it was almost too late."

Seasonal and inter-annual changes in the state of the sea and regional atmosphere can provide clues to the likely frequency of tropical cyclones, the possible onset of drought, and the chances of high sea levels that damage coastal communities and infrastructure.

Despite this, early warning systems have not kept pace with human development in the region. Climate services are in high demand by sectors such as health, water, agriculture and fire control. But accuracy and forewarning have been hampered by low numbers of monitoring stations, a shortage of equipment, vast distances, and limited access to robust communication networks.

The World Meteorological Organization (WMO) Secretary-General Michel Jarraud says if the world doesn't invest in stronger weather and climate services, "extreme-weather events could simply wipe out years of development effort" in the South Pacific.

The WMO produces a world map highlighting major gaps in observations and monitoring. The Pacific Islands are dotted in red, signalling what has until recently been an alarming shortfall in monitored weather and climate data.

For the Pacific Islands, limited resources have meant insufficient collection of climate and weather data, and inadequate dissemination of climate advice to decision makers and vulnerable communities.

Gaps in local data collection have also made it more difficult to study the long-term trends that might signal changes in climate and weather risk factors that could impact Pacific Island countries.

NIWA's Doug Ramsay, Manager for the Pacific. (*Dave Allen*)

NIWA climatologist Alan Porteous says that over recent decades the region suffered from less than adequate resourcing for meteorological work, due in some cases to a withdrawal of international support.

"Over those decades, Pacific meteorologists were stretched to maintain basic services," he says.

Porteous is full of praise for the local efforts. "Meteorologists and climate staff were able to maintain many basic services, and also continued to supply weather observations to the global meteorological community."

The efforts of Pacific meteorologists were supplemented by meteorological satellites, first launched in 1960. These enhanced the Pacific data by interpreting images of cloud cover to assess weather conditions. Rapid development in sophistication and numbers of satellites continued to patch the gap.

In 1978, United States Congress passed the National Climate Program Act, setting off a chain of new investment in meteorology.

NIWA technician Barry Waugh with Fiji Meteorological Service technician Anal Chandra at Nadi airport's EWS site. Observations have been recorded at this location for more than 70 years, much longer than most other regions of the Pacific. (*Dave Allen*)

One reason for the growth was growing appreciation of the cost of weather-related harm. The Meteorological Society of America estimated in 2001 that a 20 per cent improvement in predictions of hurricane landfall, track and intensity could save $80 million per storm, or roughly $500 million annually.

Improvements in monitoring, measuring and forecasting then dovetailed with the 1990s' explosion in climate change research. Weather data now not only signalled whether to irrigate crops, they were feeding into climate change models.

Porteous says the development of early warning science around climate variability and change means the world is hungry for weather data close to the source, in real time, and with greater detail and accuracy. This has meant Pacific Island meteorologists can now realise their vision for improved local forecasting and climate services.

"They've long known what they need – but now, with climate change prompting renewed attention to climate services, there are new resources through the UN [United Nations] and other multilateral funds to help launch their plans."

Samoa is achieving this through its National Adaptation Programme of Action (NAPA), a UN supported programme that focuses on building infrastructure and services to address the country's priorities for community resilience and environmental sustainability. Backed by two years of community consultations across Samoa, the NAPA plan addresses needs in all social and economic sectors, with climate early warning identified as one of the eight priority action areas.

Improving the ability of regions like the Pacific Islands to produce high-quality weather and climate services is also a goal of the recently launched WMO's Framework for Climate Services. It is also a key element in the Secretariat of the Pacific Regional Environment Programme's (SPREP's) Pacific Islands Meteorological Strategy, which sets out strategic and technical outcomes for the development of meteorological services in the Pacific region.

The challenge is not just better monitoring, but better ways of letting people know what the weather and climate are doing. In the world's most weather-susceptible region, the value of weather forecasting is forewarning. When you know what's coming, you can prepare.

This requires getting the right balance in investment across infrastructure, training, and the design and implementation of services that support a range of weather forecasting and climate service needs, so that early warnings of risks on all time scales – day-to-day, seasonal, and decadal – can be provided and communicated in ways that are easily understood and acted on at all levels within a country.

Mary Power, the WMO's Director of Resource Mobilisation and Partnership, says the aim is to spread availability of weather forecasts to people whose "low incomes and marginal living conditions increase [their] vulnerability".

Climate action stations

WMO, together with SPREP and other partners, is working to improve communication of weather information in partnership with national meteorological services, the media and communities.

SPREP Acting Director-General Kosi Latu says, "SPREP recognises that weather forecasts and warnings, such as those given during tropical cyclones, do not have a shelf life – they must be disseminated rapidly to the public or else they are useless."

Since 1999, in association with SPREP, with support from the New Zealand Ministry of Foreign Affairs and Trade, NIWA has worked with Pacific Islands meteorological services to produce the Island Climate Update (ICU), a bulletin providing seasonal climate outlooks for the next one to three months. The ICU supports advice provided by Pacific meteorological services to their national ministries and communities, through an exchange of observational and modelled data. A recent development has been the ICU Water Watch, a monthly update that keeps an eye on potential water shortages in the region.

A climate change and disaster risk management specialist in the Pacific region Rebecca McNaught has found the update a useful tool in planning for reducing disaster risk in the Pacific.

"The ICU Water Watch presents forecasted rainfall compared to recent rainfall information. This helps to determine whether the forecast is a concern or not. We're particularly watching for low rainfall, as that affects things like water supply catchments and crops. It even helps plan for the recovery from other disasters such as cyclones."

She began using Water Watch last year working for Red Cross. She says it is a product that will assist many organisations in the Pacific.

"The tool makes climate information accessible across national boundaries, which is key to my role working with different countries every day. The language and graphics aren't technical, so it's easily understood and acted on. It's a great additional tool for disaster managers and advisers in the Pacific region."

Under national programmes like the NAPA, NIWA has also been assisting with the development of national climate early warning systems in Samoa, Fiji and Solomon Islands. These countries have identified climate early warning as an urgent priority for the sustainability of their environments and communities. Under the direction of the responsible ministries in these countries, NIWA has helped develop a programme to upgrade weather monitoring capacity and climate services capability that link in with existing infrastructure to provide actionable climate information for a range of uses.

A key element has been the development of enduring partnerships, with an emphasis on self-reliance, but enabling additional technical collaboration to take place as needed.

The outcome is shared benefits; Pacific Islands are better prepared to adapt to weather and climate, and the world has a better handle on how weather systems and developments in the region affect regional and global weather.

NIWA staff Alan Porteous and Kevin Manson assist Samoa Meteorology Division staff to repair a soil temperature probe at a research station near Apia, Samoa. (*Dave Allen*)

Samoa's climate choices

By Sally Round

From predicting honey flow to protecting forests – a climate early warning system helps Samoa.

Samoan farmer Luasamotu Tusani Nuusa starts the day by checking an app on her phone for the latest weather information.

She gets daily and weekly forecasts that help her run her 150-acre plantation at Lefaga on the island of Upolu.

"I just open my phone and I have this climate update every day. I know when to weed, when to put water on my farm and when I don't have to water," she says.

On the other side of the island, just outside the capital Apia, Raymond Voigt tends beehives for honey, some of which is exported to New Zealand, Australia and the United States.

The forecasts he receives via email every couple of months help him manage his 50 hives by predicting honey flows up to six months ahead.

"We know there's a wet and a dry season in Samoa, but sometimes it doesn't always follow the same pattern," said Mr Voigt. "The projections they've provided have helped us a lot to know what sort of a harvest to expect. With more rain, we will have fewer plants blooming. Blooms are a source of nectar, so we can expect a lesser honey flow."

Such timely, user-friendly advice is becoming increasingly important as Samoa anticipates changing weather patterns due to climate change, which are likely to affect risks associated with drought, flooding, rising sea levels, and changes to the frequency and severity of cyclones.

Climate-related disease and pests also have the ability to hamper the development of Samoa's small and vulnerable economy.

Farmers like Luasamotu Tusani Nuusa were part of three years of wide-ranging community consultation on Samoa's environmental priorities in the face of a changing climate.

A climate early warning system (CLEWS) was identified as among the top priorities for the country, and specifically climate services for agriculture, health and forestry.

Starting in 2008, NIWA helped build CLEWS, which includes automatic stations around the country feeding into a climate database management system, out of which comes climate forecast maps and other information.

"Manual stations have been operated in Samoa over many years, sometimes going back over a century," says NIWA's Alan Porteous. "These data are very valuable and have become the foundation for building climate and weather services for the country. But the ongoing use of manual observations requires people sitting down and typing in data from paper records."

He says the automated system of data arriving automatically at hourly intervals or less, and being instantly processed, enables Samoa to produce more detailed and timely forecasts.

"You can do much more immediate monitoring and analysis of things like extreme rainfall intensity and rainfall distribution across Samoa."

> "I just open my phone and I have this climate update every day. I know when to weed and when to put water on my farm"
>
> Samoan farmer Luasamotu Tusani Nuusa

The Director of Samoa's Meteorological Division, Mulipola Ausetalia Titimaea, says the forecasting system is a collaborative effort, but the impetus came from Samoa.

"We have had drought in some areas and excess rainfall in others, so it was very important we had quality data," he said. "We also needed to digitise historical data."

He said the climate early warning system was a joint concept created with NIWA and the Australian Bureau of Meteorology on the software development side.

The authorities in Samoa are proud that it is now fully locally run and continues to develop in conjunction with local communities who are consulted on the new technology.

"Even though the technology is sophisticated, we want to have it in a language that any layman can understand," says Suluimalo Amataga Penaia, CEO of Samoa's Ministry of Natural Resources and Environment.

"Our team works with communities to make sure they understand the system. We want to make it friendlier for communities, so that they can champion our early warning system."

"Community leaders have regular meetings with our Disaster Management Office and they continue to be briefed with the technology we want to put in place," he says.

Climate action stations

Around 60 per cent of Samoa is covered in forest that needs protection to reduce the risk of landslides, flooding and poor water supply. It is at risk of devastation through cyclones and fire during periods of strong winds and drought.

But the fire risk is being significantly lowered with tailor-made products through the climate early warning system.

One of these is a fire early warning system that was adapted for the Pacific by NIWA from the Canadian model used in New Zealand. Two boards highlighting the risk of fire are now in place in high fire risk areas and more are planned.

Other tools used by the Forestry Division of the Ministry of Natural Resources and Environment are a drought warning index, a cyclone tracking atlas, and climate variability and climate change projection maps.

The division has also updated its forestry management database to include climate maps and projections that can be used in policy and management.

"Samoa's forest is considered one of the most vulnerable sectors to increasing climate change and human-induced damage," says the Head of Forestry at the Ministry of Natural Resources and Environment, Moafanua Tolusina Pouli.

"Climate change impacts on the trees and forests of Samoa are very complex and not easily predicted. So CLEWS needed to be more user-friendly to suit forestry needs and help with our work in forestry management and ecological restoration."

Along with workshops and meetings on climate change and resilience, farmers, and those in the health and forestry sectors, now have access through CLEWS to climate forecasts up to six months out.

For farmers, that means increasing crop yields and reducing costs.

"I adjust the activities on the farm according to the weather forecast, for example spraying or not spraying insecticide and other chemicals, sending people to work at the inland farm or at the nursery by our house," says Luasamotu Tusani Nuusa.

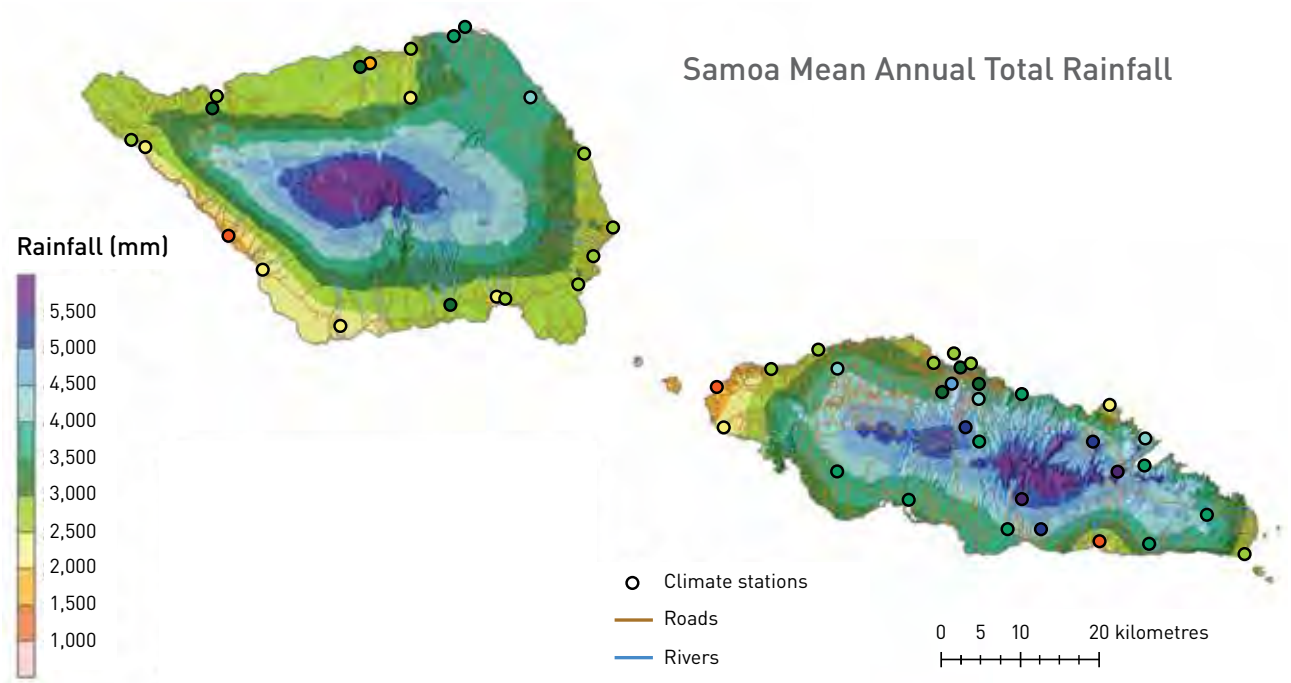
Better forecasting means farmers can pick more resilient crops for a changing climate, and health authorities can put out timely warnings for diseases like dengue fever which thrives after heavy rain.

"We are getting feedback that people are applying this information in their daily lives," says Mulipola Ausetalia Titimaea.

He says the government is working on raising awareness of Samoa's climate early warning system through radio and TV announcements and programmes. Disaster management officials also go out into the community to spread the word.

"We have a communication outreach strategy. We are focusing on this part of the delivery. We have more or less covered 50 per cent of the villages and we will continue to make this a priority."

Tourism is becoming an increasingly vital segment of the Samoan economy and at risk from climate change and natural disasters.



Maps of climate information within CLEWS produced by Samoa Meteorological Division provide vital information for the agriculture and forestry sectors.

What's the weather like?

NIWA climate scientist Dr Andrew Lorrey says weather in the South Pacific is dominated by the South Pacific Convergence Zone (SPCZ), a diagonal rain band stretching from the northeast of the Pacific to the southwest.

Dr Lorrey, who is currently part of a project in the Cook Islands examining coral and fish earbone chemistry to help understand the climate history of the South Pacific, says the location of the SPCZ moves about depending on the season and wider weather patterns.

The SPCZ exists in summer and winter, but can change its orientation and location during the El Niño/La Niña cycle (known as the El Niño-Southern Oscillation, or ENSO). It generally stretches from the Solomon Islands through Fiji, Samoa, and Tonga. Low-level convergence along this band forms cloudiness as well as showers and thunderstorms.

During a warm El Niño phase, the west Pacific becomes cooler and part of the eastern ocean warms; during a cool La Niña phase, the opposite occurs.

El Niño events are typified by weakened trade winds, with the SPCZ moving northeast of its usual position. This usually positions the band of rainfall over Wallis and Futuna, Tuvalu, Tokelau, part of Samoa, the Society Islands and the Tuamotu Archipelago in French Polynesia.

Dr Lorrey says the shifting of the SPCZ and subsequent El Niño and La Niña events have different impacts on different areas of the South Pacific, with island nations experiencing potential drought or flood conditions.

In addition, tropical cyclone activity is affected, with cyclones likely to have straighter, quicker trajectories in La Niña conditions, but more winding and dangerous trajectories in El Niño conditions.

The owners of the Seabreeze Resort on Upolu's south coast know the hazards of the natural environment all too well.

The hotel was devastated by a tsunami generated by a huge earthquake in September 2009, but has been rebuilt, winning the accolade of 'Samoa's Leading Hotel' in the 2013 World Travel Awards.

Co-owner Wendy Booth says early warning systems are crucial, given the resort's remoteness.

"Forewarned is forearmed. We wouldn't send our guests out knowing a cyclone was coming. It gives us comfort knowing we have the right information."

The Samoa Tourism Authority wants to review how operators are using climate information available at present.

It has been circulating the CLEWS user-friendly 'dashboard' of vital weather statistics around the tourism industry, accessed via a web link.

It is a bright and attractive series of animated barometers, and wind speed and temperature gauges, and includes weather maps and a fire risk board.

"We have been discussing with our colleagues at the meteorology office a way to tailor the information to our industry, particularly the small scale operations located in vulnerable areas," said Amiaifolau Afamasaga Luatua, Tourism Climate Change Project Manager at the Authority.

One of the aims of CLEWS was to draw together historical experience and traditional knowledge with science-based observations and modern technology to help warn people about changing risk levels.

Mulipola Ausetalia Titimaea says the Meteorology Division now has a project underway to incorporate traditional ways of predicting the weather into the contemporary system.

He explains that, in Samoa, an infestation of cockroaches at night means a sunny morning, and a bountiful season of fruit can mean a particularly active tropical cyclone season.

"It is important to us, the knowledge of our forebears. Under this current project, we are compiling all the knowledge from the various villages and putting it together in a compendium, then comparing it with the scientific knowledge so we can make a complete assessment.

"When we see that knowledge aligns and there is a scientific proven aspect to the traditional knowledge, we will make the necessary forecasts."

The authorities in Samoa say the country's new climate forecasting system is a life-changing tool and will continue to develop.

"We are working on further improvements with our partners to make sure our people are resilient and more prepared for hazardous events, especially considering the different types that are coming across the Pacific at the moment, because of climate change," says Suluimalo Amataga Penaia.

"We are not just going to sit around and watch what's going to happen. We are going to keep moving forward and enhance what we are doing."

Pacific portrait

NIWA photographer Dave Allen, joined NIWA teams working in Kiribati and Fiji.

Traditional building on stilts above a turquoise coloured lagoon, North Tarawa, Kiribati.

Pacific portrait

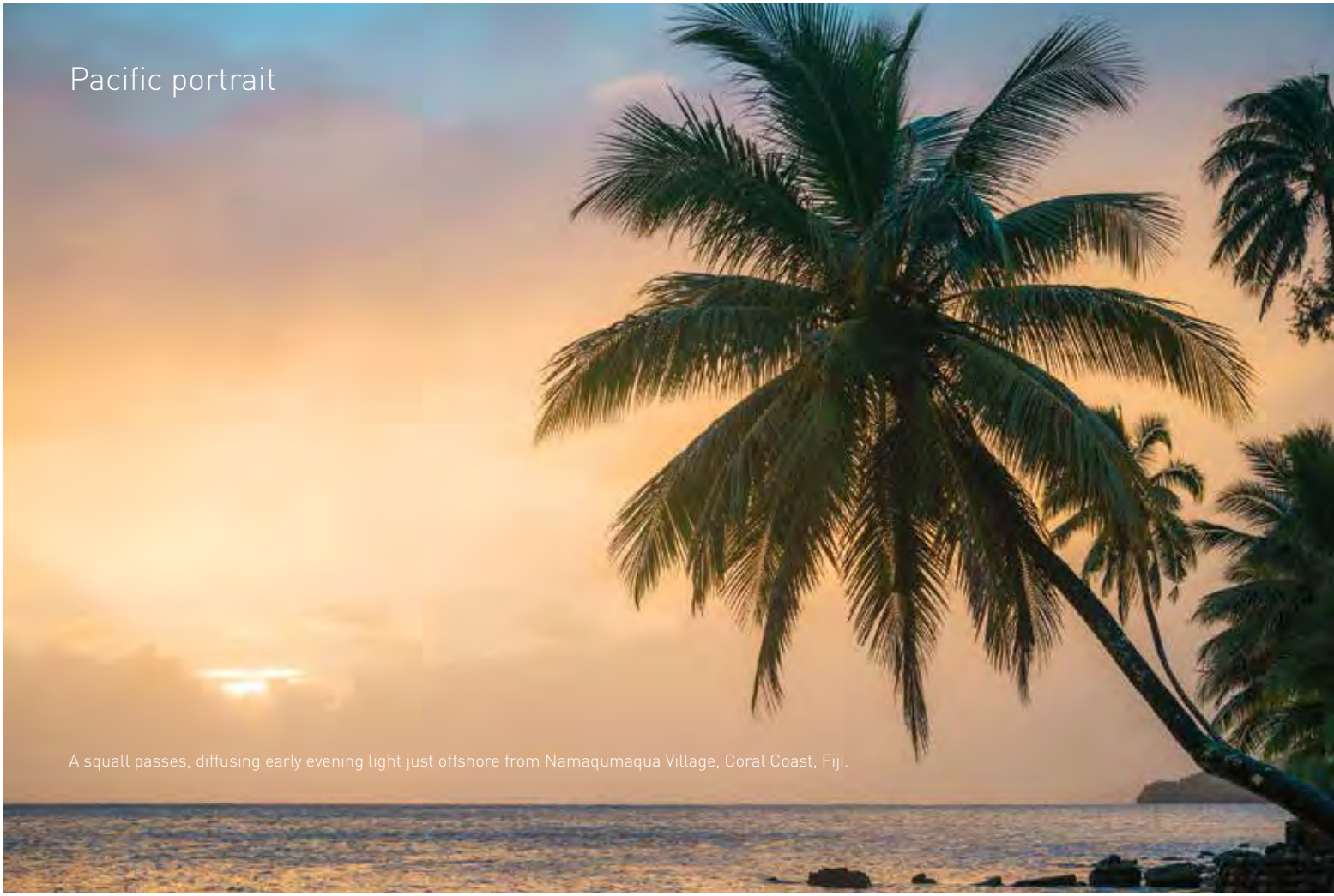
A young boy dancing in the evening light, lagoon side, Bairiki, South Tarawa.

Pandanas leaves formed into traditional thatched roofing are shipped across the lagoon from North Tarawa to be used on buildings in South Tarawa.

Pacific portrait

Towering cumulus clouds form behind a very small offshore island near Banraeaba, South Tarawa.

Pacific portrait



A squall passes, diffusing early evening light just offshore from Namaqumaqua Village, Coral Coast, Fiji.

Children fishing from a wharf, Kiribati.

Pacific portrait

Streetside fish market, Kiribati.

Profile

Nava Fedaeff

At the age of seven, NIWA's youngest climate scientist, Nava Fedaeff, swapped sub-arctic Siberia for balmy Auckland – and her first job was to learn to swim.

Determination is a word that comes to mind when you meet Nava Fedaeff, the youngest member of NIWA's Auckland-based climate team. The strong-willed 26-year-old takes bold challenges in her stride.

Nava was born in Tomsk, Siberia, a place where winters are long and temperatures drop to -21°C. In the distant past, the winter-bitten town received Russia's malefactors and political troublemakers. Over time, the combination of extreme weather and cerebral exiles seem to have led the city into becoming a cultural and educational enclave. It subsequently produced many of Russia's pre-eminent scientists, particularly geologists.

As a budding scientist herself, the seven-year-old Nava knew one thing about New Zealand when her parents moved here in 1996; it was surrounded by sea, and the coast was always close. So en route to New Zealand, she determined it was essential she learn to swim before she arrived. The eruption of Mount Ruapehu delayed their flight from America, giving her the chance she needed.

"I refused my parents' pleading to leave the hotel's pool until I was satisfied that I had mastered basic swimming."

Now living on Auckland's North Shore, only five minutes' drive from a beach, swimming is second nature. Nava has doggedly taken on more challenges, with climate and coast a constant theme.

She traces her climate interest to her early fascination with the movement of nature around her.

"Science fascinated me from a young age. I was at my most contented just sitting and watching the world go by: the clouds in Tomsk, and the waves on an Auckland beach. I wondered how and why these processes occur."

Nava graduated Auckland University with a Bachelor of Science with Honours from the School of Environment. Her dissertation focused on coastal geomorphology, and she spent the final year of university on the coast, analysing beach cusps.

"I looked at the climate and physical mechanisms that create mounds and valleys of sediment on beaches. It is fascinating to see erosion scarps on beaches and know that it is often a footprint of a storm. I make a point of visiting beaches during a storm to see the dramatic shift in the waves."

Determined to pursue a science career, Nava made the most of her university holidays, with climate matters featuring repeatedly.

She spent the summer of 2009 on a rainforest expedition in Costa Rica, volunteering at a biological research station.

The following two summers were spent in Thailand on a sea turtle conservation project. She first volunteered in 2010, monitoring beaches for fresh sea turtle nests, returning in 2012 as a research assistant.

"Climate has a massive influence on turtles. The gender of a sea turtle is decided by the temperature of the sand the egg sits in. Warmer sand results in female hatchlings, while cooler sands produce males.

"Understanding climate plays a huge role in planning for conservation. If the sand warms to such an extent that fewer male turtles are hatching, the species may not be able to survive."

The climate-focused research stints gave Nava a head start in the tough post-university job search.

"As a junior scientist, landing your first job is a challenge. With a passion for coast and climate, a job with NIWA was my dream. The fact that I was already experienced working in the field was definitely an advantage.

"NIWA works on the areas that fascinate me. This is the place to work if you want to learn from the best."

She has eagerly taken on the wide range of tasks thrown at junior scientists, which have become increasingly climate related.

One task is the preparation of NIWA's monthly and seasonal climate summaries. "It's fascinating to review the data of the climate stations – the data paint a picture, forming patterns before your eyes."

Pictures are in Nava's genes. Her father is an artist and her mother works in fashion. Nava has pursued photography as a serious hobby.

"I like to take pictures of nature at work, like weather events and landscapes – the things that can never be manmade".

A skilled GIS (Geographic Information System) software user, Nava takes pleasure in turning complex climate data into easy-to-understand graphics.

Pacific portrait

NIWA's new forecaster, Nava Fedaeff. (*Geoff Osborne*)

"The artist in me loves transforming data into something people can see and respond to. I think it is a far more powerful communication medium than presenting someone with a 20-page report they need to decipher."

Climate science is a perfect match for someone so fascinated by natural movement and patterns.

"The climate is alive – and changes constantly. It makes the science feel fresh and new every day.

"There is nowhere in New Zealand like NIWA, where we do such a variety of climate research under one roof. It is great to take part in preparing for the future of the climate.

"We are collecting data on things like adverse weather events and comparing events to assess whether they are out of the ordinary. As we learn more, we find there are still more questions to be answered. Discovering the answers, or even just discovering the questions, helps plan for the future – for today, tomorrow or even the state of the climate in a few decades' time," she says.

Counting the beat

New Zealand economists and NIWA have counted the economic benefits from investing in environmental research. **Mark Blackham** reports on a case study where NIWA research was estimated to return economic benefits at least seven times the cost of the research itself.

In 2010, US President Barack Obama announced a resurgence of science funding, saying: "Science is more essential for our prosperity ... than it has ever been before."

In the same year, the New Zealand Government made science funding a centrepiece of the 2010 budget. Sir Peter Gluckman, the Prime Minister's Chief Science Adviser, said the policy meant science would no longer "be seen as a cost to the New Zealand economy, but rather as a major and underpinning investment for New Zealand's economic growth".

Although the rhetoric sounds logical, it has been difficult to ascertain the return on that investment.

An analysis in Nature magazine (issue 465, 2010) found "the numbers attached to widely quoted economic benefits of research have been extrapolated from a small number of studies ... [which were not] objective assessments".

Moreover, these studies have generally derived their estimates based on indicators, rather than tracing causal links between specific pieces of research and quantifiable, realised or future economic outcomes.

Against this background, NIWA commissioned research from Enveco*, an environmental economics consultancy, to see if quantifying the economic benefits that follow from its research was possible.

According to Dr Bryce Cooper, NIWA's General Manager of Strategy, the absence of hard evidence about the economic value of environmental research has been awkward when making decisions about science investment.

"The direct causal link between, say, aquaculture production research and the flow-on economic benefits is relatively easy to understand and quantify in dollar terms. The environmental benefits of environmental research are also often easy to understand and quantify, albeit in non-monetary values such as ecosystem biodiversity protected or improved water quality. The difficulty arises when the economic benefits of environmental research are to be quantified and yet, intuitively, we know there are some.

"If we can measure the value of environmental research in all its dimensions (economic, environmental, social and cultural), we can all better judge the relative merits of investing in such research against the more obvious."

Cooper says the reason NIWA commissioned Enveco was to see if there was a way of moving beyond the hand-waving to actually providing an economics methodology that could be applied across its research fields, and to see if rules of thumb were possible.

"NIWA's Statement of Core Purpose, determined by the government, is to enhance the economic value and sustainable management of New Zealand's aquatic resources and environments ... so we must develop means to measure how well we are doing at that."

Annabelle Giorgetti, an economist with Enveco, says that the lack of international research gave few starting points for benchmarks or methodologies.

"Until now economists have used a broad brush in describing the value of science research. Few people have taken the time to count up what users do with the results, and to put a dollar value on the real world effects."

Agriculture and health have been the focus of most studies. For example, there are over 1800 separate agriculture studies on record. The return on investment varies wildly, up to 40 per cent in some cases, but averages between 5 and 7 per cent.

"It has been easier to count the value added by producing a more productive strain of crop, or by people recovering from illness.

"It's been far more difficult to count the value of the wider effects from environmentally linked research," she says.

A study, one of the few, by Natural Environment Research Council (NERC) in the United Kingdom made an effort to count the flow-on benefits of specific environmental research projects.

Rather than apply unsuitable models across NIWA's work, Enveco decided on 'micro-research' – assessing a small handful of NIWA case studies to test if an approach could work.

Giorgetti says it was fascinating to draw links between NIWA's research and what others were able to achieve using the research.

*Enveco, specialises in coastal and disaster risk management, climate change, waste, water quantity/quality, control of pest species, energy and aquaculture.

"Traditionally, scientists are pre-occupied with research and solutions, and the users are pre-occupied with applying the results. In these case studies, we held workshops to connect the research to what the users had done 'on the ground' because of the results."

Giorgetti says the workshops were critical to understanding not only what things had changed, but also the extent to which the NIWA science was instrumental in the changes – that is, the attribution.

"Research is often one strand of a user's attempt to solve a problem. There are many other people involved in making changes. All of them, quite rightly, have a claim to be influential on the result. So we needed a fair assessment from those end users about the proportional influence of the research on what they ended up doing."

The major part of the project was the counting: Enveco had to physically trace and value all the things that resulted from the research findings.

For example, one case study was research into the effects of land use on stream water flows. The economic research measured what happened to the value of agriculture and forestry production when land use policy changed in response to NIWA's stream research.

The study calculated that for every $1 spent on the research, NIWA's client generated between $7 and $148. The variation arose from the extent to which NIWA's research could be said to contribute to the bulk of the client's project and outcomes. The higher the attribution, the higher the benefits.

Giorgetti concluded that the economic benefits from using NIWA research to aid water allocation decisions were very high. The large benefits were because NIWA's research informed changes in regional plans that affect large areas of land and economic sectors, for example, for forestry or irrigation.

When Giorgetti carefully extrapolated the case studies to all of NIWA, she found that NIWA's research contributes around $825 million of economic benefits in a given year at a modest five per cent attribution level. These benefits would more than double to over $1.7 billion at an average 20 per cent attribution level, suggesting every dollar invested would return over $14.

Bryce Cooper says the research is a useful first step towards filling in that 'economic' gap in valuing the research that NIWA does.

"We now have a concrete example from an economic analyst that our research can lead to returns at least seven times the cost. Such a cost-benefit ratio seems quite impressive to me.

"That makes our research a safer bet, gives funders more confidence, and can reassure communities that such research is very likely to result in better, and more profitable, decisions," Dr Cooper says.