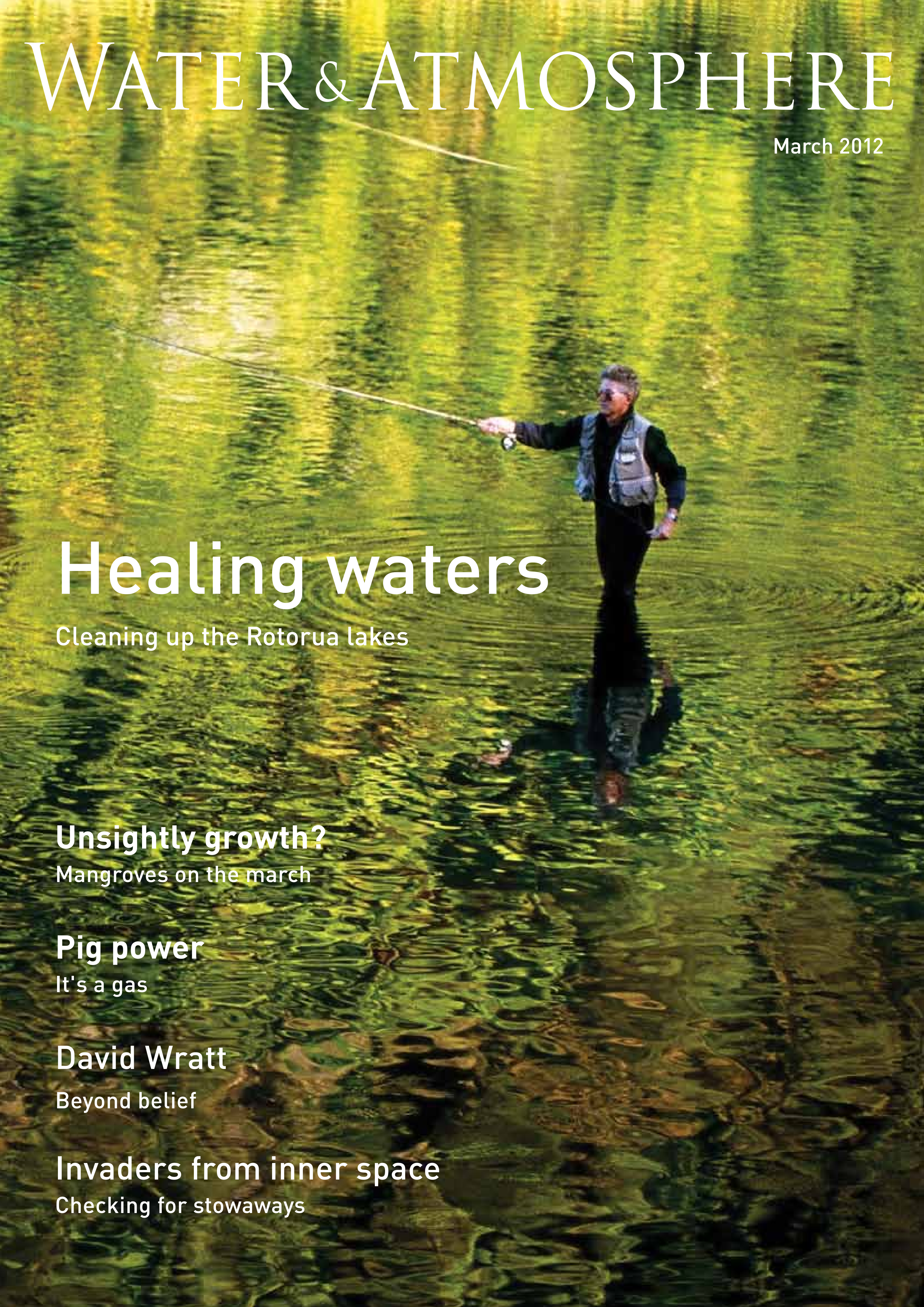
Water & Atmosphere

March 2012



Healing waters

Cleaning up the Rotorua lakes

Unsightly growth?

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Pig power

It's a gas

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Beyond belief

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Checking for stowaways

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Cover
A fly fisherman tries his luck on a still Rotorua morning. Many of the district's lakes are polluted by nitrogen and phosphorus runoff, and five are the focus of a multi-agency cleanup programme. Returning those lakes to health is seen by some as the foundation of the city's economic future. (*David Hallett/Hedgehog House*)

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NIWA
Taihoro Nukurangi

Realising our assets

In November 1994, the skipper of a Russian super trawler, the *Yefim Gorbenko*, put his vessel into Calliope dry dock in Devonport, complaining of excessive fuel consumption and high engine temperatures. As the dock drained, workers were greeted with an incredible sight: the trawler's hull was festooned with a mass of organisms described by one observer as "an entire ecosystem."

A thick mat of living creatures – mussels, sponges, goose barnacles, seaweed and anemones – covered the *Gorbenko* from waterline to keel. Many of the hitchhikers were aliens. Dock workers eventually carted away 90 tonnes of organisms from the *Gorbenko*, which had been working New Zealand territorial waters for several months.

As contributor Marieke Hilhorst points out in this issue, a 2002 Statistics New Zealand report calculated our marine economy to be worth $3.3 billion annually, contributing 2.9 per cent of GDP and providing 21,000 jobs.

It could take but a single organism – one egg, one larva, one gravid adult – to slash millions from that value. According to MAF Biosecurity New Zealand, our shellfish industry is worth $315 million. If the northern Pacific sea star – one of the country's least-wanted – ever established here, it could slash shellfish stock by as much as 50 per cent.

Last year, Deloitte estimated that the didymo incursion had cost $127.8 million so far, and could lead to further losses of between $210.6 million and $854.8 million out to 2020.

A healthy New Zealand economy relies critically upon a healthy New Zealand environment. Primary exports are high-value earners that underpin our standard of living, but the ecosystem services that sustain them must prosper too.

We're still paying the bill for past practices that exploited our soils, our air and our waters without understanding the consequences. In 2008, poor air quality was estimated to cost the economy $1.14 billion – $421 for every New Zealander – each year. $210 million has been allocated to clean up the Waikato River; another $12 million for ailing Lake Ellesmere. It will likely cost $200 million to return the Rotorua lakes – also featured in this issue – to health.

A 2008 report by the New Zealand Business Council for Sustainable Development forecast the costs of freshwater clean-up, under present allocation mechanisms, to climb to as much as $330 million a year through lost production and hampered economic growth.

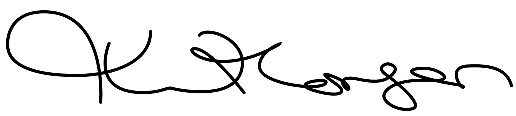
Clean air, clear waters, robust ecosystems and balanced energy and nutrient cycles are New Zealand's most valuable asset portfolio, yet all too often we run them like a hedge fund: highly leveraged, with a short-term strategy.

It's not enough that rivers and lakes simply look clean enough to satisfy tourists; their value runs much deeper than their picturesque surface, into every sector of primary industry. When they are truly healthy, they represent a powerful natural asset that marries economic and environmental prosperity.

It will always be cheaper to stop invasive organisms establishing here, than to try to eradicate them once they have. It will always be cheaper to stop nutrients and pollutants reaching our waterways, than to try and clean them up after the event.

Investment in protecting our natural resources, then, be it surveillance, monitoring, research or innovation, isn't just smart, or expedient – it's critical. As NIWA freshwater scientist Max Gibbs says in these pages: "The premise is that you understand the system."

New Zealand's environment is NIWA's domain, and knowledge of it is our speciality. As you'll read in these pages, our scientists and technicians work to better understand New Zealand's natural asset base, so that when we, as a nation, make choices, they're informed by the best possible science.



John Morgan
Chief Executive

In brief

Members of the award-winning team with Prime Minister John Key, from L to R: Dr Evelyn Armstrong and Dr Robert Strzepek (University of Otago), Dr Cliff Law, Professor Philip Boyd and Dr Kim Currie (NIWA), Associate Professor Russell Frew (University of Otago), Dr Rob Murdoch (NIWA), and Professor Keith Hunter and Dr Sylvia Sander (University of Otago).

Climate change scientists win PM's top science prize

A team of NIWA and University of Otago scientists has won the New Zealand Prime Minister's Science Prize for 2011 with world-leading research on geo-engineering.

The nine-member team investigated the merits of adding iron to the ocean to lower levels of atmospheric carbon dioxide (CO_2), thus helping to mitigate climate change.

"We were essentially testing the iron hypothesis put forward in the early 1990s," says team leader and NIWA oceanographer Dr Philip Boyd. "Parts of the world's oceans – particularly the Southern Ocean – are deficient in iron, which seems to be the limiting factor for phytoplankton growth." Phytoplankton are microscopic plants that play a key role in the world's climate by drawing CO_2 from the atmosphere into the ocean.

"Ice core records of Antarctic climate over the last million years have shown periods when atmospheric CO_2 has been significantly lower than it is today," says Boyd. "This could be linked to higher phytoplankton abundance, fuelled by iron blown into the ocean from the deserts of Patagonia, Namibia and Australia."

A growing commercial lobby has seized on the iron hypothesis as a rationale for fertilising large swathes of ocean with iron, considered a form of geo-engineering.

The scientists, based at the Centre for Chemical and Physical Oceanography at the University of Otago, spent weeks in the stormy Southern Ocean aboard NIWA's research vessel *Tangaroa*, and in the Gulf of Alaska, to test the hypothesis. They fertilised large tracts of ocean – an area equivalent to a million olympic-sized swimming pools – with an iron solution, successfully producing phytoplankton blooms big enough to be detected by satellites.

But Boyd says that, while the experiment proved that increasing iron supply enhances the ocean's ability to remove CO_2, "the effect wasn't as great as expected. The process would be very costly, and it's fraught with complex side effects, including the release of other, more potent, greenhouse gases."

Findings from the study – regarded globally as seminal work – have been published in prestigious international journals. They have also informed international geo-engineering workshops and governmental decision-making.

The Prime Minister's Science Prize recognises transformative science and was presented in Auckland in December. The team plans to use most of the $500,000 award to fund a state-of-the-art laboratory for studying Southern Ocean phytoplankton.

In brief

NIWA's General Manager of Research, Rob Murdoch, with friends during the Our Far South voyage. (*Our Far South*)

A cold case for our farthest south

In February, philanthropist Gareth Morgan set sail with a crew of scientists, educators, business leaders, campaigners and commentators, bound for the subantarctic and beyond into Antarctica. Morgan mounted the voyage, dubbed Our Far South, to increase understanding of the issues facing the polar latitudes and the wildlife that calls them home.

"The more aware we are of the issues that face Antarctica," says Morgan, "the more likely our future governments are to make decisions that reflect an ongoing commitment to this region."

Aboard *Spirit of Enderby*, the crew examined impacts on climate change, biodiversity, overfishing, tourism, territorial aspirations and mineral exploration.

NIWA General Manager of Research, Dr Rob Murdoch, says the voyage was a unique opportunity to raise public awareness about the Southern Ocean and Antarctica, as well as New Zealand scientific research conducted there.

"As a major New Zealand and international provider of Antarctic and Southern Ocean scientific research, NIWA's delighted to have been involved in this voyage. NIWA is playing a key role in helping New Zealand and the world learn more about the Southern Ocean and the Antarctic – knowledge that will help everyone respond to the significant challenges this unique environment faces, such as climate change, a potential decline in biodiversity, the use of the area's natural resources, and the future influence this region will have on New Zealand."

During the voyage, Murdoch presented findings from NIWA's Antarctic work, such as the Southern Ocean's critical role in regulating the Earth's climate, ocean acidification and trophic webs. Videos from his talks are posted online at www.niwa.co.nz/antarctica/ofs/blog, where you can also read his blog posts.

The voyage was open to all New Zealanders on the condition they make some contribution to the project's goal, says Morgan. "We need the awareness of New Zealanders lifted, and the best way is viral communication. The ship's complement ended up as I'd hoped: a wide cross section of New Zealanders."

Spirit of Enderby visited the subantarctic Snares, Auckland and Macquarie island groups before rounding Cape Adare and entering the Ross Sea, and on the return leg, it called into Campbell Island.

"The trip was spectacular," says Murdoch. "It really did emphasise the uniqueness of the subantarctic islands. The wildlife is spectacular – there's no other way to describe it. It's just awe-inspiring.

"The voyage highlighted the central importance of the Southern Ocean in driving the global and NZ climate. The climate will continue to change, and if we're to adapt, we need to have a feel for how it will change."

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Climate shifts thousands of kilometres away determine how much water our rivers carry, found Ross Woods. (*NIWA*)

Water security – the positives and negatives

We tend to take it for granted: when we turn on a tap, we simply expect water to appear, but Dr Ross Woods has been thinking about where that water might come from in our changing future.

A NIWA Principal Scientist, Woods has examined how climate shifts in New Zealand's drier places could affect our water supplies. "We're asking how these water resources might look in the future."

Weather and climate vary across decades, and water availability follows suit. So Woods is studying decadal variability in river flows, looking at long-term records for 35 sites across New Zealand between 1967 and 2010. "I calculated annual values of the mean flow, maximum flow and seven-day low flow," he says.

As they plan for the future, farmers, energy companies, councils and businesses need to know how dependable those flows will be. "Understanding variability in stream flow over decades can be critical. Without this understanding, it's difficult to use river flow data from the past as a guide to the future."

Part of the Ministry of Science and Innovation-funded Waterscape programme, his study has looked at how rivers respond to the Interdecadal Pacific Oscillation (IPO), a cyclic shift in the Pacific's ocean and atmosphere, in which characteristic circulation patterns, known as phases, switch every 20 or 30 years.

Flow data were first sorted according to which IPO phase prevailed at the time, then Woods looked for any significant difference in flow between phases. Between 1945 and 1977, the IPO was in a negative phase, after which it flipped, until 1999, into a positive phase, which saw more El Niños and more frequent westerlies. While the west and south of the South Island got more rain than usual, the Bay of Plenty suffered more droughts.

In 2000, the IPO changed back to a negative phase. Between that year and 2009, says Woods, the Buller River's mean annual flood was 15 per cent lower than it was between 1978 and 1999. Over the same period, flows in 15 other South Island rivers also slowed. Given that this negative IPO phase might have another decade to run, he says, "If you had to make a guess about the coming 10 years, expect a slightly drier South Island."

When planning around water availability, he says, "it appears prudent to make allowance for the possibility that flows for the next 10 to 20 years could be slightly lower than the long-term average. It certainly affects Canterbury, and has implications for the design of irrigation and hydro power schemes."

Woods points out that IPO shifts are not directly related to climate change; rather, they're an entirely natural phenomenon. "It's a shift in climate that will probably shift back again in another 10 or 20 years."

However, he says, "over the next century, we expect that increases in greenhouse gases will drive warmer temperatures and stronger westerly winds. The impacts of that on river flows are important too, so we're also working on them in the Waterscape programme."

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In brief

Plugging into the mains while in port, rather than running generators, could save shipping companies thousands in hull-cleaning costs, says Dr Serena Wilkens. (*Dave Allen*)

Wired for sound: ship noise attracts marine hitchhikers

Ship noise is a homing beacon for mussel larvae, a NIWA Biosecurity Scientist has discovered.

When Dr Serena Wilkens played recordings of ship noise to free-swimming mussel larvae, they settled more readily than did a control group in a silent tank.

The experiment, a collaboration with Auckland University researchers at Leigh Marine Laboratory, found that the vessel sounds prompted more larvae to settle, and that they settled much sooner – within a few hours.

It's well-known that the larvae of many marine creatures, such as fishes and crabs, are attracted to the sound of breaking waves around coastal reefs, and noises produced by other reef-dwellers.

Sound is a reliable cue underwater, as it travels long distances, unaffected by wave action, currents or clarity. In some places, however, natural cues are being drowned out by noise from more international vessel traffic, which is increasing as much as fourfold every decade.

In Wellington port, the scientists recorded the intensity and frequency of noise from ships' generators, which run most of the time vessels are berthed.

"We recorded the noise generated by a range of vessels, including NIWA's deepwater research vessel *Tangaroa*, log transport ships, container ships and cruise ships," says Wilkens.

The study suggests vessel noise could be an important cause of hull fouling by mussels and other marine organisms. Fouling represents a huge overhead to shipping, as the increased drag from marine hitchhikers burns up more costly fuel.

It also poses a biosecurity risk, as unwanted organisms can be transported all over the world. Hull cleaning costs run to millions of dollars each year, but cutting underwater noise – by switching to a shore-based electrical supply, for instance – might be one way to make big savings, suggests Wilkens.

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A familiar face. When he was tagged in March 2010, great white shark Grim was a three-metre long adolescent. He travelled to Fiji, Tonga and Niue, before turning for home that November. This month, researchers hope to bump into him again. Grim is reckoned to be around nine years old: too young yet for the responsibilities of raising a family. (*Malcolm Francis*)

Tracking pilgrim's progress

NIWA researchers head to Foveaux Strait this month to look up an old friend. 'Grim', a young male white shark, made headlines in 2010 when satellites followed his epic swim from Stewart Island to Fiji. The transmitter he carried has since fallen silent, but NIWA Principal Scientist, Dr Malcolm Francis, says Grim has been spotted back at Edwards Island, the largest of the Titi Islands in Foveaux Strait, this year.

For the sixth consecutive year, a joint NIWA, Department of Conservation and Auckland University research team will tag and photograph sharks off Bench, Edwards and Ruapuke Islands in a bid to learn more about this enigmatic, now-protected species.

The waters around Stewart Island are a favourite haunt of white sharks. Last year, the team photographed 41 individuals, 18 of which had been previously sighted in 2010. Researchers have encountered two returning visitors – large females – every year since 2008, one of whom made two return trips to the Auckland Islands last year before setting off for the same seamount in the Coral Sea she visited in 2010.

Then, of course, there's Grim, who was satellite-tagged near the Bunkers Islets in March 2010.

The team has also been listening in on acoustically-tagged sharks around northeastern Stewart Island and Ruapuke Island, says Francis, using electronic buoys which record the unique sound emitted by each shark's tag. "We know which shark has swum past which buoy," says Francis.

"Data collected so far confirm that most white sharks depart from this region in winter, as they undertake long-distance migrations to the tropics. A data download in late January showed that at least four of the sharks tagged in March 2011 had returned to the region."

Another download on this trip should reveal which sharks have returned. "We'll also find out how long each shark spends in each location, and how mobile or residential they are," he says.

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In brief

Golden Bay farm manager Kevin Davis and his family feared for their lives when December floodwaters burst from the banks of the Aorere and Anatoki Rivers. (*Chris Skelton, Nelson Mail*)

What happened to the golden weather?

We should have been in for a cracking summer. Seasonal forecasts late last year, taking their cue from a La Niña phase in the Pacific, tantalised with visions of beaches, basking and barbecues.

But in mid-December, Nelson wallowed under one-in-50-year floodwaters. Rain and drizzle, along with gale northerlies, spoilt many a North Island holiday, and disenchanted vacationers began to suspect the forecasters had got it wrong. But did they?

Only a little, says NIWA Principal Scientist, James Renwick. "The overall weather patterns were not too far from what we were expecting, but the local pattern was a bit different."

NIWA's seasonal climate outlooks draw on several global models that predict the climate a season ahead from current atmospheric and oceanic conditions. They take account of large-scale patterns that strongly affect New Zealand's climate, such as the El Niño Southern Oscillation (ENSO), which affects water temperatures in the Pacific, and the Southern Annular Mode, which affects the position of westerlies over the Southern Ocean.

About half of season-to-season climate variations can't be predicted, he says. "The deluge over Nelson and Golden Bay before Christmas is some of the unpredictability we're not going to capture." Each La Niña or El Niño plays out slightly differently over New Zealand. "A little like the commute to work, perhaps – we know roughly how the drive will go, but traffic conditions vary each time.

"Typically, in La Niña conditions, we get highs sitting east of New Zealand, bringing warmer temperatures. That happened this summer, and all December's climate models were pointing to a little warmer and drier than normal," says Renwick. But the highs drifted further east and south this time, allowing lows from the Tasman to deliver wetter, windier and cooler weather than expected.

Middle latitude climates such as New Zealand's, he says, can be highly variable, but NIWA's forecasting success rate matches that of most other mid-latitude agencies, such as those in the United States and western Europe.

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Mangroves on the march

Priceless or pestilent? Your view of mangroves, finds **Greta Shirley**, often depends on how many mangroves are in your view …

The Coromandel is well-used to raging debate over native forests, usually because they were disappearing. But in the township of Whangamata, the argument isn't so much about a vanishing flora, as a burgeoning one.

Mangroves are on the march. Around here, as in much of the upper North Island, they've thrived on the extra sediment washed down from cleared hills and felled forests. In the 1940s, small patches of mangroves covered around 24ha along the edges of Whangamata Harbour. Today, thickets of the salt-loving native shrub sprawl across some 100ha, raising the ire of many locals who feel they're smothering the harbour's aesthetic and recreational values.

They regard mangroves as a weed: an eyesore and a hazard, hindering access and marring views, lowering fish catches and property values alike. But others say nature should be left to its own devices, and warn that removal or control of the mangroves will have irreversible consequences for the harbour ecosystem, destroying important habitat for fishes and birds, and triggering still more coastal erosion.

Emily O'Donnell has heard every claim, every plea, every rebuttal. Harbour and Catchment Management Coordinator for the Waikato Regional Council (WRC), O'Donnell has spent close to a decade helping the people of Whangamata find an accord. "Both sides of the argument come from a real place of passion," she says. "The scale of removal … is at the heart of the debate."

In 2005, frustrated by what they saw as regional council inaction, 120 locals took matters – and chainsaws – into their own hands. Twice, they illegally cleared a swathe of mangroves in the harbour, one the size of two rugby fields.

When former local MP Sandra Goudie weighed into the protest, it made national headlines. Goudie, who copped heavy criticism for her involvement in the illegal clearance, said it was a wake-up call for regional politicians: "These people are sick of the political correctness. They don't mind a bit of oversight or a few guidelines, but they just want tools to manage it, or they want (the then) Environment Waikato to manage it."

> "Both sides come from a real place of passion"
>
> Waikato Regional Council's Emily O'Donnell

O'Donnell agrees: "Part of the angst is just how long it's gone on for. For some of these people, it's been a 13-year discussion – they want to see action.

"Some of them have been holidaying or living in Whangamata for 40 or 60 years in some cases … they know the harbour intimately. It is where they go daily, to fish or gather shellfish, and a lot of them are genuinely interested in the natural environment. They feel that a lot of those values are being eroded by mangrove expansion."

Local Whangamata resident and environmental scientist Dr Brian Coffey has spent more than ten years providing scientific support to Whangamata Harbour Care – a group of 60 or so passionate local residents helping manage the mangroves. They've successfully applied for resource consent to clear some small patches themselves.

Coffey says past abstention by regional councils has resulted in ad hoc attempts to control and manage mangrove spread across the upper North Island – some illegal, some consented.

"Groups like the Pahurehure Protection Society, the Mangawhai Harbour Restoration Society, the Waiuku Ratepayers Association and Whangamata Harbour Care began advocating for mangrove management in the late 1990s," he says. "They were left to their own devices and funding sources to get consents to undertake experimental removal, or get their hand-weeding consents, and then there were some locals who took it upon themselves to get in and clear areas on their own."

In the early 2000s, says Coffey, regional councils finally addressed that ad hoc process with formal harbour and estuary management plans that also tackled the causes of mangrove spread, such as sedimentation and nutrient run-off.

Mangroves on the march

Waikato Regional Council Harbour and Catchment Management Coordinator Emily O'Donnell at Whangamata: "There are opportunities for more learning on all sides." (*Dave Allen*)

Good science then became critical, he says. "If mangrove management is done as part of a comprehensive harbour or catchment management plan, that's got to be science-driven. It needs to be looked at as a holistic management effort – well-coordinated, well-planned and well-resourced, addressing all the issues – not a ragwort control programme, which is how the locals previously viewed it."

NIWA is working with a number of regional councils and local community groups to develop best practice for mangrove management, and monitoring the effects where mangroves have been removed. Researchers are currently looking at what drives mangrove spread (see page 15), understanding more about the ecological functions of mangrove habitats, and how mangroves might respond to sea-level rise.

Choosing between stopping or suffering the spread of mangroves isn't really a science argument, says NIWA Principal Scientist, Dr Malcolm Green. "To me that's a values argument. It's about how people want their estuaries to be."

Rather, he says, science can help answer questions around whether removal will be effective in certain areas, and what the ecological impacts might be. "Pick the battles that you are going to win and the ones you should stay away from." Each setting is unique, and will not respond to intervention in the same way, he says.

"Overseas research shows that tropical mangroves are hugely productive, and provide habitat for birds, fishes and all kinds of invertebrates. No doubt they have some function like that in New Zealand, but I don't think we really understand the scope of that very well yet. We need to keep working on it."

It's important to look beyond the harbour to the catchment, says Green: "If you don't control the sources of sediment – and possibly nutrients – that cause mangrove spread, then you can pull them out until your heart's content and they're just going to come back."

The WRC has done just that. Mangrove control is now part of their wider harbour and catchment management plan. After years of community consultation, scientific research and environmental assessment reports, the Council last year applied (to itself, ironically) for resource consent for the staged removal of 31ha of mangroves from Whangamata Harbour. The application attracted 180 submissions, with only eight opposed. Independent commissioners agreed that staged removal could go ahead, but not before environmental monitoring and operational plans are in place, and then only over half that acreage: 16.5ha of new removal and some additional tidying up.

O'Donnell, who's managing the consent application, believes the Council's adaptive management approach made a compelling case, but "the commissioners have proceeded with extreme caution. They seemed to feel that there wasn't enough evidence to support any further removal," she says. "There was concern around impact on banded rail habitat and ... what impact that quantum of removal would have on the harbour."

Having waited 13 years, Whangamata locals face another delay, however: the consent was appealed by Forest and Bird, who say only 1.72ha should be removed, mainly for maintaining drainage channels. The Council has counter-appealed, seeking clearance of the original 31ha. The debate is possibly headed for the Environment Court.

Despite the uncertainty and delay, says Coffey, it's good that the WRC has taken responsibility for Whangamata's mangroves, and taking that broader catchment approach has moderated local attitudes to them.

"I don't think it's a divisive issue for the community now – the locals are pretty much of one mind. They're not advocating complete clearance of mangroves from any harbour. It's a matter of keeping a balance, to stop further spread, and having some objective basis for deciding what proportion of the mature established mangroves can be removed without any adverse ecological effects."

Coffey says Whangamata has become a test case for those opposed to mangrove clearance.

Isn't it ironic?

Mangroves of one sort or another have lined stretches of New Zealand coast for at least 19 million years. *Avicennia marina*, or manāwa, our only present-day species, is thought to have arrived here about 11,000 years ago. Traditionally utilised by Māori for food, fuel and medicine, mangroves reach the stature of small trees in the far north, but shrink to shrubs further south. They don't occur – naturally, at least – any further south than Ohiwa Harbour on the east coast of the North Island, or Kawhia on the west.

While New Zealand mangroves are currently spreading at around an estimated five per cent each year, they've been decimated overseas. Globally, mangroves have disappeared from about half their former range – mostly stripped for timber, fuel, medicine and food – to become one of the most threatened natural community types.

Recognising their role in coastal protection, water quality, wildlife and fisheries habitat, and tourism, many countries now spend millions each year on mangrove conservation, restoration and management. Of the 90 countries that have mangrove vegetation, around 20 are involved in rehabilitation initiatives.

Detritus still marks the scene at Welcome Bay, on Tauranga Harbour, where mangroves were mulched in early 2011. Contrary to expectations that the mangrove debris would 'mobilise,' the tides failed to carry away the mulch, or the mud that supporters of the operation had hoped it would remove. In subsequent trials, the mechanical mulcher was followed by a beach groomer, which collected the slashed material. (*Dave Hansford*)

NIWA Principal Scientist Dr Malcolm Green. Mangrove clearance, he says, is "a values argument. It's about how people want their estuaries to be." (*Dave Allen*)

"There's a middle ground there now ..."

NIWA Principal Scientist Dr Malcom Green

"People coming in from the outside tend to be more vocal against it, to be honest. The illegal clearance became high profile, so it's become quite important for Forest and Bird and others ... to make an example of Whangamata I think."

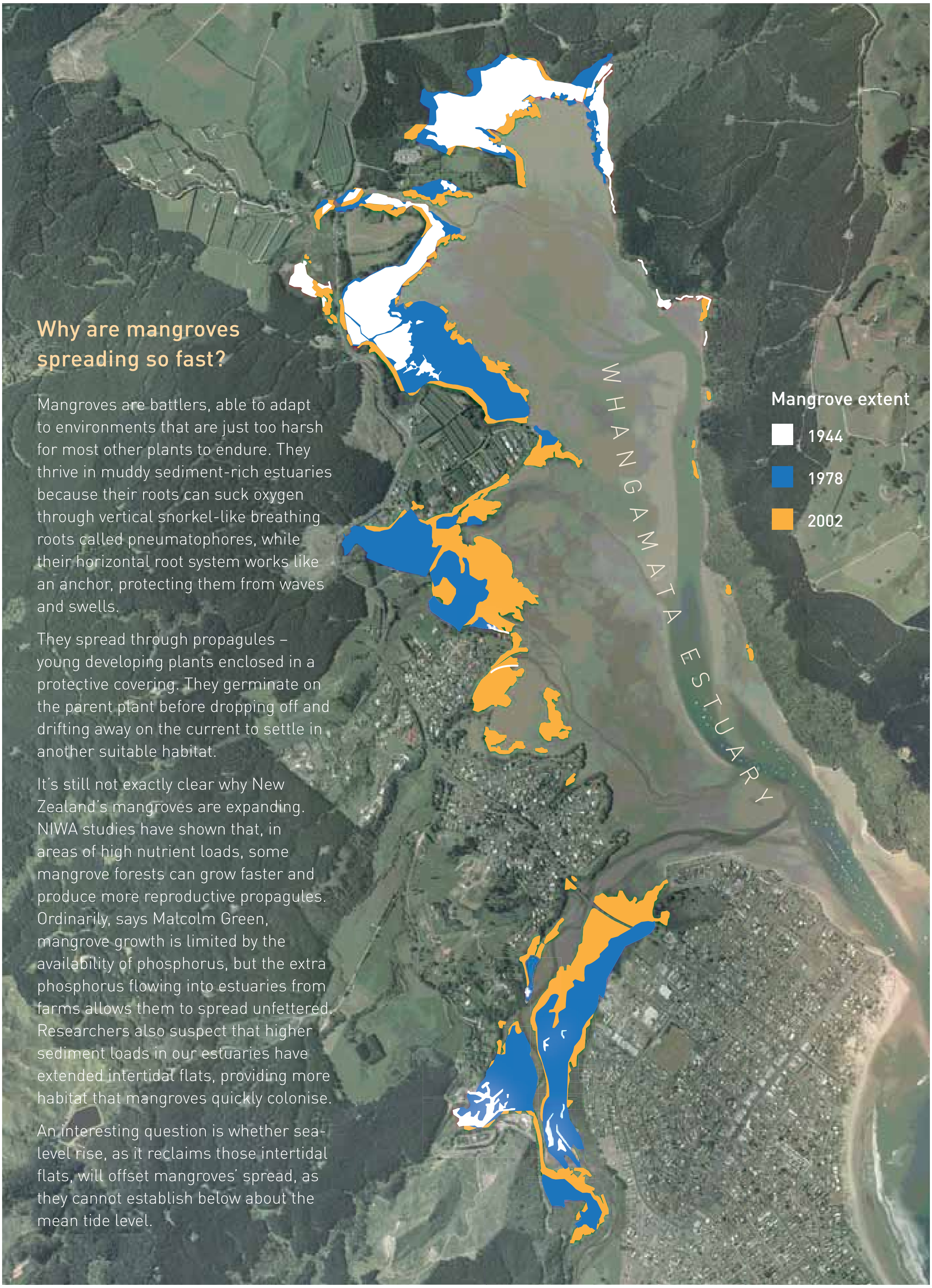
Large-scale mangrove clearance has had a chequered history. Over 2010, the Bay of Plenty Regional Council (BOPRC, formerly Environment Bay of Plenty) mulched 80ha of mangroves around Welcome Bay, in Tauranga Harbour, with a tracked machine. The mulch was left lying on the mudflats in the belief that it would 'mobilise' – or drift away on the tides. However, the mulch proved stubbornly immobile, and hectares of harbour reeked with rotting mangrove debris. Concerns were raised that the mudflats beneath would be smothered. NIWA scientists are now helping the Council assess the ecological impacts and potential recovery measures. BOPRC resumed the clearance in January 2011, but afterwards picked up the mulch.

Tauranga offered a cautionary tale for other councils. "We're grateful that we were able to learn from the Tauranga experience," says O'Donnell. Until the Welcome Bay operation, WRC had been considering mechanical mulching in the Whangamata Harbour, but reconsidered after seeing the impacts.

"It's provided quite a catalyst for us to investigate other options. BOPRC has been really forthcoming with information to us. It's provided an opportunity for a whole lot of dialogue between the councils around options we were looking at. We, like others, were under the impression that the mulching would mobilise quite quickly, but obviously it didn't do that."

Adding science to the debate usually softens peoples' views, says Green. His first few exchanges were with community groups who wanted every last mangrove pulled out. But, he says, after only short discussion "you could see people shifting their position, realising that's not desirable, but also it's not practical either. There's a middle ground there now, and Whangamata has been a good example of that."

O'Donnell gives a wry laugh at the suggestion: "There are opportunities for more learning on all sides, and to look at how we communicate and share the information." She says it's critical to look at mangrove management "under the umbrella of the wider harbour and catchment management plan, so that we address the wider issues too. Better that, than being the ambulance at the bottom of the cliff." W&A



Why are mangroves spreading so fast?

Mangroves are battlers, able to adapt to environments that are just too harsh for most other plants to endure. They thrive in muddy sediment-rich estuaries because their roots can suck oxygen through vertical snorkel-like breathing roots called pneumatophores, while their horizontal root system works like an anchor, protecting them from waves and swells.

They spread through propagules – young developing plants enclosed in a protective covering. They germinate on the parent plant before dropping off and drifting away on the current to settle in another suitable habitat.

It's still not exactly clear why New Zealand's mangroves are expanding. NIWA studies have shown that, in areas of high nutrient loads, some mangrove forests can grow faster and produce more reproductive propagules. Ordinarily, says Malcolm Green, mangrove growth is limited by the availability of phosphorus, but the extra phosphorus flowing into estuaries from farms allows them to spread unfettered. Researchers also suspect that higher sediment loads in our estuaries have extended intertidal flats, providing more habitat that mangroves quickly colonise.

An interesting question is whether sea-level rise, as it reclaims those intertidal flats, will offset mangroves' spread, as they cannot establish below about the mean tide level.

Megan Birchall's family have milked cows beside Lake Ōkaro for 30 years. Concerned about nutrient runoff into the lake, they and five neighbours formed an action group, adopting progressive farming practices – such as the constructed wetland behind – that have seen phosphorus loss fall by 38 per cent in six years. (*Dave Hansford*)

Healing Waters

Cleaning up the Rotorua lakes

"We want fertile land, not fertile water." So said Parliamentary Commissioner for the Environment, Jan Wright, earlier this month. In her latest report: *Water Quality in New Zealand: Understanding the Science*, she referred to nitrogen and phosphorus runoff as "the focus of most concern today."

Dave Hansford looks at the various ways NIWA's helping to cleanse some Rotorua lakes of these pernicious pollutants.

Each day, every dairy cow in the country wees out 23 litres of urine, and according to Statistics New Zealand figures last year, there were 6.2 million of them. There were also 3.9 million beef cattle, which means our landscape gets drenched with more than 230 million litres of bovine urine (plus the outpourings of calves and 32.6 million sheep) every day.

Once it hits the ground, billions of soil bacteria go to work, breaking down urea in the urine, first into ammonium, then nitrites and finally nitrates – the first few steps in a global nitrogen cycle. All living things need nitrogen, to make DNA, proteins and amino acids. It's also a vital plant nutrient, but the majority of nitrogen occurs naturally as inert gas (it makes up 78 per cent of the atmosphere) which plants can't access directly – they need nitrogen-fixing bacteria to convert it to a soluble form they can use.

The production of nitrogen fertilisers, and atmospheric fallout from fossil fuel combustion, has roughly doubled the supply of plant-available nitrogen to Earth's ecosystems. That's seen agricultural production soar, but it's come at a cost to water quality.

A single urine patch can carry nitrogen loadings equivalent to a tonne per hectare (you can see the urine patches in any paddock: the grass is darker and longer), and soil, plants and cattle can only reabsorb so much. The rest, being so very soluble, leaches away with the next rain.

The volumes are huge: more than 750 tonnes of nitrogen run into Lake Rotorua each year – less than 100 tonnes of it from 'natural' sources. That sort of fertility sends plants into overdrive: algae run riot, exploding into blooms and sometimes even forming thick mats of toxic scum.

Even as algae thrive, other organisms suffer: high levels of dissolved nitrate have been shown to stunt development and reproduction in aquatic invertebrates and fish, or kill them outright.

When the bloom ends and all those algae die, the mass-decomposition can rob so much oxygen from a lake that bigger creatures die with them.

In 2006, regional council data revealed that, of 134 monitored lakes, 56 per cent were eutrophic – full of enough nutrients to trigger a bloom – or worse. Rivers are faring no better. NIWA manages the National River Water Quality Network, a monitoring programme that regularly samples 77 sites country-wide. They're showing data trends that head obstinately in the wrong direction: between 1989 and 2007, overall nitrogen loads increased by 1.4 per cent each year. Phosphorus concentrations mostly followed suit.

> "10 years ago, nobody really thought that hard about it"
>
> Lake Okaro farmer Megan Birchall

Slowing the flow

On this November morning, an oily film clings to the reed beds along the shore of Lake Ōkaro, south of Rotorua – the first sign of a looming bloom. Megan Birchall's seen it countless times. She and her parents run a dairy farm right across the road – 60ha of it drains to Ōkaro – and they're critically aware of what that means for the lake.

"My family's been on this property for 30 years," she says, "so we've seen Ōkaro in all its forms. Dad realised that, being right on the lake edge, we needed to change our management practices to mitigate what we were doing."

In winter, this Rotomahana silt loam is quick to bog: that's when nitrates either leach, or simply run straight off, into the nearest watercourse. So the Birchalls make sure their 450 cows never stand too long in wet paddocks. They spend some of each rainy day in two 'herd homes' – vast covered stand-off yards, with slatted floors that allow effluent to run through, down into holding tanks. The homes cut the farm's nitrogen loss into Ōkaro by an estimated 30 to 60 per cent.

The collected effluent is later pumped back onto the pasture as fertiliser, but only at times, and rates, that ensure it can be converted into grass growth with minimal losses. "Dad always gets me to check the soil moisture content nowadays, before he even thinks about putting effluent on," says Birchall. "It's the first thought that enters his head – whether it's going to run off or not. Even 10 years ago, nobody really thought that hard about it."

Her grandfather fenced off the farm's streams long before it was common practice, to keep cows and their by-products out of the water, and the cows only get milked once a day now. But the Birchalls' biggest commitment writhes, like an eel, across the flats below us. Ranks of flax and cabbage trees crowd shallow ponds where, just this morning, a flock of grey teal ducks have arrived. Pied stilts fossick beside beds of reeds. Out of the paddocks to the north, a serpentine stream wends through thickets of rushes. Their stalks and roots are one of nature's most efficient filters, trapping suspended sediments, nitrogen and phosphorus, and slowing the flow before the stream empties into Lake Ōkaro.

Only two centuries ago, wetlands like this stretched for mile after marshy mile. Landcare Research estimates wetlands once covered 2.4 million hectares – nearly ten per cent of the country – soaking up and purifying floodwaters before gently releasing them into rivers and lakes. But the colonists regarded wetlands as an untenable waste of scarce flat land: they burnt, cut and drained with such zeal (empowered by the Swamp Drainage Act of 1915) that, today, just ten per cent – around 250,000ha – survive.

NIWA Principal Scientist Chris Tanner is studying the effectiveness of constructed wetlands in capturing nitrogen and phosphorus that might otherwise leach off farms and into waterways. The right mix of rushes, reeds and shrubs, says Tanner, is critical – even when it's dead. Plant litter, he explains, fuels the primary nitrogen removal process – microbial denitrification. (*Dave Hansford*)

"Benefits accrue to a much wider section of society than just farmers"

NIWA Principal Scientist Chris Tanner

Which is why the Birchalls' wetland had to be built again, from scratch. In 2007, when Bay of Plenty Regional Council (BOPRC) announced plans to rebuild a small wetland across the road, the Birchalls gifted two retired paddocks immediately behind it, adding another 2.3ha to the project. Diggers excavated the ponds, and a stream, deliberately designed to wind over as much of the wetland as possible, to maximise its cleansing power. Trucks delivered sawdust and topsoil, into which went 60,000 native plants.

NIWA's Chris Tanner designed it. "Wetlands are really my thing," says the freshwater scientist. "They're beautifully adapted to deal with water treatment issues.

"We know wetlands are very good at settling out and retaining suspended sediments. We also know they're very good at removing nitrogen, because their saturated soils and plant detritus support bacteria that convert nitrate back into nitrogen gas, so it can be released back into the atmosphere.

"We know how these processes work, but it's much harder to determine how well they're working. How big does a wetland need to be, for instance, to remove any given volume of contaminant-laden sediment? Dissolved nitrogen? A pocket handkerchief wetland can't perform magic. You need something with enough size and integrity to process the load and deal with all those fluxes and fluctuations – particularly the highly variable flow regime."

Tanner's serpentine design disperses and holds water in the system for the longest possible time, so that plants, soil and microbes can thoroughly cleanse it. The right mix of plants is important, he says, but hydrology is critical. If a wetland is hit by sudden, large inundations – what Tanner calls "pulse" flows – and can't hold them for long enough, "it's going to struggle. You're not going to get much nutrient removal."

Constructed wetlands don't come cheap, which is why Tanner believes in "making them work for their money." To that end, he's keen to know just how much nutrient wetlands can sustainably retain. So he and his NIWA colleagues calculated wetland performance against expanse, to give farmers an idea of how much of a catchment they'd need to achieve a given target. They found that, on average, one per cent of a catchment could trap about 20 per cent of nutrients. "Set aside five per cent, and you're removing between 50 and 60 per cent – although that will vary from year to year."

Constructed wetlands, then, can be efficient filters, but the benefits don't stop there – they also absorb greenhouse gases, store carbon, contain stormwater flows and erosion, and provide safe nurseries for fishes and habitat for waterbirds. Collectively, those functions are known as ecosystem services, and wetlands provide them free of charge.

"So looking more broadly," says Tanner, "towards landscape and biodiversity values – those benefits accrue to a much wider section of society than just farmers. Once you add up all the different services, constructed wetlands can be really quite cost-effective."

Bay of Plenty Regional Council Lakes Operations Manager Andy Bruere inspects a floating wetland on Lake Rotorua. First trialled by NIWA on nearby Lake Rotoehu in 2005, floating wetlands can remove 40 to 60 milligrams (mg) of phosphorus per square metre every day, and between 500 and 800mg of nitrogen. (*Dave Hansford*)

Which raises another interesting issue: if everybody benefits, should farmers have to bear the costs alone? BOPRC doesn't think so: since 2005, it's funded some three-quarters of the environmental works on the Birchall farm; a recognition that they benefit a much wider community.

That's the carrot: the stick is what Megan Birchall calls "targeted ratings", essentially a regional council tax on nutrient runoff. For now, they're only a rumour at Ōkaro, raised several years ago, but the prospect persists. "Basically, it means we'd be charged a per-hectare rate for our discharge," she says. "I think it was probably going to cost us around $50,000 a year."

It was enough to galvanise the Birchalls and six of their neighbours: in 2009, they formed the Ōkaro Catchment Lake Restoration Group. Supported by the Sustainable Farming Fund, they're looking for ways to ease the consequences of their operations for the lake. BOPRC calculated each property's average nutrient loss from between 2001 and 2004, then set those figures as benchmarks.

Ever since, the group's been putting their stocking and production figures through a dedicated software programme, Overseer, to analyse any trends. So far, phosphorus loss is down 34 per cent, but nitrogen remains stubbornly slippery: it's slightly up at three per cent.

P soup

As the Council's Lakes Operations Manager, it's Andy Bruere's task to nurse 12 Rotorua lakes back to health, under the Rotorua Lakes Protection and Restoration Action Programme. Not all are equally sick: four are eutrophic – which means they carry high nutrient loads – four are oligotrophic, or healthy, and four, described as mesotrophic, sit somewhere in between.

The Regional Council has set an annual target nitrogen load for Lake Rotorua of 435 tonnes; a volume not seen since the early 1960s. Around the five most polluted lakes – Rotorua, Ōkaro, Rotoiti, Rotoehu and Ōkāreka – it's also prescribed nutrient discharge limits for properties larger than 4000m^2. As at Ōkaro, landowners in those catchments have been benchmarked.

Another regulatory option, currently being modelled by Motu Economic and Public Policy Research Trust with input from NIWA and GNS Science, is nutrient trading. Similar to the emissions trading scheme, nutrient trading is based on 'cap and trade'. The 'cap', set by regulation, is the total amount of nutrient that farmers can discharge. Those who reduce their nutrient runoff below their allocation can 'trade' any surplus with those that haven't.

“Eventually you have to face the fact that it's the land use that has to change”

Bay of Plenty Regional Council Lakes Operations Manager Andy Bruere

To that end, NIWA scientists have helped develop NManager, a computer model that simulates the generation of nitrogen on farms around Lake Rotorua, the times it takes to reach the lake, and the economics of alternative nitrogen 'cap and trade' schemes in the catchment. The model is helping BOPRC to develop policy to reduce nitrogen loads, and to assess the advantages of a 'cap and trade' scheme over regulation.

But farming isn't the sole culprit: leaky sewage reticulation and septic tanks are responsible for up to 25 per cent of some lake phosphorous loads. A geothermal vent at Hell's Gate releases 30 tonnes of nitrogen into Lake Rotorua every year, and the volcanic plateau's pumice soils are naturally high in phosphorus to start with, one reason why the Rotorua lakes are especially prone to eutrophication.

And people don't often realise, points out Bruere, that even healthy lakes naturally recycle nutrients from sediments. “That's not a bad thing, but when a lake becomes eutrophic, that natural circulation becomes much more significant.”

The Council's water and land plan sets a target trophic level for each lake, “but they're not all going to be pristine, oligotrophic lakes,” he cautions, “even if we meet all the trophic level indices. In fact, some of them will still be eutrophic – they'll just be at a more acceptable level.”

They range in size from 8000ha down to 30ha. Bruere says the smaller lakes offer a valuable test bench for engineering "interventions" because any results show up faster. Because there's a raft of different problems, the Council – in partnership with NIWA, GNS Science, AgResearch and Waikato University – has come up with a range of proposed solutions.

Fix or float?

In an ideal world, the lakes would once again be surrounded by wetlands – cradled, shielded, by their reedbeds. But not everyone has the spare land, or the inclination, of the Birchalls. Bruere isn't fazed: if you can't make more wetlands on land, he figures, why not put them out on the lake itself?

Here on Lake Rotorua, a stiff nor'easter is goading the waters into a troublesome chop, but Bruere coaxes the boat skilfully into the lee of what he likes to call a giant SpongeBob. It's an island of what used to be soft drink bottles, reconstituted into a fibrous mat. Between the fibres is a foam that makes this plastic island so buoyant we can, with some awkwardness, step ashore.

The thing heaves and bucks under our steps, as Bruere checks the cleats that keep it moored to the lake bed, off the Ohinemutu shore. Cores have been drilled out of the SpongeBob, and in their place, native rushes and reeds have been planted. Theirs is a hydroponic life: their roots dangle clean through the island and half a metre into the lake. Collectively, they're a floating wetland, the latest thing in lake restoration.

At first, Chris Tanner thought they were a gimmick, “but then we started to realise they had a few advantages.” Unlike their earthbound counterparts, he says, floating wetlands are immune to fluctuating water levels, and can be installed in most any dam, treatment pond, reservoir, lake or estuary.

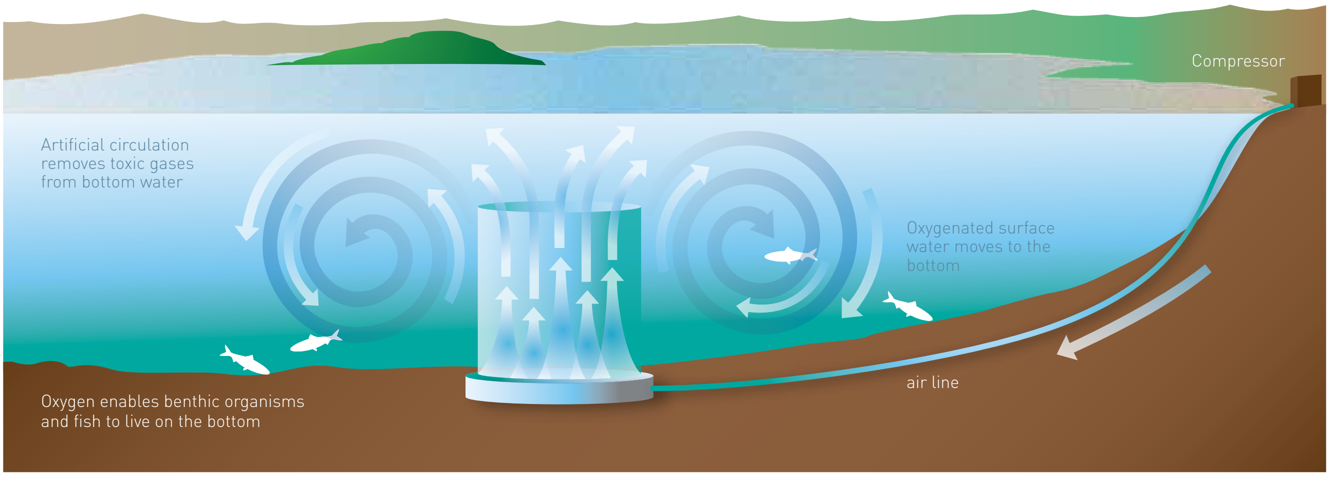
The tangle of roots attracts microbes that de-nitrify the water, and the mat casts a shadow that hampers algal photosynthesis. In a recent trial, Tanner found that those roots could remove 40 to 60mg of phosphorus per square metre each day, and between 500 and 800mg of nitrogen.

But perhaps their biggest benefit, he says, is that they're in peoples' faces. “They get people thinking and talking about water quality; it helps them connect the dots.” The proof is just 30m away. The people of Ohinemutu marae have taken a lead from the floating wetland, removing willows and gorse from their lakeshore land, and planting wetland rushes in their stead.

Sediment capping agents, such as this one, applied by NIWA Environmental Chemist Max Gibbs, work by encouraging particles to clump together, thereby locking nutrients into lakebed sediment, or neutralising them. (*NIWA*)

If the cap fits ...

Most Rotorua summers and autumns, still air and warmer temperatures tend to trap cold lake waters near the bottom for up to a fortnight, kept apart from sunlit upper waters by a distinct thermocline. When that happens, sediments start losing oxygen, which in turn allows nutrients to escape. In Lake Rotorua, this can happen three or four times a year, releasing around 360 tonnes of nitrogen and 36 tonnes of phosphorus each time. That's when Bruere has another algal bloom on his hands.



Aeration creates a mixing current, preventing cold bottom waters from turning anoxic.

NIWA's helping him find a solution. A sediment cap is a thin layer of material that can adsorb phosphorus at the lake bed, permanently binding it to that material. Once locked in, or adsorbed, it's permanently denied to algae.

NIWA Limnologist and Environmental Chemist Max Gibbs has trialled a number of different capping, or inactivation, agents: alum – an aluminium-based chemical commonly used in drinking water treatment; allophane – a natural central North Island volcanic ash; Phoslock – a modified bentonite clay; and Aqual P – a modified zeolite clay developed by Scion.

All those substances encourage particles to clump together, either locking nutrients into the sediment, or neutralising them. "The trick is to apply enough inactivation agent to neutralise all of the phosphorus in the sediment. That takes detailed testing beforehand," says Gibbs, who scaled up successful laboratory trials to lakes such as Rotoehu, using 1.6 metre-wide tubes, or mesocosms, suspended vertically from the surface to the lake bed.

"We've pretty much got a handle on the loading rates needed to treat sediments in the lake, and how long they'll last." Trials at Lake Ōkaro have shown capping can quickly lock up bottom-sediment phosphorus, denying blue-green algae the fertiliser they need to bloom. "In summer 2009/10, Ōkaro was mesotrophic for the first time in 20 years."

But there's a problem, says Bruere: "Lake Rotorua, for instance, accumulates sediment at around one centimetre a year, so any capping material would quickly be smothered. If you don't synchronise it with land-use change, any mitigation is pretty short-lived. So it may be that we put down smaller applications, one at a time, until we have a matrix of material."

But not everyone is enthusiastic about capping. Some communities have concerns over the use of zeolite clay in lakes, which is why Bruere's also considering aeration.

Making airwaves

Aeration is basically a way of keeping cold bottom water from turning anoxic, even after warm and cold waters have stopped mixing for the summer. Air is pumped by a compressor to the bottom of an air lift device tethered to the lake bed. The air enters a three metre-wide draught tube, where it mixes with the cold water. "That induces a vertical flow," explains Gibbs. "Putting the air in makes the water less dense, so it rises up the tube."

Near the lake surface, the water disperses sideways, releasing the bubbles of air. "That creates a mixing current. The bottom water is passed very close to the surface, so a natural exchange from the atmosphere does the oxygenation. The more bottom water you pump upwards, the greater the volume you create in the upper layer, and that causes the thermocline to move down," says Gibbs.

"Eventually, that boundary layer sinks to meet the sediment, and mixing is complete." Once oxygen levels are back up to two parts per million at the lake bed, sediments stop releasing phosphorus.

Changing our (water) ways

For all their ingenuity, these measures can only ease the symptoms of a sick lake. Says Bruere: "If we're to bring them back to lasting health, we need to do something about the cause."

"The reality is that you first have to fix the things you do around that watercourse. You can put as much stuff in the lake as you like, but eventually you have to face the fact that it's the land use that has to change."

A pine forest, he tells me, typically leaches between two and four kilograms of nitrogen per hectare, per year. Sheep and deer farming lose between eight and 15kg. Dairying loses

28 to 100kg. "What that tells me is that we've got a few options. Look at dairying – it seems to me there's a lot of scope to do things better."

Unfortunately, there are a couple of wild cards out there; game-changers that may yet undo much of what the lakes cleanup has achieved. One of them is called lag time – the number of years it takes polluted groundwater to reach a water body.

Work by GNS Science has shown the average lag time for the Rotorua lakes is 60 years – in some catchments, it's more than 120 years.

Water quality has been declining here for around 30 years. That means there's at least three more decades worth of accumulated pollution still to come, no matter what we do. Using ROTAN (see sidebar), NIWA's Chris Palliser and Kit Rutherford have predicted nitrogen loads to Lake Rotorua under a number of different land use change scenarios. They concluded that, with appropriate land use and management change, loads could drop sharply within about 35 years, much faster than many thought possible, although full recovery might take more than a century.

ROTAN

NIWA's ROtorua and TAupo Nitrogen model (ROTAN) is a GIS-based, rainfall/runoff/groundwater model designed to predict water flows and nitrogen concentrations in streams in daily or weekly time-steps. It can take account of time lags between nitrogen leaching, and its arrival at the lake.

Should a landowner, for instance, be thinking about converting hill country from sheep to forestry, ROTAN can model any changes in nitrogen leaching rates – as well as accommodating any mitigation measures, such as tree planting along riparian margins – to predict the effects of those changes on future nitrogen loads to Lake Rotorua.

ROTAN offers land managers:

- maps of flow and nutrient delivery pathways from each part of the catchment to the lake
- tables for each part of the catchment, showing quantities of flow and nutrients, time delays and nutrient losses
- tables and graphs showing historic trends in land use, stocking rate and fertiliser usage
- tables and graphs showing the relationship between historic trends in land use, rainfall and stream nutrient concentration
- predictions of nutrient inputs to lakes under various land use, rainfall and mitigation scenarios.

One thing everyone agrees on is that things will necessarily get worse before they can get better. "There's a hump in nutrient levels coming through that we can do nothing about," says Gibbs, "We need to stabilise nutrient sources, so that catchment groundwaters aren't loaded up beyond a certain point. That's essentially what Waikato Regional Council is doing around Lake Taupo. Under Plan Variation Five, they've capped nitrogen levels at 20 per cent lower than they presently are, in the expectation that, by 2080, water quality will be back to where it was in 2001."

But then there's climate change. NIWA projections for the Bay of Plenty out to 2090 show the region getting much the same annual mean rainfall as it does today. The devil, however, lies in an expectation that rain will come in less frequent, but more intense dumps. Such deluges might deliver shock loads of stormwater, sewage and farm run-off that will sorely test the capacity of engineered solutions like Chris Tanner's constructed wetlands to contain them.

"Two or three storms in a month could carry as much nutrient as the entire month's base flow," says Bruere. "It's got the potential to double the amount of phosphorus coming down."

Longer dry spells, says Tanner, might increase the demand for irrigation. "That could alter water tables, and irrigation, if it's not done well, can simply exacerbate runoff issues." And then there's the prospect of warmer temperatures stimulating still more rampant algal growth.

It took a century to pollute the Rotorua lakes, and it'll take longer still to clean them up. It's a catchment problem, and ultimately, it'll be a catchment solution. Best practice might only take us so far – beyond that, we may well need to re-survey the boundaries of sustainability.

Whichever options we take, "The underlying premise," points out Gibbs, "is that you understand the system. That's where NIWA's doing its bit. We want to understand these systems better, so that we can use restoration techniques more effectively." W&A

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Pig power

Right now, millions of cubic metres of biogas either gets flared off, or wafts downwind to annoy the neighbours. But that gas could be generating electricity, powering vehicles and balancing our trade deficit at the same time, finds **Dave Hansford**.

Something had to happen. From downwind, complaints were starting to come, and Steve Lepper knew that fines would be coming too. He got to thinking ....

To be fair, pig poo can smell pretty bad, and Lepper's farrow-to-finish farm, at – where else? – Lepperton, in Taranaki, makes an awful lot of it. Four hundred sows produce 9500 piglets a year, and, in that time, they get through more than 2000 tonnes of feed. That produces several hundred tonnes of manure solids – and a waste problem.

Since the eighties, when the Leppers built the piggery, the consequences of all that gluttony had been treated in two large effluent ponds close – too close, it turned out – to Lepperton. Meanwhile, the piggery was running up monthly power bills of between $6000 and $7000.

Both problems had the same solution – a purpose-built covered anaerobic digester pond. The pig effluent is still treated in the 7200 cubic-metre (m^3) pond. Nowadays, a heavy-duty plastic cover traps the offending odour – and something much more powerful: a renewable, high energy biofuel.

Each day, the cover traps around 300m^3 of biogas, containing about 200m^3 of methane, which is drawn off through a network of collecting pipes. The gas is compressed, then pumped through a scrubber to neutralise hydrogen sulphide, the cause of so many bad smells and complaints. Once scrubbed, the gas powers a petrol engine, which in turn spins a 40 kilowatt electricity generator.

"I think we'll see more built in the next few years"

NIWA Research Engineer Stephan Heubeck

In its first month, the system produced 133m^3 of gas a day, and daily electricity use in the piggery fell by 28 per cent. Two hundred cubic metres of methane now supply roughly half the piggery's daily electricity needs, but the benefits don't stop there: heat exchangers take the engine's heat – which is otherwise wasted energy – and use it to heat water to 80°C, sufficient to warm part of the piggery via under-floor pipes. That's reduced reliance on costly, inefficient radiant heat lamps.

As the biogas system continues to grow and improve, more hot water heating panels will further reduce the need for heat lamps. Lepper expects to recoup his $120,000 investment ($30,000 came from an Energy Efficiency and Conservation Authority [EECA] grant) within three years, and he no longer has to worry about energy blackouts.

In 2010, the Lepper biogas system won the Small-Medium Business category in the EECA awards.

Taranaki Regional Council's happy too: they consented the project, subject to special conditions on Lepper's water discharge, water abstraction and air discharge permits. They've watched with interest as the country's first new biogas digester in 20 years signals what a Council report says could be a more common solution to "new regulatory conditions," citing cleaner waste water discharge and fewer greenhouse gas emissions as just two reasons why they should see more widespread use. In 2010, the Council presented the Leppers with an environment award.

The digester pond was designed by NIWA Research Engineer Stephan Heubeck, applying the results of five years of NIWA research into anaerobic digestion. Heubeck's designed covered anaerobic piggery ponds before, but the objective had only been to control odour: the biogas was simply flared off. Lepper's is New Zealand's first full co-generation design based on covered anaerobic pond technology.

Taranaki pig farmer and biogas pioneer Steve Lepper. This anaerobic digester pond produces some 200m³ of biogas a day. Scrubbed, compressed, and pumped to a generator, it now provides roughly half the piggery's daily electricity needs. (*Geoff Osborne*)

Pig power

"Piggeries are one of the best sites to do this," says Heubeck, "because they have a high waste output and a high demand for electricity and heat."

Energy independence, reduction of greenhouse gas emissions (the process slashes fugitive methane emissions), and better effluent management are all seen as secondary benefits by pig farmers, says Heubeck. "To some degree it's the tail wagging the dog (or the pig?). The big motivation for the New Zealand pork industry is the reduction of waste odour, but anaerobic digestion provides an excellent opportunity to utilise that biogas, with all the associated benefits."

> **"Biogas offers the highest value proposition as a transport fuel"**
>
> NIWA Research Engineer Stephan Heubeck

He points out that the first oil shock in the early eighties spurred kiwi ingenuity into building dozens of digesters around the country, mostly producing gas to fuel vehicles. But when oil prices dropped again a decade later, they shut down one by one, leaving only Fonterra's industrial plant at Tirau.

Now, he says, "there's renewed interest in these systems, and I think we'll see more built in the next few years." Farmers at large, says Heubeck, will learn and benefit from Lepper's "pioneering spirit."

Biogas digesters have broad potential, but he says current economics mean they will necessarily be confined for the time being to "situations where you can link the supply of manure feedstock to a local demand for electricity and/or heat. Often, you don't have both in the same place."

Farmer Neville Barr (L) and NIWA resource engineer Stephan Heubeck use a gas analyser to measure levels of methane, carbon dioxide, hydrogen sulphide and oxygen from the covered anaerobic digester pond beyond. (*Dave Allen*)

In Lepper's case, the feedstock supply couldn't be much closer to the end use.

His next step is to adapt the concept for the dairy sector, where, he says, it could find application on up to 10,000 New Zealand dairy farms. Over the next few years, he points out, more stringent dairy effluent regulations will see more and more farmers constructing storage ponds.

What is biogas?

When biodegradable matter, such as manure, sewage, municipal organic waste, green waste or energy crops break down in the absence of oxygen, biogas will be produced. This process occurs naturally in swamps, buried sediments or the digestive systems of animals, but it's known as anaerobic digestion when we facilitate the process.

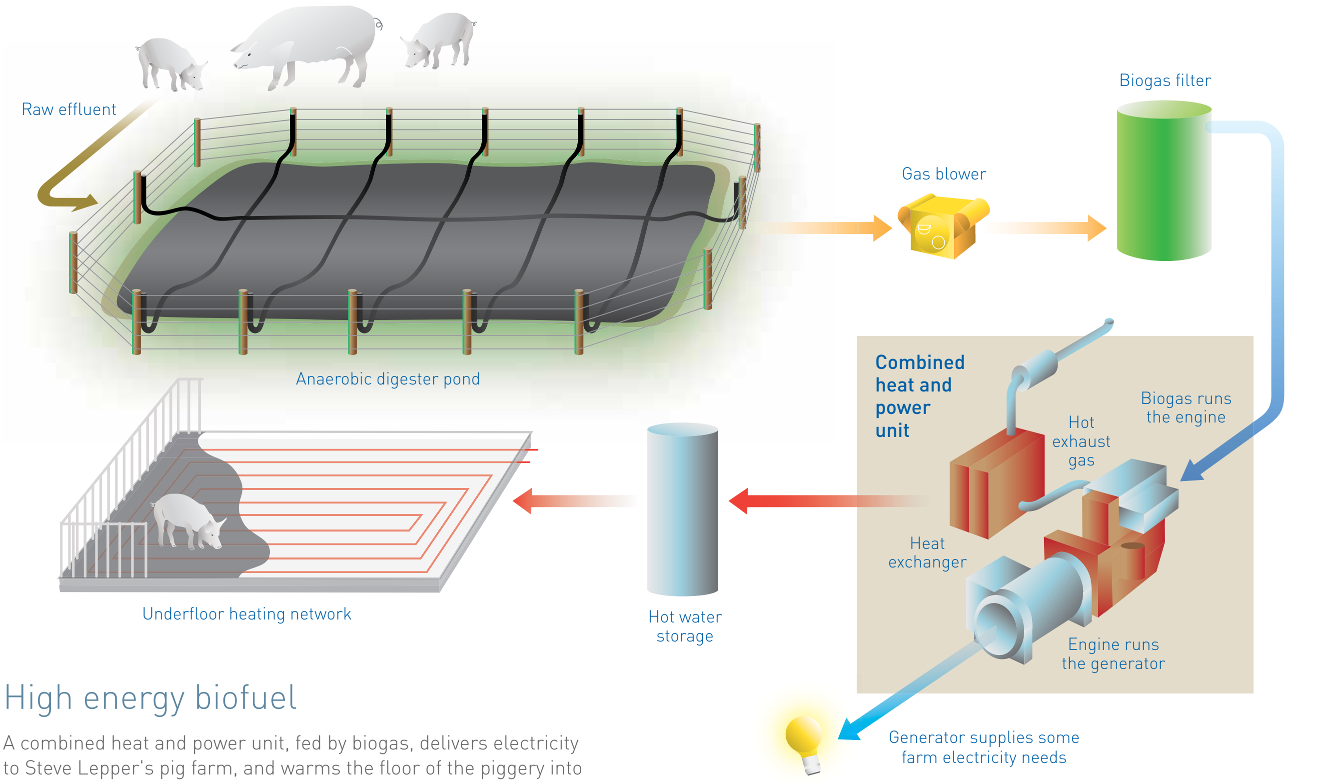
Biogas is mostly made up of methane (CH_4) and carbon dioxide (CO_2), but may also contain smaller amounts of hydrogen sulphide (H_2S), ammonia (NH_3) and moisture.

The main component, methane, is combustible, which means biogas can be used as a fuel for heating, cooking, electricity generation or – once purified and compressed – powering vehicles.

Cleaned and upgraded to biomethane, it can be piped into the natural gas pipeline network.

According to the Texas State Energy Conservation Office, one cow produces enough manure each day to generate three kilowatt hours of electricity; more than enough to power a 100-watt light bulb for that day. That's all well and good in an indoor farming regime, where all manure can be easily collected: in New Zealand, however, our cows normally only come indoors to be milked, so we might only collect around 15 per cent of their waste, although greater use of herd homes (see page 18) might see that figure climb.

Nevertheless, says Heubeck, the potential biogas resource on most New Zealand dairy farms could make them between 50 and 100 per cent energy self-sufficient (depending on farm size and technology used). Economies of scale mean biogas is already financially viable for larger dairy farms, or will become so in the near future.



High energy biofuel

A combined heat and power unit, fed by biogas, delivers electricity to Steve Lepper's pig farm, and warms the floor of the piggery into the bargain.

It would make perfect sense, says Heubeck, to build biogas recovery systems into those new pond systems up front, or at least leave provision for retrofits.

"Covered anaerobic pond technology is a smart pre-treatment option for deferred dairy effluent irrigation systems. At present, methane recovery from such systems remains one of the very few practical options for reducing greenhouse gas (GHG) emissions in the dairy sector, and, with energy prices increasing all the time, utilising a locally available, waste-derived energy resource is becoming more financially attractive."

Those benefits haven't gone unnoticed across the Tasman. Encouraged by New Zealand success, industry association Australian Pork Ltd (APL), has collaborated with NIWA and various pork producers to design and build covered anaerobic biogas systems in most of Australia's key agricultural regions. Four systems are currently at various stages of construction, with more in the pipeline.

Australia has also embraced their potential to reduce GHG emissions, says Heubeck. With help from NIWA and other supporters, APL has designed a method to quantify GHG emission reductions from utilising pig manure methane.

Approved under the Australian Carbon Farming Initiative, the methodology opens the door to incentives for Australian pig farmers who reduce their GHG emissions using covered anaerobic ponds.

Heubeck believes biogas is our most versatile renewable energy resource. Having proven that it makes perfect sense as a source of heat and electricity, he now wants to show that it "offers the highest value proposition as a transport fuel – a practical solution that is economically and environmentally sensible."

In 2010, a collaboration between Transpacific Industries, Greenlane Biogas, NIWA and DieselGas International Ltd, converted a rubbish truck to run on upgraded biogas from Auckland's Redvale landfill. "If all that landfill biogas were upgraded to biotransport fuel, it could save us 54 million litres of diesel a year." Given that New Zealand gets around half its consumer energy from oil – most of it imported – the biogas-to-fuel project offers not just cleaner exhaust emissions, says Heubeck, but increased energy security and a better balance of trade.

Biogas transport uptake cuts GHG emissions by displacing fossil fuels, while minimising fugitive methane emissions, but it demands a certain minimum scale, says Heubeck, and is currently uneconomic for small biogas resources, such as those commonly found on many farms.

Despite that limitation, Heubeck remains confident that: "Up to five per cent of New Zealand's current transport fuel requirements could be met with waste-derived biogas." W&A

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Portfolio

This issue, we present more images from the cameras of our staff: remarkable moments snatched during another day at NIWA's office, the New Zealand back – and front – country.

These bottlenose dolphins were photographed mid-cavort in the Hauraki Gulf by NIWA benthic ecologist Jenny Beaumont.

Masters student Angelika Reigler shot this picture "during an amazing alpine flight from Tekapo. One of the first things you see on the way to Mt Cook are incredibly beautiful formations and colours where Godley River flows into Lake Tekapo. Glacial 'flour' from four large glaciers upstream colour some braids turquoise, while other braids are dark blue.

NIWA photographer Dave Allen braved the elements to capture very rare weather: snow falls in the main street of Johnsonville, Wellington.

Water resources technician Jani Diettrich took this moody study while tramping on Mt Titiroa in the Te Anau basin. The summit area, known as Geiger's Garden, is remarkable for its peculiar white granite boulders.

Dr Graeme Smart spotted the smile to be had from this twin-boled South Island rata on the Karamea floodplain. "Man and nature moving in opposite directions," he wryly observes.

NIWA instrument technician Dave Gibb photographed this little shag on a pond along the Taylor Pass above Blenheim.

Invaders from inner space

The price of prosperous waters, finds **Marieke Hilhorst**, is eternal vigilance ...

New Zealand has at least 3.3 billion reasons to make sure our seas are free from invasive species. According to a Statistics New Zealand report, in 2002 the marine economy contributed $3.3 billion to our gross domestic product. New Zealand's unique marine ecosystems sustain and enable our marine economy, so we must protect them from unwanted pests.

Freeloaders aplenty

That presents a huge challenge. Every year, more than 45,000 cargo ships move up to 10.9 billion tonnes of ballast water globally, transporting an estimated 5000 or more species on any given day.

As a small, isolated island nation, international shipping carries our economy: 99.6 per cent of New Zealand's exports and 99.5 per cent of our imports travel by sea.

Each vessel, each trip, offers a lift to exotic hitchhikers, and the opportunities are growing: since 1960, annual international shipping arrivals have more than doubled from about 1000, to 2154 commercial vessels and 700 yachts and private vessels.

New overseas markets compound that risk, while cruise ships and yachts follow their own pathways, potentially harbouring still other pests.

An age-old problem

Invasive species are nothing new. Biofouling in New Zealand goes back to 1769, when Cook ordered his crew to scrub the *Endeavour's* hull not once, but twice, so snarled was it with barnacles and seaweed. By 2010, more than 300 exotic species had been recorded from New Zealand waters. Around half of them settled permanently.

Our focus on marine biosecurity has sharpened over time, and the rate of discovery has quickened. It took 188 years to record the first 114 species, but the next 35 were discovered in the space of just nine years.

NIWA Biosecurity Science Leader, Dr Graeme Inglis, says the detection rate has been particularly high over the past decade, thanks to national survey programmes funded by MAF Biosecurity New Zealand and implemented by NIWA and others. These include baseline surveys of marine species in New Zealand ports, ongoing targeted surveillance for high-risk marine pests, and a survey of biofouling on 500 international vessels to identify precisely where risks lie.

Another tool, the web-based Marine Biosecurity Porthole, launched last year, provides public access to MAF and NIWA data on marine invaders (www.marinebiosecurity.org.nz).

Why worry?

The impacts of marine interlopers vary. Some are competitive, displacing native plants and animals. Others can alter the underwater seascape and change the way the ecosystems function. Some are so prolific that they can block shallow coastal waterways.

Humans are not immune: a major cholera epidemic in Peru in 1991 that killed 10,000 people was blamed on ballast water carrying an Asian strain of the disease.

In New Zealand, effects on human health have so far been mild, but we've nonetheless suffered environmental and economic costs. In 1967, a tubeworm, *Ficopomatus enigmaticus*, invaded the Whangārei tidal basin, forming encrustations 20cm thick on hulls and wharf piles. It then spread to Auckland's Tāmaki estuary where, in 1980, it blocked the cooling-water intake of Ōtāhuhu power station, forcing temporary closures.

In 2000, *Gymnodinium catenatum*, a microalgae of uncertain origin, bloomed in Manukau Harbour, where it caused the largest toxic algal bloom New Zealand had yet experienced. Shellfish gathering and mussel farming were closed along 1500km of coastline for nine months.

But marine invaders aren't always bad news. The Pacific oyster, *Crassostrea gigas*, which established here in the early 1970s, grows faster than the New Zealand rock oyster, and now drives a $30 million-a-year industry.

NIWA phycologist Roberta D'Archino inspects the *Tangaroa's* hull for unwanted organisms. (*Peter Marriot*)

International leaders

The Ministry of Agriculture and Forestry (MAF) is responsible for the integrity of New Zealand's biosecurity systems – both terrestrial and marine – but works with other agencies to implement them, including NIWA and regional councils.

Dr Naomi Parker, MAF's Manager, Science and Policy, says New Zealand's isolation, economy and environment are strong motivations to take a lead on marine biosecurity.

Until recently, the major international focus has been on ballast water, and New Zealand is in the process of signing up to the International Maritime Organisation's (IMO's) Ballast Water Convention. An Import Health Standard on ballast water discharges, already in place, will fulfil New Zealand's obligations under the IMO convention.

More recently, says Parker, biofouling has taken more emphasis, with research showing it's likely responsible for 87 per cent of arrivals in New Zealand waters. Parker says that sort of evidence drove a push with Australia, the United Kingdom and others to get biofouling on the international agenda, alongside ballast water. It worked: in July 2011, the IMO adopted voluntary international biofouling guidelines.

On the local stage

MAF is developing an Import Health Standard to manage biofouling. The new standard, due out in April 2012, doesn't target specific species. Rather, it aims to manage pathways, and reduce risk by providing an incentive for all vessel hulls to be as clean as possible before they arrive in New Zealand ports.

The standard won't be enforced for another four years, says Paul Hallett, MAF's Team Manager, Operational Standards, so as "to give industry groups time to come up to speed, while encouraging early adoption. How each industry group meets the standard will depend on it and MAF working together to develop something that fits."

Last year, NIWA scientist Dr Oli Floerl, in collaboration with Australian scientist Ashley Coutts of Aquenel, revised the 1997 Australia New Zealand Environment Conservation Council (ANZECC) Code of Practice for Antifouling and In-Water Hull Cleaning and Maintenance for MAF and Australia's Department of Agriculture, Fisheries and Forestry (DAFF). Hallett says the guidelines – developed to manage toxic antifouling paint and cleaning chemicals – didn't sufficiently cover biosecurity risks, and needed to be brought up to date in other areas as well.

The revised Code includes mechanisms and information to help industry meet the new biofouling import standard.

NIWA's research has been integral to understanding what risks need to be covered by the new biofouling import health standard. In 2004, along with other researchers, NIWA began a two-year study that measured the biomass and identity of fouling organisms on the hulls of more than 500 vessels – merchant, fishing, recreational and passenger vessels, and towed barges. Within days of arrival, the vessels were surveyed and sampled to identify the species on their hull, their density and their location, and whether these were native or non-native. Vessel owners and operators were interviewed about where they had been, the hull's maintenance history and how much time had been spent in ports and at sea.

> "Science is most definitely informing policy"
>
> MAF Manager, Science and Policy, Dr Naomi Parker

Floerl says the survey created what is possibly the world's most comprehensive dataset on vessel biofouling, travel history and maintenance. "The goal was to use statistical modelling to identify factors associated with a vessel's build, travel or maintenance history that will help determine the risk it poses to New Zealand's biosecurity."

Inglis says risk is a mix of things: "Our modelling showed that the most important contributors tended to be the time elapsed since the vessel was last painted with antifouling paint, whether it was fast or slow moving, and the amount of time it had been inactive in port. However, it also highlighted the complex mix of economic, geographic and ecological influences on biofouling that makes it difficult to accurately predict risk for individual vessels."

The data support MAF's marine biosecurity management decisions, including the development of a decision tree to identify the highest risk factors.

Parker says research by NIWA and others has helped ensure a rigorous, science-based Import Health Standard, and robust international biofouling guidelines. "Science is most definitely informing policy," she says.

The challenge of non-compliance

The next challenge is how best to deal with the suspected five per cent of vessels that MAF anticipates don't meet the standard. Turning vessels around at the border, or refusing them entry, is unlikely to find favour with New Zealand's trading partners.

As a first step, NIWA was contracted by MAF to provide an analysis of existing risk management options, such as dry docks, in-water cleaning or other biofouling management tools.

Floerl says the review found challenges with most existing options. For example, New Zealand has just two dry docks, which can only accommodate vessels shorter than 180m. What's more, the time and cost of dry docking make it a difficult option if either are in short supply.

NIWA biosecurity technician Lisa Peacock checks wharf piles at Port of Lyttelton for the Mediterranean fan worm, *Sabella spallanzanii*, during a 2008 survey. (*NIWA*)

Similarly, in-water cleaning has to be managed carefully, so that dislodged organisms can't settle on the seafloor. "We don't want to end up helping them to arrive," says Floerl. Most current cleaning practices weren't developed with biosecurity in mind. "The tools are good at cleaning the main hull surfaces of vessels to help with fuel efficiency, but most of them are large brush- or water jet-based systems that can't necessarily reach into the nooks and crannies where biofouling is often most diverse."

Surveillance

Managing risk pathways to stop marine pests arriving is just one part of the marine biosecurity jigsaw. Surveillance is another. NIWA is a key player in a MAF port surveillance programme to identify and respond to new exotic marine species before they take hold.

Inglis says NIWA's surveillance and survey work is underpinned by specialist taxonomic expertise. MAF draws on that knowledge under a service contract, the Marine Invasives Taxonomic Service (MITS), in which NIWA identifies novel species. Since 2005, MITS has handled more than 49,000 samples and identified more than 1200 organisms, including more than 200 exotic species.

Since 2001, MAF has funded NIWA and other research providers to complete 43 baseline surveys of ports and marinas. In addition, NIWA does twice-yearly surveys of 11 commercial ports and associated harbours, searching for 'least wanted' exotic species. A priority list currently has five primary and four secondary target species, but that varies over time, as new high-risk species emerge and/or others become established here.

In 2008, the programme found the highly invasive Mediterranean fanworm, *Sabella spallanzanii*, in Lyttelton Port. NIWA provided scientific and technical support to a MAF eradication effort, using statistical analysis and GIS mapping to direct commercial divers. As a result, they removed more than 97 per cent of the creatures.

Although the fanworm was later found in Auckland as well, the control programme in Lyttelton is seen as a success: monitoring shows the population hasn't rebounded.

Much of NIWA's marine biosecurity work has an end-user focus, says Inglis. Largely funded by the Government, it's designed to provide benefits for New Zealand's economic prosperity and environmental stewardship. "I think it's fair to say that, with Australia, New Zealand is recognised internationally as being at the forefront of marine biosecurity research, because what we do is innovative and produces practical outcomes." W&A

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Keeping it real: David Wratt

NIWA's climate chief, David Wratt, on science, steadfastness and spark plugs. **Dave Hansford** finds out more ....

David Wratt doesn't 'believe' in climate change. In fact, 'believe' is one word he would happily see banned from the climate change lexicon.

"It's not about belief," says NIWA's Chief Climate Scientist, "it's about looking at the scientific evidence, then weighing up what it's telling you. It's a rational thing, not a belief thing, and the evidence is now stacking up that human activities influence the climate".

Wratt has wrought a career out of sticking with the facts, and doesn't hide a distaste for splashy headlines and exclamation marks. "I think most scientists are averse to the idea of turning their work into a front-page sensation – things can get taken way out of context."

He would probably disapprove, too, of terms like 'quiet achiever', but the man who insists he didn't become a scientist in order to make the world a better place nonetheless has a Nobel Peace Prize – shared with everyone who worked on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report – on his office wall, and a Queen's Service Order after his name.

Wratt is always quick to deflect, or at least diffuse, any credit for either onto his colleagues, but the modesty is refreshingly genuine. When I ask him what superpower he'd like to have, he doesn't hesitate: "A sharp and agile brain. At least, sharper and more agile than it is at present."

NIWA's chief climate scientist David Wratt: "One thing I find difficult is people who have decided what it is they believe, and are now looking round for evidence to support it." (*Dave Allen*)

"How many people nowadays have to gap their own spark plugs?"

NIWA Chief Climate Scientist David Wratt

He might have that mind on the clouds, but his head is turned fixedly toward the day-to-day: he's less interested in the big questions than what he calls "the smaller questions underneath.

"I don't think there's just one, big unknown," he tells me. "What really attracts me is the synthesis. I think that's why I'm so interested in working with the IPCC – that concept of how it all fits together."

Wratt grew up on a farm in Motueka, but "figured out early on that I didn't especially want to milk cows all my life. I was always good at science and maths, so I went to the University of Canterbury to take a degree in physics."

He instinctively gravitated towards the natural sciences: "geophysics, earthquake science, volcanoes, that sort of stuff, because they're grounded in our day-to-day existence, as opposed to quantum mechanics, which is pretty abstract."

He studied upper atmospheric physics, and continued that work with a post-doctorate at the University of Illinois in the United States before returning to New Zealand in 1976 to take a job with the New Zealand Meteorological Service. He was supposed to train as a weatherman, but got diverted into more atmospheric science, modelling the potential emissions from planned Think Big generation plants.

In 1992, he was transferred to the nascent NIWA, where he's since published papers and book chapters on air pollution meteorology, applied climatology, mountain influences on weather and climate, regional climate projections, and climate change impacts and adaptation.

Wratt is a vice-chair of IPCC Working Group 1, which assesses the physical science of climate change. He was a coordinating lead author for the Australia and New Zealand chapter of the IPCC's Third Assessment, and a Bureau member for the Fourth.

He's a Companion of the Royal Society of New Zealand, and a past chair of the Society's New Zealand Climate Expert Panel. He is also the Director of the New Zealand Climate Change Centre, a collaboration between Crown Research Institutes and three universities.

We put a few more questions that, just for once, weren't about climate change ...

What unfailingly continues to amaze you?

"The resilience of human beings. In my younger days, I did quite a bit of travelling in developing countries, and what I saw there was that, despite many difficulties and troubles, people just keep pushing on with their lives."

What do you do for fun?

"Riding a bike, even if it's just riding to work. When the kids were younger, we'd go for bike rides out from Tawa, to Makara and Takapu Road. When we went on our Christmas holidays this year, we took four bikes on the back of the car.

"When I've got time, I read. I don't want to pretend that it's all serious – it's often fairly light detective stuff. I was reading some of those Scandinavian crime novels, but they got a bit dark and gloomy for me."

What's your most frivolous purchase?

"I'm not sure I've told my wife yet, but I took out an online subscription to the *New York Times*. I really enjoy the opinion pieces and the blogs. I think it's partly related to having lived in the States a couple of times, and being fascinated with the place."

What was the worst decision you ever made?

"Not buying shares in Apple. I was a very early adopter of Apple computers, and I'd probably be quite rich by now."

What gets you out of bed in the morning?

"Usually my wife saying: 'The alarm went off half an hour ago.' I have to get up quite early – six o'clock – because I use either public transport or a bike to get to work, and I live across the other side of town."

Could you gap a set of spark plugs?

"Yes. In my student days, I owned a succession of pretty useless old cars. Ever since I've owned Japanese cars, I haven't had to. That might be an age thing."

Did Gary Larson pretty much have scientists nailed?

"My memory of Larson's cartoon scientists were scatterbrained, myopic people in white coats flicking rubber bands about the lab, with complicated equations on blackboards. In my opinion, that's not scientists at all, so no, he didn't.

"To me, scientists are people that can discover and understand complex things, but who can also explain them in clear and simple terms."

Is there one big question out there that you'd dearly love to see answered in your time?

"In my younger days, I might have said that I'd like to see a unified theory of everything, and to understand it. But nowadays, my interest tends to be focussed on climate systems and their impacts on people. There's no single burning question, the answer to which is going to solve everything at a stroke. It's a process of gradual understanding." W&A

Q&A

Stable isotopes: signatures of life and times past

What are stable isotopes?

Isotopes are naturally-occurring atoms of the same element that have equal numbers of protons and electrons, but different numbers of neutrons.

The number of neutrons partly determines the isotope's atomic mass. More neutrons mean a 'heavier' isotope: for instance, carbon-12 has six neutrons, but the heavier carbon-13 has seven.

It also helps determine the energy in the isotope's nucleus. If excess energy is present, the isotope 'decays' radioactively over time, and is said to be unstable. If the energy level is low, the isotope doesn't change, and is known as a stable, or non-radioactive, isotope.

Why are they so valuable to scientists?

In their natural state, stable isotopes exist in constant proportions. Atmospheric carbon, for example, is 98.89 per cent carbon-12 and 1.11 per cent carbon-13. A good stable isotope has a large relative mass difference between heavy (rare) and light (abundant) isotopes.

During certain chemical and physical processes, however, those ratios change. This is called isotopic fractionation, and occurs because chemical bonds formed by lighter isotopes are weaker than those formed by heavier ones. As a result, some stable isotopes are taken up more readily than others.

Fractionation acts on all isotopes, but crucially for scientists, the large mass ratio of some (for instance, hydrogen, carbon, nitrogen, oxygen and sodium) means the ratio of light to heavy isotopes can be measured.

Processes that leave recognisable 'signatures' of isotopic fractionation include photosynthesis, temperature changes in seawater, salinity changes (or migration between marine and freshwater systems), decomposition of organic matter, changing diet and/or metabolism and the formation temperature of rock and mineral systems.

When matter has undergone one or more of these processes, scientists can learn an enormous amount about it by studying a range of stable isotope ratios within it. They can work out how – and how quickly – the environment changed: over time scales of decades, tens of thousands of years, or just a few seasons.

Stable isotope signatures pass into the food web, and animals take in a chemically-imprinted life history of the foods they eat.

Dr Helen Neil checks samples for a 24 hour carbonate (Kiel and IRMS) stable isotope run. (*Dave Allen*)

This can tell us much about a creature's life: how far it travelled, what it ate at different times of the year, where it got that food from, and how quickly it was metabolised.

Combining such information with other research helps scientists make deductions about all manner of biological and geological processes. Beyond atmospheric and aquatic applications, for example, stable isotopes can help identify the origin of illicit drugs, or detect human stomach ulcers.

Scientists can also introduce synthesised isotopes into natural environmental systems, to trace pathways of adsorption, diffusion or assimilation. For example, a synthetic nitrogen-15 substrate is used to measure nutrient uptake and identify transport pathways in ecosystems.

What do NIWA scientists use them for?

Almost every branch of NIWA's science employs stable isotope analysis.

In the sea, stable isotopes form a vital part of NIWA's contribution to palaeoceanography – the study of the evolution of ocean systems.

When seawater cools as a result of seasonal transition, long-term climate change or ocean circulation, it becomes isotopically heavy, with a higher ratio of oxygen-18 to oxygen-16. The reverse happens when seawater warms.

What's more, when aquatic creatures absorb sea water over their life, they take up the isotopic signature of that water, and the various temperature changes it's undergone.

As a result, stable oxygen isotope ratios unlock a wealth of information about the migration patterns and life histories of certain species of fish, about seasonal and long-term climate change (including glacial and interglacial periods), and about broad-scale ocean circulation.

NIWA scientists can even assess the age of paua, based on the number of seasonal cooling and warming sequences 'imprinted' in the stable isotopes of carbon and oxygen in their shells.

In the atmosphere, NIWA is working with stable isotopes to understand seasonal and long-term changes in concentrations of atmospheric methane, measured at Baring Head in Wellington and Arrival Heights in Antarctica. NIWA's measurements of stable carbon isotopes in atmospheric methane are recognised as among the most precise in the world.

The ratios of stable carbon isotopes in these samples help scientists explain what may have caused short-term peaks in methane concentration (e.g., wetland activity, forest fires, and destruction of 'sinks') and from where that methane may have been transported.

They also hold clues to a marked long-term increase in carbon dioxide (CO_2) concentrations observed over the last 50 years. Stable isotope ratios, combined with other analyses, indicate that fossil fuels are squarely to blame.

How are stable isotope ratios measured?

Measuring stable isotope ratios is a complex process using an Isotope Ratio Mass Spectrometer.

Because samples at NIWA are measured as CO_2 gas, original material such as carbonate and methane is usually prepared to first form that gas.

A small amount of CO_2 gas is then drawn into a high-vacuum chamber and directed toward a filament, where it's ionised. A series of metal plates at high voltage (10,000V) then accelerate and focus the ions into a narrow beam.

This beam of ions enters a flight tube, where it encounters a very strong magnetic field. As the charged particles move through the field, they're bent in arcs, rather than following straight lines. Ions from the lighter isotopes are bent in tighter arcs than the heavier ones. Precisely-positioned collector cups then capture and count the ions as they arrive. Software then calculates the isotope ratio of the sample, based on the data obtained in each cup against a known reference material and the sample itself.

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NIWA
enhancing the value of New Zealand's natural resources

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

NIWA's expertise is in:

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

NIWA employs approximately 670 scientists, technicians, and support staff. Our people are our greatest asset.

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

Back cover:

A young southern royal albatross 'gams' on subantarctic Campbell Island. Non-breeding birds gather in small groups, stretching their massive wings, clapping their bills and preening one another, in practice for adult courtship. Biologists call this behaviour 'gamming' – a term originally lent to friendly social exchanges between seafarers. (*Rob Murdoch*)

NIWA
Taihoro Nukurangi