Our freshwater 2020

New Zealand's Environmental Reporting Series

Ministry for the Environment
Manatū Mō Te Taiao

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Tatauranga Aotearoa

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Cover: Exploring Te Awa Kairangi / Hutt River.
Photo: Ministry for the Environment

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Message to readers

As a nation, we value and care deeply about our freshwater – for its own sake as well as the benefits it provides for our wellbeing and our economy.

Our freshwater 2020 lands at a time when Aotearoa New Zealand is in the midst of a discussion about what is required to improve the health of our freshwater. There is broad and increasing recognition that things need to change, and a growing willingness to act.

This report provides the evidence to enable an open and honest conversation about our choices going forward. It builds on the information we have presented in previous reports but goes deeper into the evidence, to provide insights on the most pressing issues for freshwater today and into the future.

Our freshwater 2020 aims to tell a national story, while recognising that significant regional variations exist. Each catchment has a distinct mix of climate, geology, and land uses within it. The combination of these features, and how (and how fast) water moves from sky to soil and groundwater and from mountains to sea, makes it challenging to provide definitive statements about the trends we are seeing at a national level.

What we can take from the report, however, is that the choices we make have impacts on our freshwater. How we live in our towns and cities, and the way we sustain our economy with factories, farms, and forests all make a contribution.

Just as regional and catchment variations influence freshwater locally, solutions are likely to be effective at these scales too. *Our freshwater 2020* features examples where different groups – schools, communities, tangata whenua, farmers, businesses, and central and local government – are working together towards a common goal.

Understanding the current state of our freshwater and the pressures on it, is essential groundwork for decisions about where to put our efforts. The data and science presented here is up to date and the best available, but there is much more we need to know. A healthy environment underpins our wellbeing and economic prosperity, yet investment in environmental data has lagged behind other data, like economic data.

Work is underway to build an environmental monitoring and reporting system that will be foundational for decision-making and community action. It will take time and investment, but there is clear consensus around the importance of this work.

Changes in the state of our freshwater – both positive and negative – can take time. Some of the effects we are seeing today are legacies from our parents and grandparents. In some places we can expect to wait decades to see the results of our efforts to raise the health and mana of water. Nevertheless, we can't afford to slow the pace of change.

Whatever your connection to water, we trust this report will inform your discussions about ensuring the freshwater our children and mokopuna inherit is healthy, vital, and plentiful.

Vicky Robertson
Secretary for the Environment

Mark Sowden
Government Statistician

Structure and content of this report

Our freshwater 2020 is the latest in a series of environmental reports produced by the Ministry for the Environment and Stats NZ. It provides more in-depth information about how the issues highlighted in *Environment Aotearoa 2019* (our most recent report on the state of the environment as a whole) relate to freshwater, and presents new data and insights (see table 1).

Freshwater is a whole interconnected system but for clarity, this report explores the most significant pressures on the freshwater environment through four priority issues. Each issue explores the critical components and variables in our water catchments and how they relate to what we have, what we are at risk of losing, and where we can make change.

Our freshwater 2020 explores:

- Issue 1: Our native freshwater species and ecosystems are under threat.
- Issue 2: Water is polluted in urban, farming, and forestry areas.
- Issue 3: Changing water flows affect our freshwater.
- Issue 4: Climate change is affecting freshwater in Aotearoa New Zealand.

The report begins with an introduction *Stepping into freshwater*, which talks about what freshwater means to us and how individual issues can interact and have cumulative effects. A summary is provided at the start of each of the four issues. Later, *Towards a better understanding of our environment* discusses the most significant knowledge gaps and how they could be addressed. This knowledge would improve our ability to respond to the issues identified here.

Table 1: How issues covered in this report relate to the themes and issues identified in Environment Aotearoa 2019

Environment Aotearoa 2019 identified nine priority environmental issues across five themes.		*Our freshwater 2020* covers four priority environmental issues for freshwater.	
THEME	**ISSUE**	**ISSUE**	**NEW DATA AND INSIGHTS SINCE *ENVIRONMENT AOTEAROA 2019***
1. Our ecosystems and biodiversity	**1. Our native plants, animals, and ecosystems are under threat**	**1. Our native freshwater species and ecosystems are under threat**	▸ Conservation status of indigenous freshwater species ▸ Deposited sediment in rivers ▸ Freshwater fish index of biotic integrity ▸ Lake submerged plant index ▸ Modelled lake water quality ▸ Freshwater physical habitats ▸ Measuring ecosystem health
2. How we use our land	**2. Changes to the vegetation on our land are degrading the soil and water**	**2. Water is polluted in urban, farming, and forestry areas**	▸ Deposited sediment in rivers ▸ Groundwater quality trends ▸ River water quality: heavy metals ▸ Modelled lake water quality ▸ Emerging contaminants (including PFAS and pesticides)
	3. Urban growth is reducing versatile land and native biodiversity		
3. Pollution from our activities	**4. Our waterways are polluted in farming areas**		
	5. Our environment is polluted in urban areas		
4. How we use our freshwater and marine resources	**6. Taking water changes flows which affects our ecosystems**	**3. Changing water flows affect our freshwater**	▸ Barriers to fish passage ▸ Consented freshwater allocation ▸ Using aquifers to manage water supply and quality issues
	7. The way we fish is affecting the health of our ocean environment		
5. Our changing climate	**8. New Zealand has high greenhouse gas emissions per person**	**4. Climate change is affecting freshwater in Aotearoa New Zealand**	▸ Freshwater ecosystems ▸ Projected impacts of climate change on freshwater flows ▸ How climate change can affect water mixing in lakes
	9. Climate change is already affecting Aotearoa New Zealand		

Stepping into freshwater

Putangirua Pinnacles Scenic Reserve.

Photo: iStock

The origin and mauri of water

In te ao Māori, a Māori world view, freshwater comes from the parting of Ranginui (sky father) and Papatūānuku (earth mother). These gods share a whakapapa (genealogy) with Māori people, and this underpins the connected relationship that Māori have with the natural environment – mountains, forests, and waters. All these elements are therefore related and hold their own mauri (life force) – a mauri that must continue in order to propagate life.

In 2017, the Whanganui River, Te Awa Tupua and all its physical and metaphysical elements was recognised in law as an indivisible, living whole, that possesses "all the rights, powers, duties, and liabilities" of a legal person. This legal recognition speaks to the relationship of interconnection and reflects a te ao Māori understanding of the world. This understanding is shared by other iwi, hapū, and whānau for their own waterways.

What freshwater means to New Zealanders

Water is essential for life. It sustains, cleanses, and refreshes our bodies and provides opportunities for recreation. Water supports how we live and how we make a living – it is fundamental for the growth of crops, pasture, and forestry, and generates much of our electricity. New Zealanders care about the state of our freshwater and Māori consider water to be sacred. For many cultures and religions, water is central to ritual cleansing, rejuvenation, and healing.

Freshwater is a taonga for Māori. Tribal identity is linked to freshwater, with each water body having its own mauri. For Māori, great care must be taken in managing human impacts on freshwater. To honour the mana (prestige) of water requires practices and policies that first acknowledge the needs of a body of water or waterway. Once these needs have been provided for and are maintained, the water will be able to sustain a full range of environmental, social, cultural, and economic values held by iwi and a community.

Water travels through our landscapes

Freshwater appears in many forms, from tiny alpine streams and springs to large lakes, wetlands, and the widest rivers. It is also present but unseen in underground rivers and aquifers. Ki uta ki tai – from the mountains to the sea – describes the journey water makes across land as small streams combine and grow bigger, reach estuaries, and eventually meet with the sea. The connections between water on the surface, in the atmosphere, and in groundwater are also part of this holistic concept.

A catchment is the land bounded by hills or mountains that gathers and funnels water into rivers, lakes, groundwaters, and wetlands. Aotearoa New Zealand's mountains are the source of our 70 major river systems. Along with a multitude of streams, our rivers run for a total of more than 425,000 kilometres.

Variations in the underlying geology and soils, weather, climate, species, and ecosystems make catchments diverse. Catchments in New Zealand vary greatly in size and form – water joins Waikato River from a huge swathe of land between Taupō and Pukekohe, while some Auckland waterways have catchments of only a few hectares.

There are 249,776 hectares of wetland in New Zealand and more than 50,000 lakes – about 4,000 lakes are larger than one hectare and the largest is Taupō. Our freshwater is also stored in reservoirs (artificial lakes or natural lakes with raised water levels) that range in size from small farm dams to hydro lakes that hold more than a billion cubic metres. Underground aquifers also store large volumes of freshwater.

Our actions, activities, and freshwater

Few of our catchments have not been touched by humans – most contain a mosaic of land uses like cities, towns, farms, horticulture, and plantation forests, as well as native vegetation. As it travels through a catchment, the state of freshwater is strongly influenced by natural factors (like climate, geology, and landforms) and how the land is being used. The intensity of land use and the management practices for each land use also have an influence. Therefore, the state of freshwater in different catchments can be different even if the same land uses are present.

Not all water moves quickly. It can take decades or more – the lag time – for rainwater to move through the soil and into aquifers, sometimes back to rivers and lakes, then exit the catchment. Water can collect and deposit contaminants throughout this journey. In Te Arawa (Rotorua) Lakes, the average lag time is about 50 years, but lag times of more than 100 years in one catchment have been reported (Morgenstern et al, 2015). This means that some of the effects on freshwater we are seeing today are legacies of past activities. Also, the impacts of the decisions made today, including restoration and improved practices, may not be apparent for decades.

Catchments can bring people together. Throughout New Zealand, numerous catchment care groups are working to improve freshwater environments with increasingly positive results. These groups strengthen communities by providing opportunities for people to connect and act around an issue of mutual interest and concern.

Freshwater is connected and effects are cumulative

The variety of natural and human-made factors that influence different catchments make it challenging to understand how freshwater will respond to change. Our activities in a catchment often interact and have compounding or cumulative effects on freshwater.

Given this complexity and the lack of long-term data, the nature of cumulative effects is difficult to predict (Larned et al, 2018). Data from field monitoring helps to build a picture of cause and effect, but the variability and changeable nature of complex processes can make it virtually impossible to match a cause to any one activity or action.

Activities that happen in a large part of a catchment can add up to a substantial pressure, even if each occurrence seems to have a small effect on its own. Taking water is one example where the overall effect of many small water takes can be large, particularly where many takes occur close together. In parts of Otago, Canterbury, and Hawke's Bay in 2017/18, computer models of the total volume of water takes (allowed by resource consent but excluding hydroelectricity generation) from many catchments was greater than the estimated natural median flow of the rivers in those catchments.

Installing dams, weirs, and other structures in waterways also has cumulative effects. For example, if there are five structures in one river, and if each structure stops half of the fish moving upstream, then only 3 percent of all fish will make it past all five structures (Franklin et al, 2018).

Different pressures can compound and have cumulative and unexpected effects. A habitat, for example, can be affected by several different pressures at the same time, like sediment, excess nutrients, warmer water, and reduced flows. Individually, each of these pressures has a harmful effect on a stream community (Quinn, 2000), but when they occur simultaneously, the effects are compounded – the damaging effect of sedimentation is stronger when water flows are low (Matthaei et al, 2010) or when water temperatures are higher (Piggott et al, 2012).

In lakes, the combined effects of land use in a catchment and introduced fish and plant species can cause a radical change from a clear, healthy state into a cloudy, degraded state when a threshold is crossed (Schallenberg & Sorrell, 2009).

Īnanga – a little fish on a journey

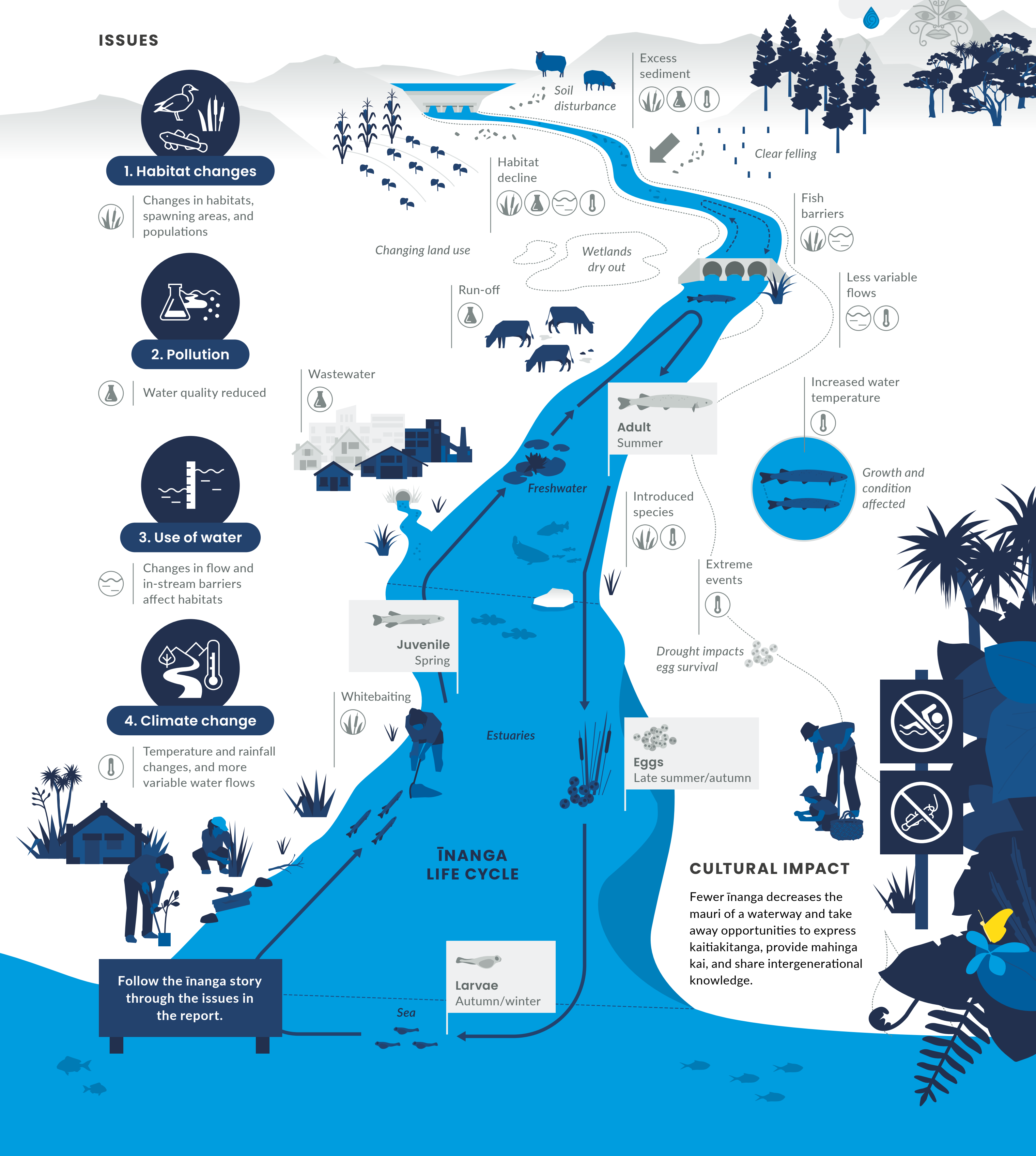
The story of īnanga (*Galaxias maculatus*) runs through this report. It helps illustrate some of the interactions between different issues that result in cumulative effects on our native freshwater species and their environment.

Īnanga are a taonga species and the most common and smallest of the native fish caught as whitebait. They move between freshwater and the sea during their life cycle, and lay eggs in vegetation beside streams and rivers where fresh and salt water meet.

Each of the four priority issues discussed in this report touches īnanga in some way, and together cause cumulative effects on this species and its habitats.

Issues overlap and have cumulative effects on īnanga

Our native fish known as īnanga shows how the issues highlighted in this report overlap and have cumulative effects. All its life stages are affected.



About Our freshwater 2020

Lake Mapourika, West Coast South Island.

Photo: Ministry for the Environment

Reporting under the Environmental Reporting Act 2015

Under the Environmental Reporting Act 2015 (the Act) the Secretary for the Environment and the Government Statistician must produce regular reports on the state of our environment. Under the Act, a report on a domain (marine, freshwater, land, air, and atmosphere and climate) must be produced every six months and a whole-of-environment (or synthesis) report every three years. Each domain report has now been published once with the exception of marine which has been published in 2016 and 2019 (see Environmental reporting series the full list).

The most recent synthesis report, *Environment Aotearoa 2019*, was published in April 2019. The previous freshwater report was *Our fresh water 2017*.

As per the Act, state, pressure, and impact are used to report on the environment. The logic of the framework is that **pressures** cause changes to the **state** of the environment, and these changes have **impacts**. Impacts to ecological integrity, public health, economy, te ao Māori, culture, and recreation are described as recommended under the Act.

Suggesting or evaluating any responses to environmental impacts is out of scope under the Act, so this report does not cover the work that organisations and communities are doing to mitigate the issues. It does provide an update on the most recent data about the state of freshwater, providing evidence to enable an open and honest conversation about what we have, what we are at risk of losing, and where we can make changes.

A focus on issues

When reviewing *Environment Aotearoa 2015*, the Parliamentary Commissioner for the Environment suggested structuring future synthesis reports around issues, where an issue is defined as:

> **…a change in the state of the environment that is (partly) caused by human activities (pressures) and has consequences (impacts).**

Taking a whole system approach, *Environment Aotearoa 2019* identified nine priority environmental issues facing New Zealand (table 1). Four criteria were established to help describe the sense of significance and urgency of the issue:

Spatial extent and scale – how much of New Zealand is affected by the issue?

Magnitude of change – is the issue increasing in scale and/or distribution, or accelerating?

Irreversibility and lasting effects of change – how hard is it to fix?

Scale of effect on culture, recreation, health, and economy – how much does it affect the things we value?

The issues discussed in this report are not the only ones that affect freshwater. Some activities have an impact but are not featured in this report because they do not rank as highly against the assessment criteria as other issues.

The following questions are addressed in each issue:

- Why does this issue matter?
- What is the current state of this issue and what has changed?
- What has contributed to this issue?
- What are the consequences of this issue?
- What are the gaps in our knowledge about this issue?

Information for this report comes from many sources

The data on which this report is based came from many sources including science agencies, central government, and regional councils. Further supporting information was provided using a 'body of evidence' approach. This is defined as peer-reviewed published literature and data from reputable sources, including mātauranga Māori, to which observational tools used to identify changes in an ecosystem contribute.

Mātauranga Māori includes observational tools that are used to identify changes in an ecosystem. These signs and signals of the natural world, ngā tohu o te taiao or tohu, are often referred to as environmental indicators. They are used by Māori environmental practitioners to identify trends or changes in the state or health of the environment.

All the data used in this report, including references to scientific literature, was corroborated and checked for consistency. The report was reviewed by a panel of independent scientists.

A list of indicators that relate to freshwater and the date they were last updated is available on the Stats NZ website.

Building our knowledge

Every report in the environmental reporting series highlights how much we still don't know about our environment. *Environment Aotearoa 2019* contained a comprehensive set of recommendations that would systematically close these knowledge gaps and improve our knowledge and reporting systems.

This approach was reiterated by the Parliamentary Commissioner for the Environment in *Focusing Aotearoa New Zealand's environmental reporting system* in 2019. The report critiqued the approach to reporting set up under the Act and outlined steps the Government needs to take to improve the system. Two recommendations relate particularly to data:

1. developing a comprehensive, nationally-coordinated environmental monitoring system
2. developing a mandated strategy to prioritise and incrementally fill data gaps.

The final section of this report, Towards a better understanding of our environment, suggests how to prioritise filling the data gaps that relate to freshwater. It also discusses how our environmental reporting system could be improved, and presents future opportunities for new technologies, innovative approaches, and integrated measurements.

Supporting information is available

Other sources of information published by the Ministry for the Environment and Stats NZ support this report:

- Environmental indicators: Freshwater – summaries, graphs, and data that relate to the state, pressures, and impacts on freshwater.
- Data tables, interactive maps, and technical reports on the Ministry for the Environment's Data Service.
- A summary of this report.

ISSUE 1

Our native freshwater species and ecosystems are under threat

▸ Longfin eel in Waikato River.

Photo: Rod Morris

This issue explores how our native freshwater species, habitats, and ecosystems are affected by the way we use our land, the species we have introduced, and the modifications we have made to natural waterways.

Aotearoa New Zealand has a very diverse and unique range of freshwater species, habitats, and ecosystems – some are rare and others are uncommon internationally.

Many of our native freshwater species, habitats, and ecosystems are under threat and continue to decline. These declines are the result of converting land to cities and towns, farms and plantation forest (and associated pollution), changing waterways from their natural form (including in-stream structures like weirs), and reducing flows, and bringing in new species intentionally or accidentally.

Collectively, these changes put our native species at risk, reduce the benefits we receive from nature, and affect our way of life and connection to freshwater.

NEW IN THIS REPORT

This issue contains updated information since *Environment Aotearoa 2019*, including new or updated data from these measures and indicators:

- conservation status of indigenous freshwater species
- deposited sediment in rivers
- freshwater fish index of biotic integrity
- lake submerged plant index
- modelled lake water quality
- freshwater physical habitats.

This issue describes how the health of our ecosystems is measured, and gives the example of the Canterbury mudfish as a native fish under threat. In an infographic, īnanga show how changes to freshwater ecosystems are affecting this native fish.

WHAT WE DON'T KNOW

- We don't have enough information to assign a conservation status to some of our species, particularly invertebrates. Nor do we have full understanding of how species and ecological processes (like decomposition) interact.
- It is difficult to measure the overall condition of our ecosystems because they are complex systems and have large variations in landscape and climate.

CONNECTIONS TO OTHER ISSUES

The other issues highlighted in this report also threaten our freshwater species and ecosystems:

- Issue 2: Water is polluted in urban, farming, and forestry areas – different types of pollution affect our waterways and their freshwater species and ecosystems.
- Issue 3: Changing water flows affect our freshwater – changes to the physical form of waterways and their flows can make places unsuitable for some species to live.
- Issue 4: Climate change is affecting freshwater in Aotearoa New Zealand – climate change is expected to exacerbate the pressures currently facing our freshwater species and ecosystems.

Why does this issue matter?

SPATIAL EXTENT

All of New Zealand's freshwater environments are affected – habitats for many species are degraded and reduced in size.

DEPARTURE FROM NATURAL CONDITIONS

There are major differences from natural conditions, with some species not found in areas they once inhabited.

IRREVERSIBILITY

Many changes to freshwater ecosystems are slow to reverse, and some are irreversible.

IMPACTS ON WHAT WE VALUE

Loss of species and ecosystems could have significant impacts on our identity, wellbeing, cultural values, and economy.

What is the current state of this issue and what has changed?

NATIVE SPECIES ARE UNDER THREAT AND CONTINUE TO DECLINE

New Zealand has a diverse range of native freshwater fish, plants, invertebrates, and birds that depend on freshwater ecosystems. Many of these species are found nowhere else in the world and some are only found in particular locations.

Taonga species

Taonga or culturally significant plant and animal species are treasured by Māori. All taonga have a mauri (life force), a wairua (spirit or soul), a tapu (sacredness), and mana (prestige). The endurance, sustenance, and heartbeat of Māoritanga (culture and way of life) is bound to the survival of these taonga.

Assessing the risk of extinction

The Department of Conservation's New Zealand Threat Classification System assesses the current risk of extinction to New Zealand species. Expert panels determine the conservation threat status using population factors, including the number of breeding pairs, past and predicted changes in population, and pressure from human-induced effects. Not all native species are assessed because the available data is limited.

Species can be:

- **threatened:** high risk of extinction in the immediate to medium term
- **at risk:** not considered to be threatened but could quickly become so if declines continue or a new threat arises
- **not threatened:** no current threat
- **data deficient:** not enough information about the populations in New Zealand to determine the conservation status.

In 2017, 76 percent of our native freshwater fish (39 of 51 species) were either threatened with or at risk of extinction. Most of these species (32 of the 39) are members of the galaxiidae family.

Galaxiids that are taonga species and threatened or at risk include all five species of mudfish, four whitebait species (shortjaw kōkopu, giant kōkopu, kōaro, and īnanga), lamprey (kanakana/piharau), longfin eel (tuna), and Stokell's smelt.

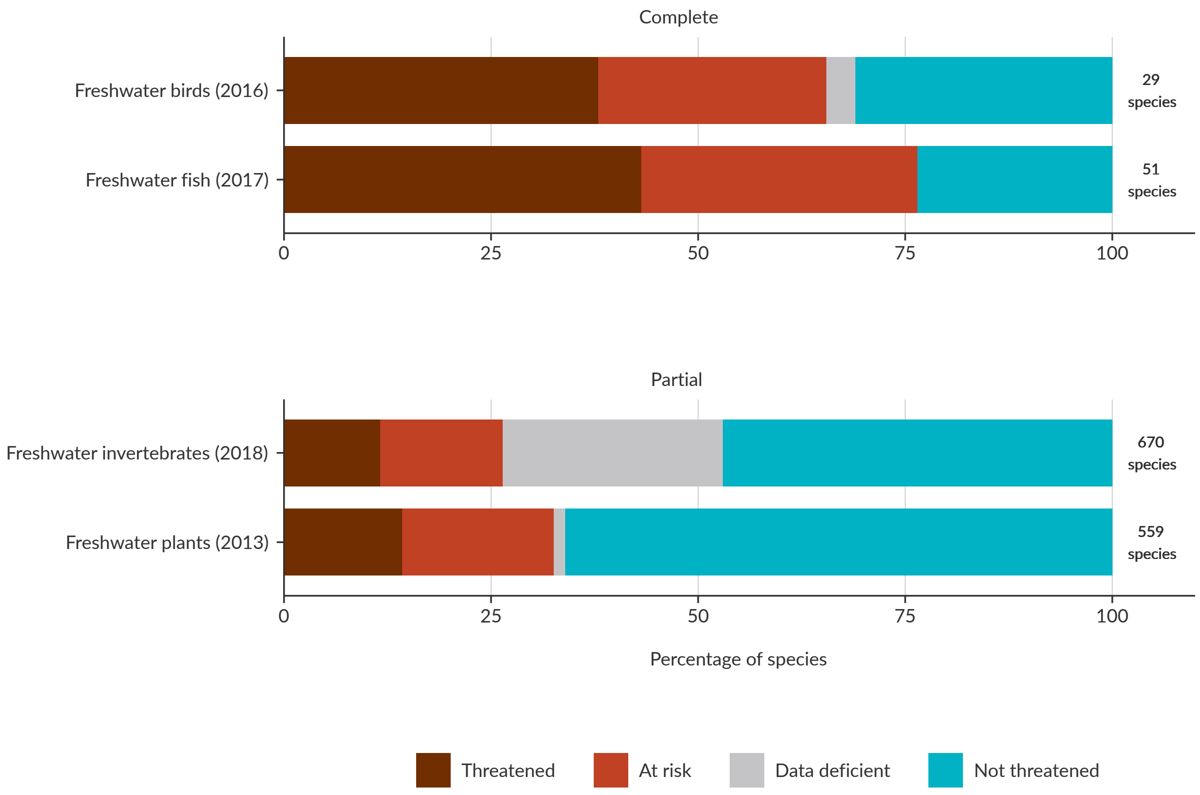
The conservation status worsened for one freshwater fish (southern flathead galaxias) and improved for another freshwater fish (lowland longjaw galaxias (Waitaki River)) from 2013 to 2017. One freshwater fish, the once common and widespread New Zealand grayling, is extinct.

More than 25 percent of native freshwater invertebrates assessed (177 of 670 species) had a threatened or at risk conservation status in 2018. Of these, South Island freshwater crayfish (kēkēwai/wai kōura) and two of three species of freshwater mussel (kākahi/kaaeo) are taonga species. The threat status of one invertebrate (tadpole shrimp) worsened from 2013 to 2018.

Almost 33 percent of assessed native freshwater plants (182 of 559 species) were threatened or at risk in 2013. Of these, almost 20 percent were in the highest risk category: nationally critical. One plant (a species of chickweed) is extinct (Gerbeaux et al, 2016).

Many of our native birds depend on freshwater environments and 66 percent of these (19 of 29 species) were classified as threatened or at risk in 2016. These include taonga species such as kāki (black stilt), whio (blue duck), and kōtuku (white heron). From 2012 to 2016 the conservation status worsened for one freshwater-dependent bird (Australasian bittern/matuku) and improved for two birds (Campbell Island teal and New Zealand dabchick). Eleven freshwater birds (some of which were taonga species) are extinct. (See indicator: Conservation status of indigenous freshwater species.)

Figure 1: Conservation status of indigenous freshwater species



Data source: Department of Conservation

Note: Total species in this figure refers to the total number of species assessed. Complete assessments are those where all known species in the group have been assessed. Partial assessments are those where not all species in the group have been assessed.

Canterbury mudfish: a taonga species in peril

Canterbury mudfish.

Photo: Angus McIntosh

Rare, quirky, and unusual, Canterbury mudfish (kōwaro) typify the uniqueness and adaptability of New Zealand's native species. They are nocturnal, gulp air if the water is low in oxygen, and can survive out of water. These fish belong to the galaxiidae family and are one of only five species of mudfish found in different parts of New Zealand. Canterbury mudfish were recorded as a taonga species in the Ngāi Tahu Settlement Act (1998).

Mudfish like to live in swampy, wet, overgrown areas if there's plenty of water around. When the rains stop, the weather warms, and wetlands dry up, they undergo the summer equivalent of hibernation – burrowing into damp places under logs, in thick vegetation, or mud. Months later when the first autumn floods come, out they wriggle again.

But Canterbury mudfish have not been adaptable enough to thrive in the combination of changes that people have made to their habitat in the past 150 years. They were originally found throughout the Canterbury Plains but are now limited to small pockets of remaining wetland from Christchurch to the Waitaki River. Losses have continued, even from areas where there were remnant populations in the 1990s.

Large-scale changes to land use have occurred in Canterbury, with wetlands drained, streams channelled, fertiliser applied, and water taken from natural waterways and re-applied through irrigators. Mudfish have colonised artificial stock water races, but these are now being closed. Add to this the lack of legal protection, the effects of predatory brown trout, and drought, and the survival of Canterbury mudfish looks bleak.

The conservation status of this species is nationally critical, – and has been since 2009. This is the highest threat status – the same as kākāpo, black robin, and rock wren. In the Department of Conservation's (DOC's) 2017 freshwater fish conservation status report, the panel noted that "its persistence is now tenuous" and that urgent action to protect its habitat is needed to avert extinction.

People are taking notice of the serious trouble these little fish are in. The community, regional council, DOC, Ngāi Tahu, and private landowners are involved in essential conservation initiatives.

Pupils and staff at St Andrew's School near Timaru are champions for the species. In the past six years they have been working to increase the population in a spring-fed stream just a kilometre from the school. With DOC, Working Waters Trust, and a local farmer they have excavated new ponds, removed weeds, and planted natives beside the water. Regular monitoring using fish traps (baited with marmite) shows the effects of their work in a growing population, and the school has been recognised in conservation awards.

Environment Canterbury led a project with Fonterra, DOC, Taumutu rūnanga, and landowners to install an electric 'fence' in a tributary of the Hororata River, about 50 kilometres west of Christchurch. The solarpowered barrier sends electric shocks across the river, which stun approaching trout and causes them to be swept downstream. Good numbers of mudfish were living further upstream, but this barrier will give them 10 percent more habitat that is protected from trout and allow the population to grow.

FRESHWATER HABITATS ARE DEGRADED AND CONTINUE TO DECLINE

Many of the freshwater habitats that our native species rely on have been reduced or damaged – sometimes entire ecosystems have been degraded. This has made some species particularly vulnerable to extinction.

Wetlands are taonga for Māori as they were often plentiful sources of important plants. These included harakeke and raupo used for weaving; and plants and trees that were used for carving and making tools. Wetlands were also ripe picking grounds for rongoā plants (medicinal plants) (Harmsworth, 2002).

An estimated 90 percent of wetland habitats, especially swamps, have been drained since pre-human settlement. Most wetlands, particularly those on flatter land near the coast, are now small remnants surrounded by developed land (Myers et al, 2013). (See indicator: Wetland extent.)

At least 214 individual wetlands with an area of 1,247 hectares were lost between 2001 and 2016 (Belliss et al, 2017). The loss of these precious ecosystems can be rapid and substantial – 157 hectares of wetland were lost *per year* in Southland between 1990 and 2012 (Robertson et al, 2018). Wetland loss and a decline in wetland health go hand in hand (Clarkson et al, 2015) – 60 percent of New Zealand's remaining wetlands are estimated to be in a moderately to severely degraded state (Ausseil et al, 2011).

Soil washed from the land can degrade habitats when it settles as sediment on a streambed. Sediment fills in the spaces at the bottom of a stream that fish and invertebrates use to hide and breed, and sediment also makes their food harder to find. Fine sediment has negative effects on streambed life when it covers more than 20 percent of a streambed that would naturally be covered in stones or gravel (Clapcott et al, 2011; Burdon et al, 2013) – a level of cover found in 23 of 215 sites assessed between 2014 and 2019. (See indicator: Deposited sediment in rivers.)

Modifying waterways with dams, pipes, concrete or rock banks, and constraints to a natural shape (such as forcing a wide floodplain into a narrower channel), can destroy and damage habitat. Removing riverside (riparian) vegetation from the banks of a waterway also reduces habitat for native species like īnanga (Jowett et al, 2009).

The characteristics and condition of river and stream habitats affect the range of plants and animals that can live there (Harding et al, 2009). Several measures are used to assess the state of the physical habitat in a stream or river. These include sediment, channel shape, bank erosion, riparian vegetation, as well as the quality, quantity, and diversity of habitat for fish and invertebrates. Between 2013/14 and 2018/19, the habitat was assessed at 369 sites in six regions in the North Island and 90 in Southland (in rivers that were small enough to be crossed by wading). The habitat was good or excellent at 79 percent of the sites and fair at 21 percent. No sites were in poor condition. (See indicator: Freshwater physical habitat.)

Regional councils collect data on the amount of periphyton (the natural growth on rocks and riverbeds) but this information does not yet provide a detailed national view. Neither does it show how the amount of periphyton in rivers is changing. Computer models can use council data to estimate the amount of periphyton using nutrient concentrations, river flows, and the type of sediment on the riverbed. At the moment, however, the models only work well at a regional scale because of variations between regional datasets and lack of robust data for some regions (Kilroy et al, 2019).

THE HEALTH OF OUR FRESHWATER ECOSYSTEMS IS VARIABLE

Assessing the health of an ecosystem is a complex process (see 'Measuring the health of an ecosystem' box). Although information about ecosystem health is presented in this report, it is not comprehensive enough to provide an overall assessment.

Measuring the health of an ecosystem

An ecosystem is a complex tangle of relationships between living things and the environment. Ecosystem health is measured by assessing a number of factors like biodiversity, the quality of habitats, and how well the essential processes like photosynthesis and decomposition are working.

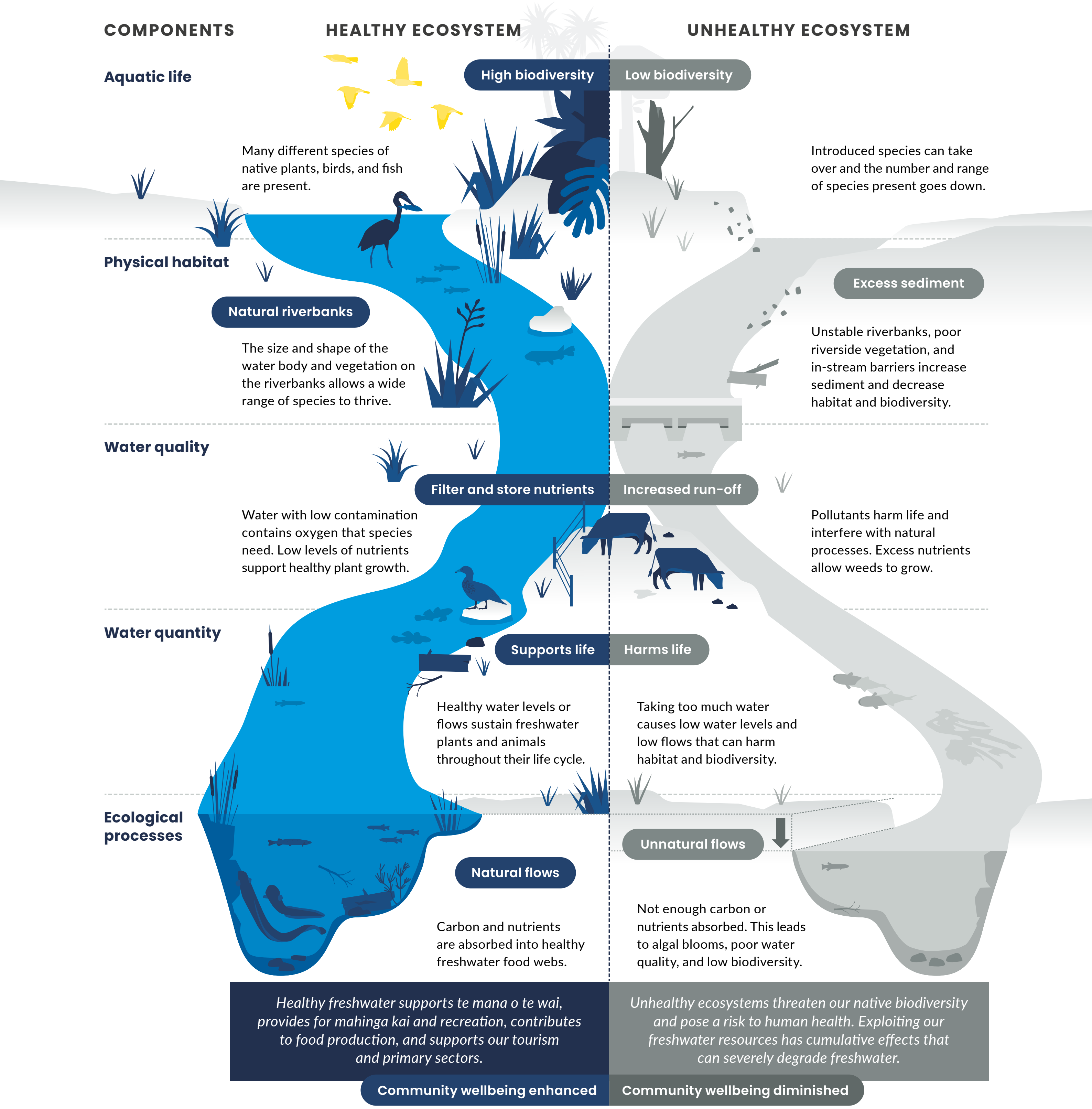
Five components are used to assess the health of freshwater ecosystems (Clapcott et al, 2018):

- **Aquatic life:** how many and which species are present, including microbes, invertebrates, plants, fish, birds, and any invasive species.
- **Habitat:** size, shape, and condition of the water body, including its bed, banks, and margins, riparian vegetation, and connections to groundwater.
- **Water quality:** physical and chemical measures of the water, including any pollutants.
- **Water quantity:** volume and variability in water level or flow, and connections to different water bodies.
- **Ecological processes:** interactions between species and their habitat.

Measuring these components varies according to the type of ecosystem – lakes, wetlands, rivers, and estuaries are all quite different. Measuring all components of an ecosystem is challenging (especially aquatic life and ecological processes), and this currently limits our ability to comprehensively assess the health of most of our ecosystems. See Towards a better understanding of our environment.

Freshwater ecosystem health

Healthier ecosystems have been less affected by our activities and contain more of the native species that would be present in natural conditions.



The ecological health of a river can be assessed by comparing the numbers and types of native and non-native fish in its habitats (its fish community) with what would be expected under natural conditions. One method is the freshwater fish index of biotic integrity (IBI), which scores a river from 0 to 60 (Joy & Death, 2004).

A study of more than 5,900 observations from NIWA's freshwater fish database for 1999–2018 reported that 34 percent of rivers had fish IBI scores above 40, which indicates a healthy native fish community. However, 18 percent had fish IBI scores below 20, which is an indication of degraded native fish communities (MfE, 2020). Sites with low fish IBI scores were mostly in Southland, Otago, and the centre of the North Island (see figure 2).

The macroinvertebrate community index (MCI) measures water quality and river ecological health using the presence or absence of different organisms (see 'Macroinvertebrate community index' box). Computer models of the MCI scores for all rivers for 2013–17 estimated that more than three-quarters of New Zealand's total river length had scores classified as excellent or good for pollution levels. However, lowland parts of Southland, Canterbury, Manawatū, Waikato, and Northland have large areas with lower modelled MCI scores (see figure 3).

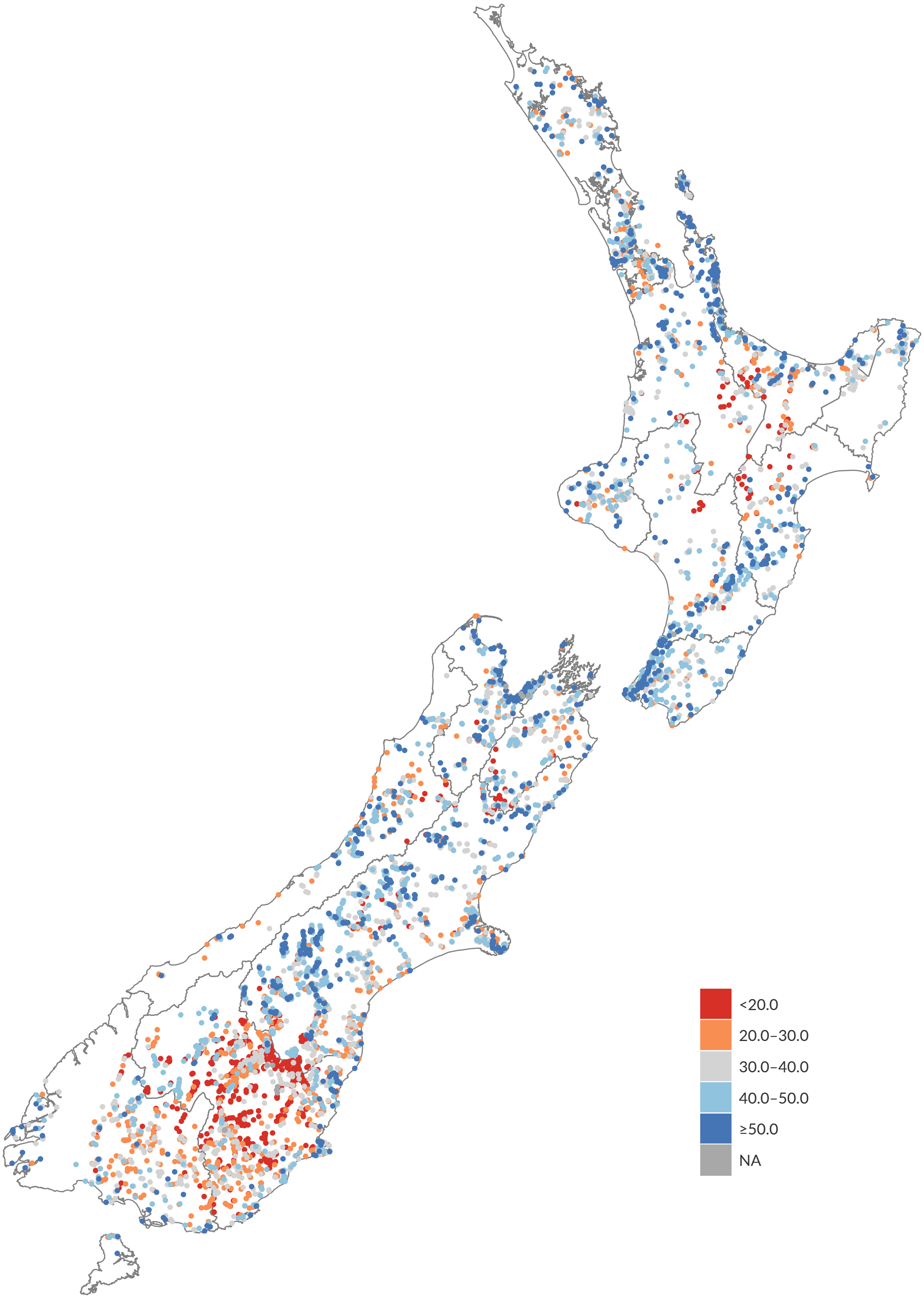
For the 573 river sites where MCI was measured for 2008–17, 38 percent had worsening trends, 26 percent had improving trends, and 37 percent had indeterminate trends. (See indicator: River water quality: macroinvertebrate community index and figure 3.)

Macroinvertebrate community index

Macroinvertebrates are animals like insects and snails that have no backbone but are visible with the naked eye. Macroinvertebrates are a useful way to measure the health of a river because they stay in a relatively small area through their life cycle, and therefore reflect the local conditions.

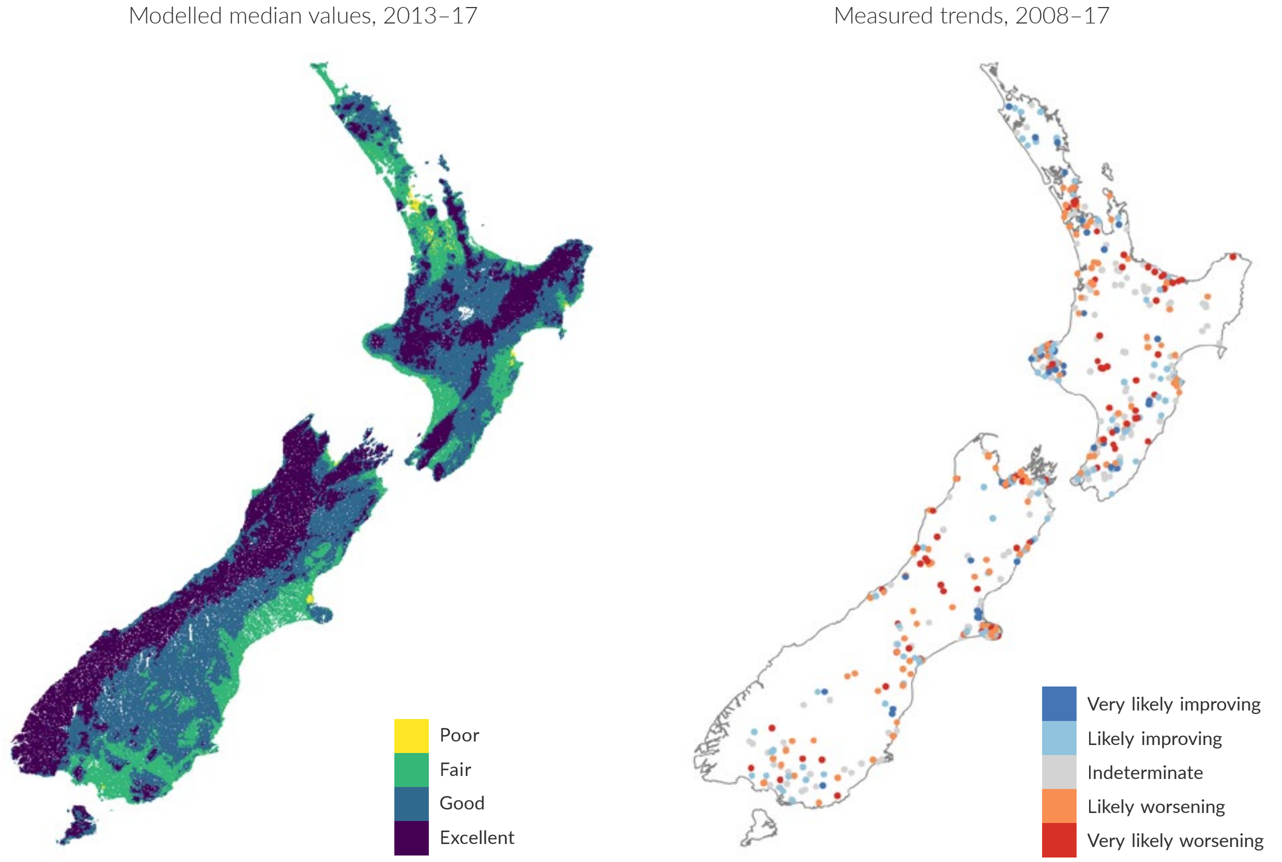
Different species are more or less sensitive to changes in the river (like pollutants, water flows, and habitat) and are given scores according to their ability to survive change. The macroinvertebrate community index score for a site is derived from the average score for the individual macroinvertebrates found there.

Figure 2: Fish index of biotic integrity scores for sites sampled between 1999 and 2018



Data source: New Zealand Freshwater Fish Database

Figure 3: River macroinvertebrate community index scores



Data source: NIWA

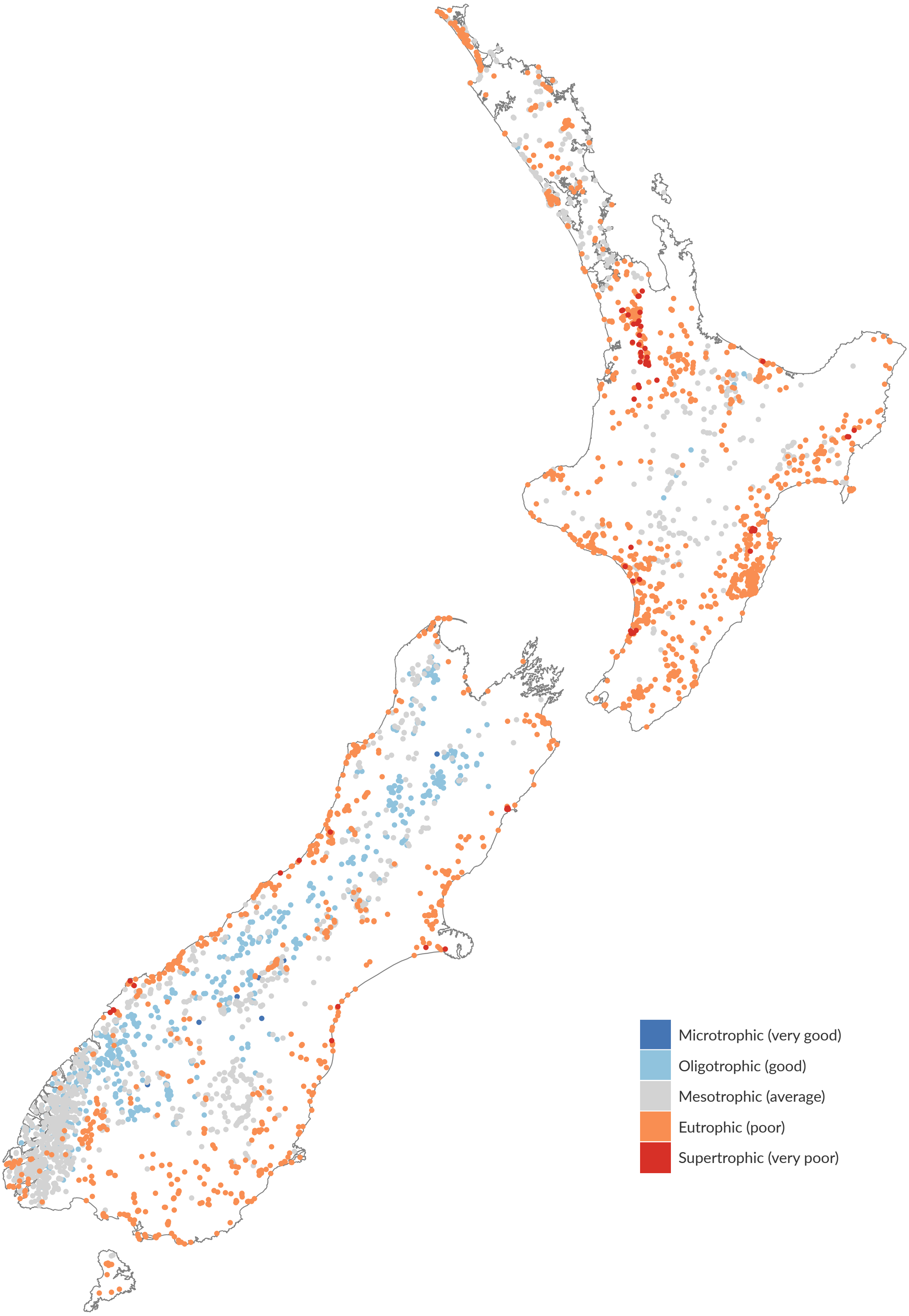
In lakes, the submerged plant index (SPI) measures ecological health by the proportion of native and invasive plants that are present. A higher percentage of native plants indicates better ecological health, while a higher percentage of invasive plants indicates poorer ecological health. Lakes with no plants are considered to be highly degraded.

SPI data is only available for 295 lakes, although there are 3,820 lakes larger than 1 hectare in New Zealand (Schallenberg et al, 2013). In the period 1991–2019 for lakes with SPI data, 34 percent were in excellent or high ecological condition, 31 percent were in moderate condition, and 36 percent were in poor condition or lacking submerged plants. Only 12 percent of the lakes with SPI data had no invasive plants present. (See indicator: Lake submerged plant index.)

The lake trophic level index (TLI) also assesses ecological health using the concentrations of chlorophyll-a (a measure of the quantity of phytoplankton), nitrogen, and phosphorus. Lakes with good or very good TLI ratings have low concentrations of nutrients and algae, and clear water (unless they are naturally cloudy). Lakes with poor or very poor TLI are often murky and have high nutrient concentrations and frequent algal blooms. These lakes have habitats that are not suitable for some native freshwater species and may not be useable for recreation (eg Lake Horowhenua in Manawatū-Whanganui).

Computer models estimated that for 2013–17, the median TLI rating for 3,802 lakes larger than 1 hectare was very good or good for 15 percent of lakes, average for 38 percent of lakes, and poor or very poor for 46 percent (see figure 4). (See indicator: Modelled lake water quality.)

Figure 4: Trophic level index rating for modelled lake water quality, 2013–17



Data source: LAWA

What has contributed to this issue?

PEOPLE HAVE CHANGED THE LANDSCAPE

Before humans arrived in New Zealand, forests covered about 80 percent of our land, but in 800 years it has been transformed (Nicholls, 1980). Waves of settlers from Polynesia and Europe cleared areas of forest and drained wetlands to make way for farming and settlements (McGlone, 1989; Clarkson et al, 2007; Gluckman et al, 2017). This led to a loss of habitats and a decline in the number of species. About one-third of original forest and only 10 percent of wetlands remain. (See indicators: Predicted pre-human vegetation, Indigenous land cover, and Wetland extent.)

Converting land in our catchments to cities, farms, and forestry in order to live and make a living has reduced the water quality and ecological condition of rivers and lakes (see Issue 2: Water is polluted in urban, farming, and forestry areas).

The effects of land conversion and our activities on freshwater ecosystems are assessed by comparing freshwater ecosystem health in catchments where the dominant land cover is urban, pastoral farming, or exotic forestry (the urban, pastoral, and exotic forest land-cover classes) with catchments where the dominant land cover is native vegetation (the native land-cover class). Although catchments in the native land-cover class are the least affected by our activities, they are not representative of natural conditions because by definition they can include some urban, pastoral, and exotic forest land cover (see Water quality and land-cover classes).

Lakes with upstream catchments in the urban, pastoral, and exotic forest land-cover classes have poorer ecological health than those in the native land-cover class. Modelled TLI ratings estimated that 71 percent of lakes (larger than 1 hectare) in these catchments had a rating of poor or very poor in 2013–17. Only 19 percent of lakes with upstream catchments in the native land-cover class had a TLI rating of poor or very poor. SPI scores were also lower for 295 monitored lakes with catchments in the urban and pastoral land-cover classes than for those in the native and exotic forest land-cover classes. (See indicators: Modelled lake water quality and Lake submerged plant index.)

Rivers also have poorer ecological health in catchments in the urban and pastoral land-cover classes than rivers in catchments in the native land-cover class. For 2013–17, the median modelled MCI scores (when compared with catchments dominated by native land cover) were 33 percent lower for catchments with dominant urban land cover and 15 percent lower for catchments with dominant pastoral land cover. (See indicator: River water quality: macroinvertebrate community index.)

Lower fish IBI scores were also found at river sites with more upstream pastoral land cover than sites with more upstream native land cover. For 1990–2018, fish IBI scores were generally better at river monitoring sites with more upstream native land cover (Joy et al, 2018). Fish IBI scores were not assessed using dominant land-cover classes.

For 369 North Island river monitoring sites, there were a greater proportion of sites with physical habitat in a good or excellent condition in catchments dominated by native land cover compared to those dominated by pastoral, exotic forest, or urban land cover. (See indicator: Freshwater physical habitat.)

The amount of sediment covering streambeds was also greater at river sites in catchments in the urban land-cover class, compared with sites in catchments in the pastoral, exotic forest, and native vegetation. (See indicator: Deposited sediment in rivers.)

IN-STREAM STRUCTURES CAN STOP OR DISRUPT ESSENTIAL FISH MIGRATIONS

Many of our native fish need to migrate up and downstream and to and from the sea to complete their life cycles (McDowall, 2010; Franklin et al, 2018). Structures like dams, weirs, culverts, and tide gates in streams and rivers can make these migrations difficult or impossible, reduce fish populations, and affect natural stream processes (Franklin et al, 2018). (See indicator: Selected barriers to freshwater fish in Hawke's Bay and Issue 3: Changing water flows affect our freshwater.)

FISHING AND LOSS OF HABITAT HAVE REDUCED THE NUMBER OF FISH

The commercial catch of short and longfin eel is managed by the Ministry for Primary Industries under the quota management system. Fishing, habitat loss, and barriers to fish migration have reduced the number of large longfin eels nationwide. Large longfin eels are now found mainly in small streams and remote locations where there is no eel fishing (Graynoth et al, 2008; Jellyman et al, 2000). Customary fishing has also declined (MPI, 2014). Lamprey, kōura, black flounder, and mullet are also targeted by commercial and recreational fishers.

Whitebait are the juveniles of five species of galaxiid and one species of smelt. They are managed collectively by the Department of Conservation as a recreational fishery. In the spring, shoals of whitebait migrate from the sea into rivers and streams, but the shoals have declined from historic levels. Contributing factors include a loss of fish habitat (particularly wetlands) and damage and loss of spawning sites (Hickford & Schiel, 2011). The effects of these changes – as well as the pressure of whitebait fishing – on the quantity and distribution of whitebait are not known (Goodman, 2018).

INTRODUCED SPECIES THREATEN OUR NATIVE SPECIES

Some of the animals and organisms that humans brought to New Zealand pose significant threats to our native freshwater species. Introduced species compete with native species for food and space, and damage existing habitats.

There are now 21 species of non-native freshwater fish in New Zealand (Collier & Grainger, 2015). Nine of these have been identified as being species of greatest concern, including koi carp, perch, and bullhead catfish. (See indicator: Freshwater pests.) Introduced fish accounted for more than 80 percent of the fish species observed at 925 river sites from 1999–2018, particularly in parts of Otago and the central North Island (MfE, 2020).

Koi carp have some of the worst effects on our freshwater ecosystems. These fish are native to Asia and were accidentally introduced to New Zealand in the 1960s. Koi carp stir up sediment and nutrients while they feed. Disturbed nutrients can lead to algal blooms. Suspended sediment and algal blooms block out light and reduce the amount of native freshwater plants (that provide habitat for native species) (Collier & Grainger, 2015; Schallenberg et al, 2013; NIWA, 2019; Rowe, 2007). In some places such as the lower Waikato River, koi carp can account for up to 70 percent of the total amount of fish by weight (Hicks et al, 2010).

Trout and salmon fishing have recreational and economic benefits for New Zealand, but can have negative effects on rivers and streams. In many waterways, trout have replaced native galaxiids as the dominant fish species and changed where kōura are found (Mcintosh et al, 2010; Usio & Townsend, 2000).

New Zealand's freshwater ecosystems also have 41 introduced plant and algae species. (See indicator: Freshwater pests.) Many introduced plants (like hornwort *Ceratophyllum demersum*) form tall, dense weed beds and spread quickly (Wells et al, 1997; de Winton et al, 2009). These plants can take the place of native freshwater species, and make the habitat unsuitable for native fish and invertebrates (Champion et al, 2002; Clayton & Champion, 2006).

There are 11 introduced invertebrates in our freshwater ecosystems, including seven species of snail.

Didymo (*Didymosphenia geminata)* is an introduced algae that can form thick, dense mats – sometimes over entire streambeds. It changes the populations of invertebrates in a stream and therefore reduces the number of native fish and trout because they prey on invertebrates. Since its discovery in 2004, didymo has spread to more than 150 waterways in the South Island, but has not yet been detected in the North Island (Jellyman & Harding, 2016; MPI, 2020).

Introduced species like rats and mice can also affect native freshwater birds, fish, and invertebrates. Mice, for example, eat īnanga eggs laid in long grass beside estuaries (Baker, 2006).

Other issues discussed in this report also contribute or are related to the loss of biodiversity:

- Issue 2: Water is polluted in urban, farming, and forestry areas.
- Issue 3: Changing water flows affect our freshwater.
- Issue 4: Climate change is affecting freshwater in Aotearoa New Zealand.

What are the consequences of this issue?

THE BENEFITS FROM NATURE ARE BEING LOST

Healthy species, habitats, and ecosystems provide us with benefits (or ecosystem services) (Cardinale et al, 2012; Clarkson et al, 2013; Schallenberg et al, 2013). Freshwater fish move nutrients by feeding and migrating between different habitats (Vander Zanden & Vadeboncoeur, 2002). Longfin eels are the top predators in rivers and control lower levels of the food chain. They also cycle nutrients by feeding and scavenging (Jellyman, 2012).

Wetland habitats and ecosystems provide benefits like storing carbon as peat, regulating water flow during storms, and purifying water by filtering out nutrients and sediments (Clarkson et al, 2013; Schallenberg et al, 2013). Reducing the extent of wetlands and the number of native freshwater fish therefore influences these important processes.

There are benefits for people and for nature when a reciprocal relationship between humans and the natural world is in place. Giving back to nature (by planting natives beside a stream, for example) creates vitality in an environment, and our wellbeing is uplifted when the environment is healthy and vigorous.

OUR WAY OF LIFE AND CONNECTION TO THE LAND COULD CHANGE

In te ao Māori, a Māori world view, people are part of the environment. Although degraded ecosystems and the loss of native species are bad for everyone, such losses can cause a disconnection in identity and culture for Māori.

Nature provides mahinga kai (food gathering) and materials for practices like raranga (weaving) and rongoā (medicinal uses) as well as seasonal indicators for managing the environment. These elements are essential for maintaining and passing mātauranga (knowledge) from one generation to another. With loss of species and ecosystems, the quality and quantity of food and materials available can be reduced. This affects important cultural values, beliefs, and practises (Harmsworth & Warmenhoven, 2002).

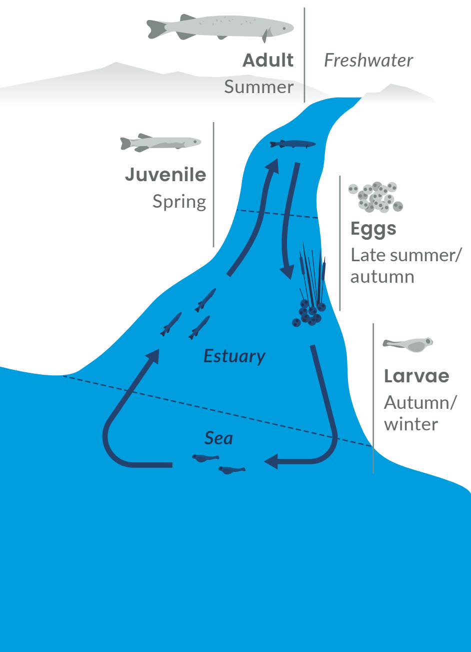
Cultural practices that use native species and natural materials are vital for maintaining and reinforcing values like mana (prestige), ahikāroa (connection with place), whanaungatanga (family ties and links), mātauranga (knowledge systems), and whakaheke kōrero (passing knowledge to the next generation) (Harmsworth & Awatere, 2013; Lyver et al, 2017a, 2017b). Losing the ability to collect mahinga kai can jeopardise the mana of an iwi, hapū, or whanau providing food for their guests (Collier et al, 2017) and compromise the cultural use of a species (Noble et al, 2016; Schallenberg et al, 2013; McDowall, 2011).

The cultural health index (CHI) assesses the health of freshwater ecosystems using factors that are important to Māori. It has three components: site status, mahinga kai status, and cultural stream health (Tipa & Teirney, 2006). For 41 sites assessed between 2005 and 2016, 11 sites had good or very good CHI ratings, 21 had moderate scores, and 9 had poor or very poor ratings. (See indicator: Cultural health index for freshwater bodies and Issue 2: Water is polluted in urban, farming and forestry areas.)

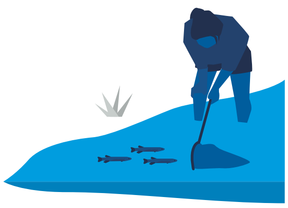
How pressures on ecosystems affect īnanga

Īnanga are under pressure from whitebaiting and introduced species, and from destruction of their habitat and spawning sites.

ĪNANGA LIFE CYCLE



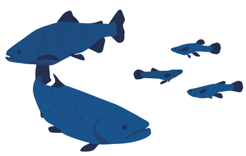
PRESSURES



Whitebaiting

Īnanga are caught when they move upstream as young fish in spring. The numbers caught and the effects of fishing on the population decline are unknown.

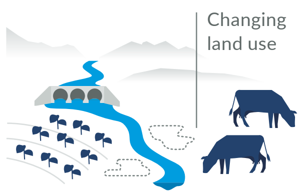
Life stage affected



Introduced species

Īnanga are eaten by introduced fish like trout. Trout also compete for the same food and habitat. Didymo can affect their food sources.

Life stages affected



Habitat reduction

Draining 90% of wetlands has significantly reduced the habitat for īnanga. Spawning sites beside rivers, streams, and the upper reaches of estuaries have been damaged or destroyed.

Life stages affected

Where are the gaps in our knowledge about this issue?

OUR KNOWLEDGE OF SOME SPECIES IS LIMITED

Information is missing at a species level. The conservation status of 27 percent (178 species) of assessed freshwater invertebrates is data deficient. The number of freshwater invertebrates, non-vascular plants, and algae assessed does not include all species. Some groups of species, and life stages within species, are not well studied. Many species are yet to be described.

ASSESSING ECOSYSTEM CONDITION IS DIFFICULT AND COMPLEX

Measuring the condition of ecosystems is difficult (Andreasen et al, 2001) because the systems themselves are complex, and climate and landscape variations are overlaid.

Despite recent efforts to improve freshwater quality, we still have incomplete knowledge about the condition of our freshwater ecosystems, habitats, and their plant, fish, and invertebrate communities. For example, although the area of wetlands has declined, little is known about the condition of the wetlands that remain. Our knowledge about large rivers and the biology of groundwater ecosystems is also poor (Sirisena et al, 2013). Only 4 percent (about 150) of the 3,820 lakes larger than 1 hectare are regularly monitored by regional authorities (Larned et al, 2019). Data for freshwater species interactions and ecological processes is poor.

At present, there is not enough high-quality data available to describe all the aspects of a healthy ecosystem. This means it is only possible to assess some aspects of ecosystem health, rather than its entirety. For example, the number of freshwater species that are threatened and at risk of extinction can be reported, but an assessment of what functionality is being lost as a result of their decline cannot be made.

ISSUE 2

Water is polluted in urban, farming, and forestry areas

▸ Stormwater pipe at Cox's Bay Reserve, Auckland.

Photo: photonewzealand

This issue explores how the way we live and use our land can result in excess nutrients (like nitrogen), chemicals, disease-causing pathogens, and sediment entering freshwater and causing harm.

Many of our rivers, lakes, and groundwaters have unnaturally high levels of nutrients, chemicals, disease-causing pathogens, and sediment. Pollution degrades the health, mauri, and wairua of waterways and can make our water unsafe for drinking, recreation, food gathering, and cultural activities.

Several different types of pollutants affect our freshwater. Nutrients (like nitrogen and phosphorus) can lead to algal blooms that degrade ecosystems and the cultural and recreational value of water. Sediment makes the water cloudy and smothers natural habitats on the bottom and banks of rivers and lakes. Pathogens like *Campylobacter* can make people ill when they drink or swim in polluted water. Emerging pollutants are non-natural chemicals that we know little about, including their effects on human health and the environment.

Rivers, lakes, wetlands, and groundwater are parts of an interconnected freshwater system, and poor water quality in one part of the system can affect water quality elsewhere within a catchment.

Pollution of our freshwater is not the result of any single land use, but comes from the mosaic of cities, farms, and plantation forests we see in most river catchments. Our activities in these areas support our lifestyles and economy but have required land to be cleared, drained, and modified. These changes and the way we manage our land have caused more pollutants to be discharged into freshwater.

Applying pesticides and fertilisers, increasing the number of cattle per hectare, felling and replanting pine trees, and faulty wastewater and stormwater infrastructure are all examples of activities that contribute to water pollution.

NEW IN THIS REPORT

This issue contains updated information since *Environment Aotearoa 2019* including new or updated data from these measures and indicators:

- deposited sediment in rivers
- groundwater quality trends
- river water quality: heavy metals
- modelled lake water quality.

Emerging contaminants (including per- and poly-fluoroalkyl substances) and pesticides are discussed in this issue, and the story of the Waiwhetu Stream is included as a local example. In an infographic, īnanga demonstrate the effects of land-based activities and water pollution on a native fish.

WHAT WE DON'T KNOW

- Our overall understanding of freshwater pollution is limited in some areas – especially the urban environment. The types and sources of pollution in our cities and towns are complex, and their cumulative effects are not well understood.
- Our knowledge has gaps about how our activities affect water quality. Each catchment's varied landforms and climate, overlaid by the mosaic of land uses within it, makes this information complex and difficult to obtain. Knowing exactly how well management methods work to reduce pollution at a particular place is an important gap to fill, especially if the methods and technologies are new.

CONNECTIONS TO OTHER ISSUES

The other issues highlighted in this report are also affected by water pollution.

- Issue 1: Our native freshwater species and ecosystems are under threat – pollution is a serious threat to our freshwater species and ecosystems.
- Issue 3: Changing water flows affect our freshwater and Issue 4: Climate change is affecting freshwater in Aotearoa New Zealand – taking water, changing the physical form of waterways, and climate change can amplify the negative effects of pollution on a waterway.

Why does this issue matter?

SPATIAL EXTENT

Pollution affects almost all rivers, many aquifers, and some lakes.

DEPARTURE FROM NATURAL CONDITIONS

Concentrations of pollutants in freshwater are higher in urban, farming, and forestry areas than in natural conditions, sometimes many times higher.

IRREVERSIBILITY

Difficult to reverse because of the scale of the issue and because some catchments respond slowly to interventions. Reducing pollution requires significant investment and changes in behaviour.

IMPACTS ON WHAT WE VALUE

Freshwater pollution threatens our native species and habitats and has a high risk to human health and cultural wellbeing, practices, and knowledge.

Our activities are polluting the freshwater environment

Waterways in urban, farming, and forestry areas are polluted by contaminants. This threatens our freshwater ecosystems and can make the water unsafe for us to use and enjoy.

SOURCES OF POLLUTANTS AND THEIR EFFECTS

Sediment

Sediment can degrade ecosystems by making the water cloudy (turbid) and smothering natural habitats on the bottoms and banks of rivers and lakes.

Nutrients

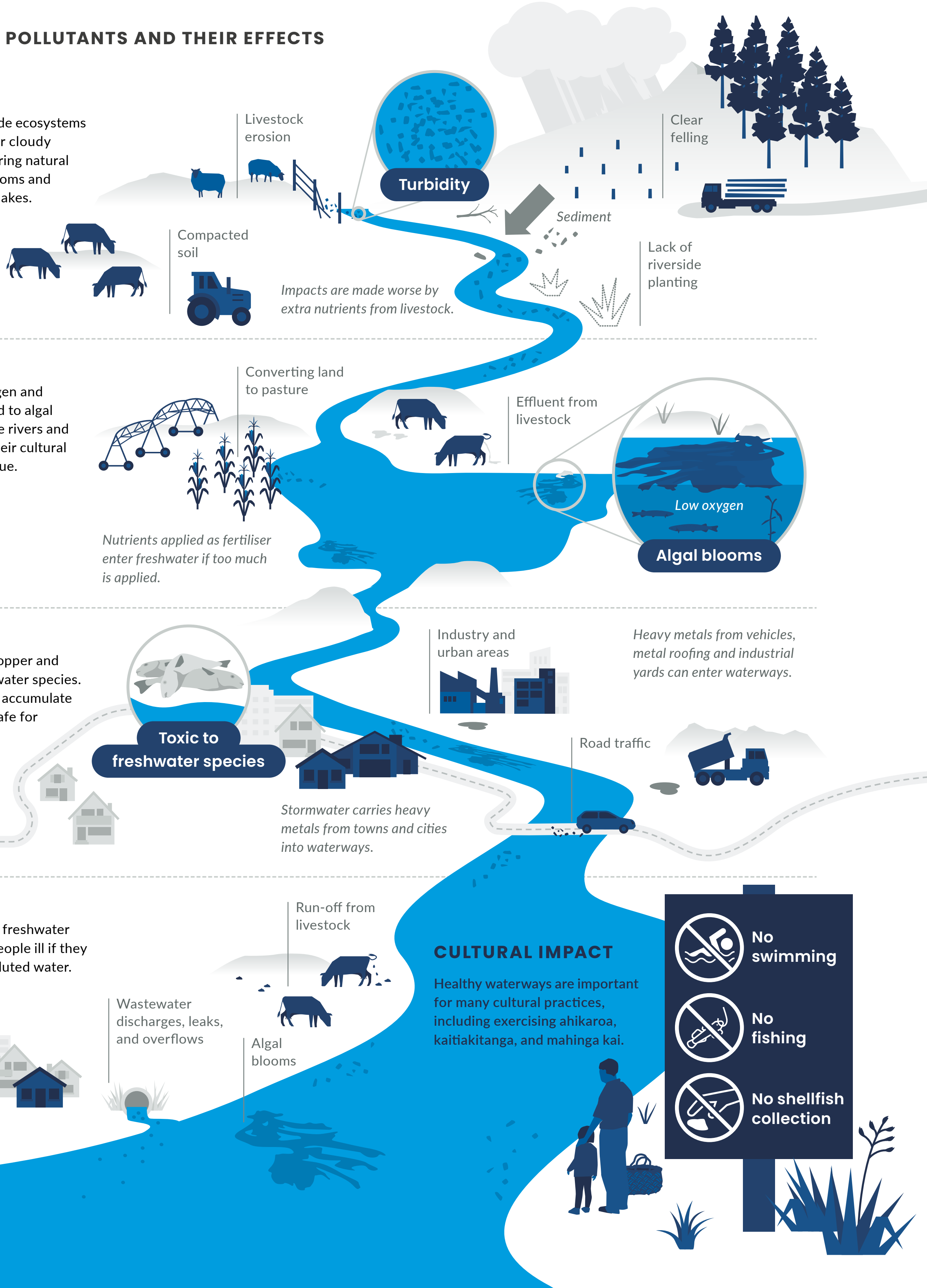
Nutrients like nitrogen and phosphorus can lead to algal blooms that degrade rivers and lakes, and reduce their cultural and recreational value.

Heavy metals

Heavy metals like copper and zinc threaten freshwater species. The metals can also accumulate and make them unsafe for us to eat.

Pathogens

Pathogens threaten freshwater species and make people ill if they drink or swim in polluted water.



What is the current state of this issue and what has changed?

Water quality and land-cover classes

Catchments usually contain a mix of different activities and types of land cover. This report uses land cover to approximate land use and estimate the effects of land use on water quality.

Dominant land cover is estimated based on the best available method, which takes into account that some types of land cover are known to have greater impacts on water quality than others (Snelder & Biggs, 2002). Catchments are assigned to one of four classes:

- **urban:** more than 15 percent of the catchment area has urban land cover
- **pastoral:** less than 15 percent of the catchment area has urban land cover, and pastoral land cover is greater than 25 percent or covers the largest proportion of the catchment
- **exotic forest:** less than 15 percent of the catchment has urban land cover, less than 25 percent of the catchment has pastoral land cover, and exotic forest covers the largest proportion of the catchment
- **native:** less than 15 percent of the catchment has urban land cover, less than 25 percent of the catchment has pastoral land cover, and native forest covers the largest proportion of the catchment.

Water quality for catchments in the urban, pastoral, and exotic forest land-cover classes is compared between classes, and to catchments in the native land-cover class (which are closer to natural conditions).

A very small proportion of catchments are assigned to an 'other' land-cover class, and are dominated by gorse, broom, surface mines, dumps, exotic shrubland, or transport infrastructure. This class has been excluded from water quality comparisons.

Water quality guidelines and thresholds

This report uses two main sets of guidelines and thresholds to assess the state of water quality.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) define default guideline values (DGVs) that correspond to the concentrations of the water quality variables that are estimated to occur in natural conditions. The DGVs describe environmental conditions expected in the absence of human influence and focus on ecosystem health. DGVs are not standards that have to be met. Rather, if a DGV is exceeded, this prompts further analysis and monitoring to find out if an aquatic ecosystem has enough protection. DGVs have been defined for river water quality and sedimentation in estuaries, but not for other aspects of water quality in groundwater, lakes, or estuaries.

The National Policy Statement for Freshwater Management (Freshwater NPS) (MfE, 2017a) defines minimum acceptable states for water quality based on ecosystem health and human health. Appendix 2 of the Freshwater NPS defines bands (ranges) for relevant attributes to support these values in rivers and lakes. These bands represent different states, with A being the best state and D or E the worst. This includes setting minimum acceptable states called national bottom lines that councils must meet, or work towards meeting over time. The national bottom line is the boundary between bands C and D.

Appendix 2 of the Freshwater NPS includes bands for the concentrations of *Escherichia coli (E. coli)* as an indicator of the risk of *Campylobacter* infection for people swimming in rivers and lakes, and bands for concentrations of phytoplankton, total nitrogen, total phosphorus, and periphyton (the natural growth on rocks and riverbeds) in relation to ecosystem health.

Note that the attribute bands are not directly comparable to the DGVs in the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZG, 2018).

MOST RIVERS IN URBAN AREAS ARE POLLUTED

Most of the rivers in catchments in the urban land-cover class are polluted with nutrients and suspended sediment, and many are polluted with pathogens and heavy metals. River reaches (or sections) in these catchments make up 1 percent of New Zealand's total river length.

Computer models estimated that for 2013–17, more than 99 percent of the total river length in catchments in the urban land-cover class exceeded one or more default guideline values (DGVs) for nutrients and turbidity (or cloudiness, a measure of suspended fine sediment). The models also estimated that *E. coli* levels (an indicator of pathogens) for 44 percent of the total river length in these catchments exceeded expected concentrations for natural conditions (McDowell et al, 2013) for the same period (see figure 5).

For river reaches in catchments in the urban land-cover class, the medians of the modelled nitrate-nitrogen and *E. coli* levels were twice as high as reaches in catchments in the pastoral land-cover class and 23 and 36 times higher respectively than reaches in catchments in the native land-cover class.

For river reaches in catchments in the urban land-cover class, the median levels of modelled dissolved reactive phosphorus and turbidity were 39 and 57 percent higher respectively than river reaches in catchments in the pastoral land-cover class, and four and three times higher respectively than river reaches in catchments in the native land-cover class. (See indicators: **River water quality: nitrogen**, **River water quality: phosphorus**, **River water quality: *Escherichia coli***, and **River water quality: clarity and turbidity**.)

Neither measured nor modelled data is available for heavy metals at a national scale, so monitored river water quality data for 2015–17 from sites in Auckland, Wellington, and Christchurch is presented here. Median concentrations of zinc exceeded DGVs at 73 percent of monitored river sites in Auckland, 60 percent of monitored sites in Wellington, and 33 percent of monitored sites in Christchurch. Concentrations of zinc are also likely to be higher at stream sites with greater proportions of urban land in their upstream catchments. For copper, median concentrations exceeded DGVs at 36 percent of monitored sites in Auckland, 20 percent of monitored sites in Wellington and at both monitored sites in Christchurch (see 'Waiwhetu Stream: the cost of pollution'. (See indicator: **River water quality: heavy metals**.)

MOST RIVERS IN FARMING AREAS ARE POLLUTED

Many studies at national, regional, and catchment scales show that the concentrations of nitrogen, phosphorus, sediment, and *E. coli* in rivers all increase as the area of farmland upstream increases (Larned et al, 2018).

Half of New Zealand's river length is in catchments in the pastoral land-cover class. The dominant land cover in these catchments is horticultural, arable cropping, and exotic grassland (including all dairy, beef, sheep, and other livestock pasture). Most of the rivers in these catchments are polluted with nutrients and suspended sediment, and many are polluted with pathogens. River water quality in farming areas varies by season – places with mostly pastoral land cover typically have higher nutrient concentrations and turbidity in winter than in summer (Whitehead et al, 2019).

Computer models for nutrients and turbidity estimated that 95 percent of the total river length in catchments in the pastoral land-cover class exceeded one or more DGVs for 2013–17. The models also estimated that *E. coli* levels for 24 percent of the total river length in these catchments exceeded expected concentrations for natural conditions for the same period (see figure 5).

For river reaches in catchments in the pastoral land-cover class, the medians of the modelled nitrate-nitrogen and *E. coli* levels were 11 and 18 times higher respectively than river reaches in catchments in the native land-cover class. The medians of the modelled dissolved reactive phosphorus and turbidity levels were also three and two times higher respectively than river reaches in catchments in the native land-cover class (see figure 5). (See indicators: **River water quality: clarity and turbidity**, **River water quality: *Escherichia coli***, **River water quality: nitrogen**, and **River water quality: phosphorus**.)

Waiwhetu Stream: the cost of pollution

Once crowned with the dubious honour of being the most toxic stream in New Zealand, Waiwhetu Stream was used as an industrial drain for decades. In 2006, its metre-deep layer of sludge contained DDT and *E. coli* and had levels of copper, zinc, and lead that exceeded environmental guidelines by as much as 90 times.

"The lead content was high enough to mine," says Te Rira Puketapu, Te Āti Awa elder at Waiwhetu Marae. He recalls how the stream changed colour during the course of a day as the local carpet factory released excess wool dye. "It could be bright yellow then turn blue or any other colour – I don't know how they got away with it."

Waiwhetu Stream begins in the Hutt Valley's eastern hills and passes through residential and industrial areas for 9 kilometres, ending in the Hutt River as it enters Wellington Harbour. It was originally part of a large wetland and river system on the valley floor.

The 1855 Wairarapa earthquake changed the course of the stream but it has also been extensively modified with sections straightened and weirs installed. Nearby land was reclaimed to accommodate growing industries in Seaview and Gracefield. These included a shipyard, railway workshops, and battery, electroplating, car, and biscuit factories.

Complaints about oil and chemical discharges from the railway workshops were common. Oil floating on its surface is said to have caught fire in the 1970s. (It was standard practice to wash out railway containers that had transported oil and chemicals without treating the wastewater.) The stream also flooded after heavy rain and stank – especially at low tide when the banks in the lower reaches were exposed.

But it wasn't always like that. Puketapu, now in his 80s, recalls spending time as a boy in the stream's deep swimming holes and pottering about in a tin boat.

"We would regularly catch eels there for the table. We were a family of 10 and after World War II, like many New Zealanders, we found it hard. Like my ancestors, we lived off the stream, eating native trout/kōkopu, freshwater crayfish, watercress, and mussels – and there was plenty. We used to catch whitebait by our marae too."

Cape pondweed (*Aponogeton distachyos*) was introduced to the stream about 100 years ago, but became a nuisance after it grew to cover the entire surface. It caused algal blooms in summer, trapped rubbish floating downstream, and made the water muddy. Because it also slowed water movement and contributed to flooding, Greater Wellington Regional Council controlled it by cutting and spraying with herbicide.

The spraying became unpopular with the local community and the weed kept growing back. "When the council applied for a resource consent to continue spraying for another 20 years, our people went to the Environment Court and got it stopped."

About this time a local care group formed, which later became the Friends of Waiwhetu Stream. The group lobbied to speed up work to improve the health of the stream and tackled many aspects of its restoration, including planting thousands of riverside plants. They manually dug out all 350,000 cape pondweed plants – a mammoth task that took four years and a team of committed community volunteers. Greater Wellington Regional Council and Hutt City Council assisted by disposing of the plants and rubbish.

Lower tidal section of the stream in 1975.

Photo: Alexander Turnbull Library

Waiwhetu Stream near Riverside Drive today showing well-established native planting.

Photo: Merilyn Merrett

Te Rira Puketapu helping with the cape pondweed removal.

Photo: Stuff Limited

After years in the planning, Greater Wellington led a project to address the flooding and toxic sediment in the lower reaches. This project began in 2010 and was funded by Greater Wellington, Hutt City Council, and the Ministry for the Environment to the tune of $26 million. About 4,000 truckloads of contaminated sludge was taken to landfill and the stream was widened and deepened.

"They put in a long concrete wall to contain the stream, apart from beside our urupā there. Our people were involved in case anything was dug out that indicated human remains, but that didn't happen. Getting rid of the greater part of the contamination has improved the health of the stream and probably the harbour as well."

Human waste continues to plague the stream, mainly from sewage discharges after heavy rain when the wastewater system is overloaded. Improvements have included pipe repairs and upgrades, as well as the installation of large holding tanks. Since more than half of Lower Hutt's stormwater ends up in the stream, the risk of it carrying contaminants and rubbish from roads, homes, and industrial areas is also high.

All these efforts have encouraged life back into Waiwhetu Stream and its so-named starry waters are beginning to sparkle once more. It is a popular place to walk and play, and murals and sculptures (including one carved from granite rollers that once crushed coconut at the biscuit factory) tell local history as part of an arts and sculpture trail along the stream. Surveys show that fish, eels, and kōura are present, and there have been community sightings of larger marine creatures in the estuarine areas.

"It's better, but it will never get back to how it was. We can't have our children swimming there. It's really a sad story." Puketapu also has fears for the future. "With climate change bringing more sunshine and hotter summers, the algae is getting worse, and for the first time in my life I've seen the upper reaches of the stream dry up completely."

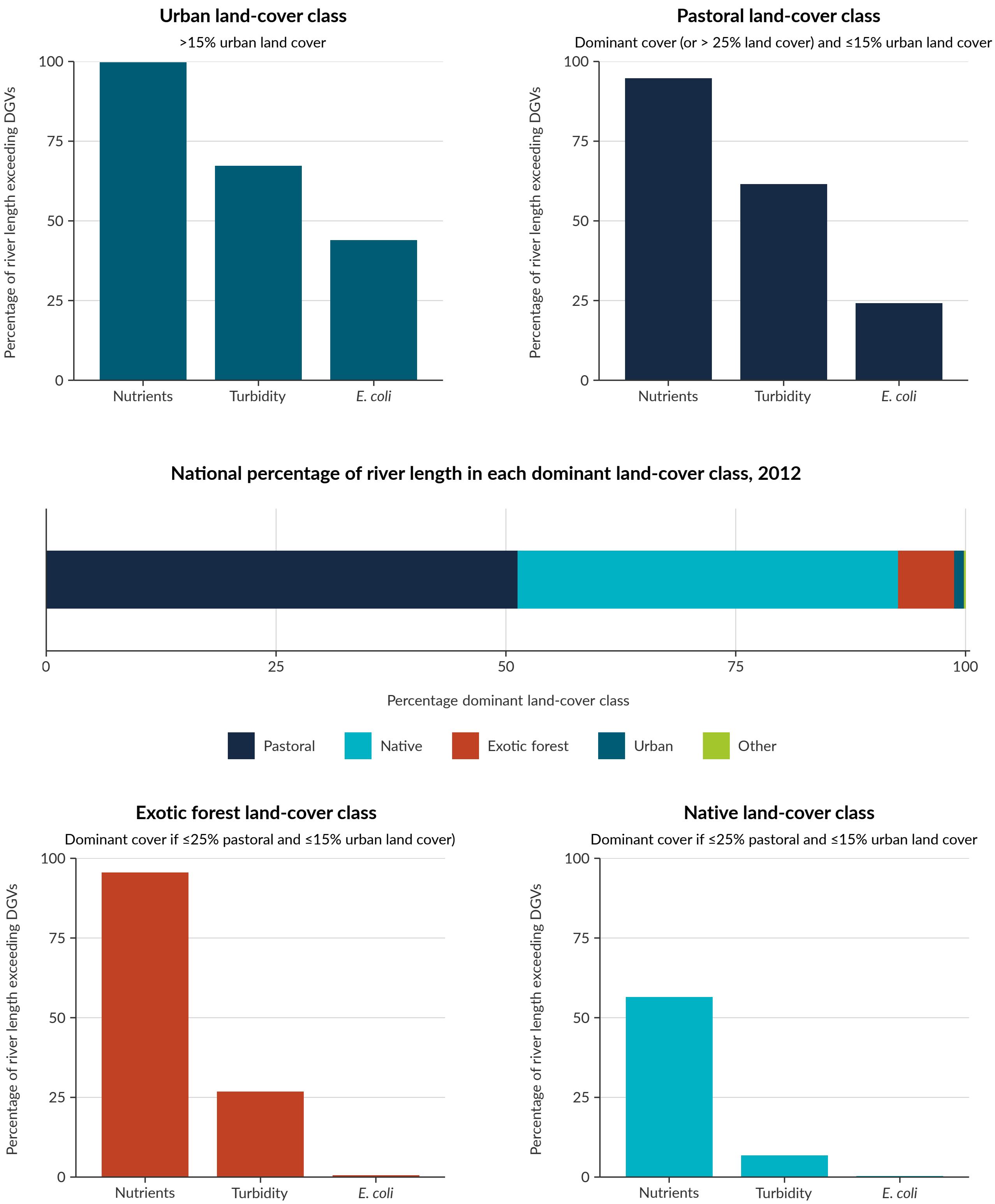
MOST RIVERS IN FORESTRY AREAS ARE POLLUTED

The water quality in catchments in the exotic forest land-cover class is generally better than in catchments in the urban and pastoral land-cover classes. However, most rivers in catchments in the exotic forest land-cover class are polluted with nutrients and many are polluted with suspended sediment.

Six percent of New Zealand's river length is in catchments in the exotic forest land-cover class. Computer models for nutrients estimate that 95 percent of the river length in these catchments exceeded one or more DGVs for 2013–17. The models also estimated that 27 percent of the total river length in these catchments exceeded the DGV for turbidity for the same period (see figure 5).

(See indicators: River water quality: nitrogen, River water quality: phosphorus, and River water quality: clarity and turbidity.)

Figure 5: Percentage of river length in each land-cover class that exceeds expected concentrations for expected natural conditions (DGVs) for *E. coli*, turbidity, and one or more nutrient (nitrogen, ammonia, and phosphorus), for 2013–17



Data source: NIWA

Note: ANZG (2018) does not include a DGV for *E.coli*, so the expected concentration for natural conditions is based on the guideline value determined by McDowell et al (2013). Because of the way a DGV is defined, under natural conditions it is expected that about 20 percent of river length will not meet the DGVs and about 5 percent of river length will not meet the *E. coli* guideline. The exceedance figures exclude 2 percent of New Zealand river length where the guidelines could not be applied. The 'other' land-cover class is made up of catchments dominated by gorse, broom, surface mines, dumps, exotic shrubland, or transport infrastructure.

RECENT CHANGES IN RIVER WATER QUALITY ARE MIXED

Overall river quality trends for nutrients (nitrate-nitrogen, ammoniacal nitrogen, and dissolved reactive phosphorus), *E. coli*, and turbidity are mixed. Improving water quality trends were found at slightly more monitoring sites than worsening trends in the 10 years from 2008 to 2017. The trends that can be determined for this period, by land-cover class include (see figure 6):

- **Urban land-cover class** – 72 percent of sites had improving trends for turbidity, 70 percent had improving trends for nitrate-nitrogen, 64 percent had improving trends for dissolved reactive phosphorous, and 55 percent had improving trends for ammoniacal nitrogen.
- **Pastoral land-cover class** – 67 percent of sites had improving trends for ammoniacal nitrogen.
- **Exotic forest land-cover class** – 62 percent of sites had improving trends for ammoniacal nitrogen and 57 percent had improving trends for *E. coli*; 50 percent of sites had worsening trends for dissolved reactive phosphorus.
- **Native land-cover class** – 59 percent of sites had improving trends for ammoniacal nitrogen.

Trends for different water pollutants varied across the country:

Nitrate-nitrogen:

- Many sites with worsening trends were in the central North Island, including parts of Waikato, Gisborne, Taranaki, and in the south-eastern South Island, including parts of Canterbury, Otago, and Southland.
- Many sites with improving trends were in Northland and Hawke’s Bay.

Dissolved reactive phosphorus:

- Sites with worsening trends were spread across much of the North Island.
- Sites in many parts of the South Island had improving trends.

E. coli:

- Many sites with worsening trends were in Manawatū-Whanganui, Hawke’s Bay, Taranaki, Wellington, Marlborough, Canterbury, and Southland.
- Sites in Gisborne, Waikato, and Northland had improving trends.

Turbidity:

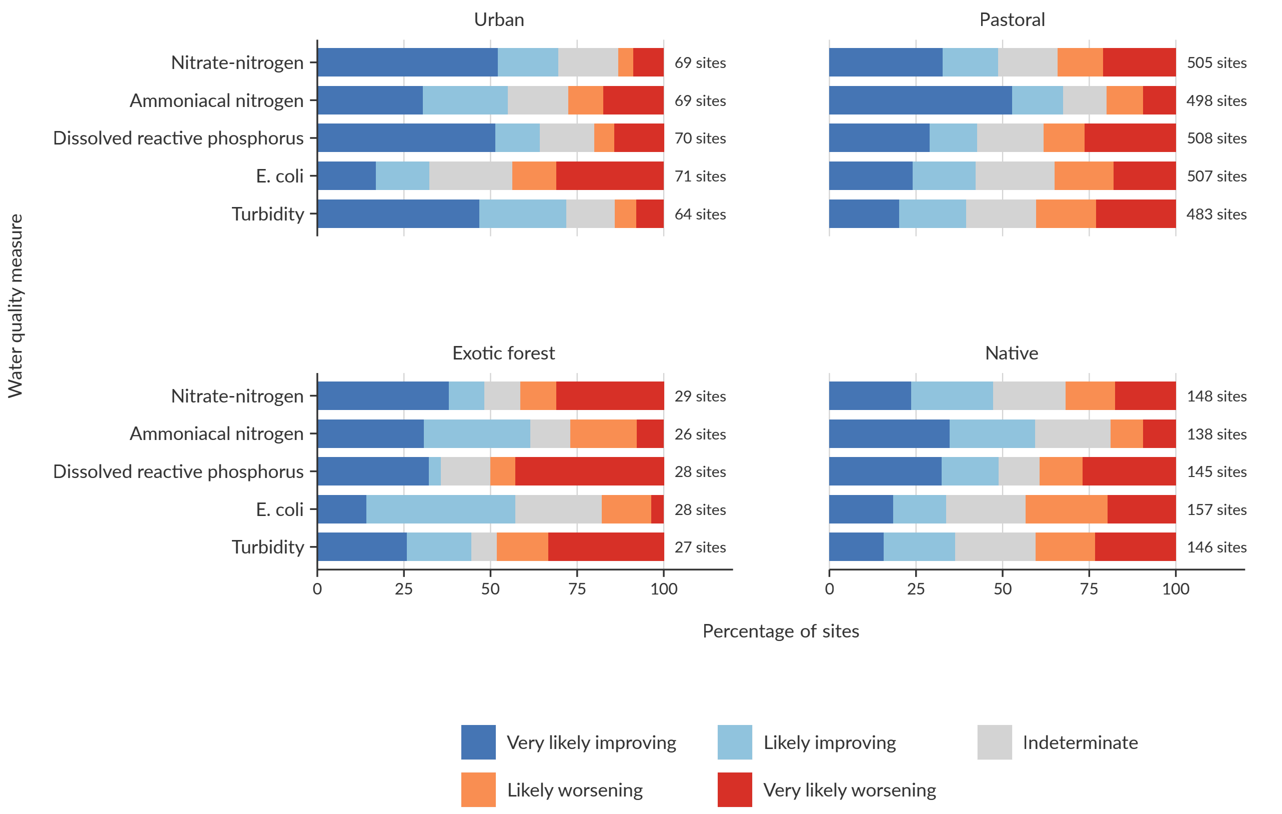
- Many sites with worsening trends were in Waikato, Gisborne, Manawatū-Whanganui, Canterbury, and the West Coast.
- Sites in Northland had improving trends.

(See indicators: River water quality: clarity and turbidity, River water quality: *Escherichia coli*, River water quality: nitrogen, and River water quality: phosphorus.)

Understanding the causes of these trends is difficult because of the complexity of freshwater systems. River catchments contain a range of interconnected water reservoirs (including groundwater), and water moves between them at different rates. This results in varying times before changes in water quality are apparent (lag times). Catchments also contain a mixture of land cover, land uses, and land management practices, which contribute to trends.

In addition, seasonal and longer-term variations in weather and climate can have a significant influence on water quality trends, particularly when these are measured over shorter periods of time. Variability is likely to increase as our climate changes but more research is needed to improve our understanding of how climate variability influences water quality trends (Snelder & Fraser, 2019).

Figure 6: Water quality trends for river monitoring sites by dominant land-cover in catchment, 2008–17



Data source: NIWA

Note: Excludes catchments in 'other' land cover, which are dominated by gorse, broom, surface mines, dumps, exotic shrubland, or transport infrastructure. Catchments in the native and exotic forest land-cover classes can contain up to 15 percent urban and up to 25 percent pastoral land cover. The number to the right of each bar shows the number of sites where a trend could be assessed.

MOST LAKES IN URBAN, FARMING, AND FORESTRY AREAS ARE POLLUTED

About half of New Zealand lakes larger than 1 hectare have upstream catchments in the urban, pastoral or exotic forest land-cover classes. Most of these lakes are polluted with nutrients. Catchments in the native land-cover class are mostly in protected areas like national parks.

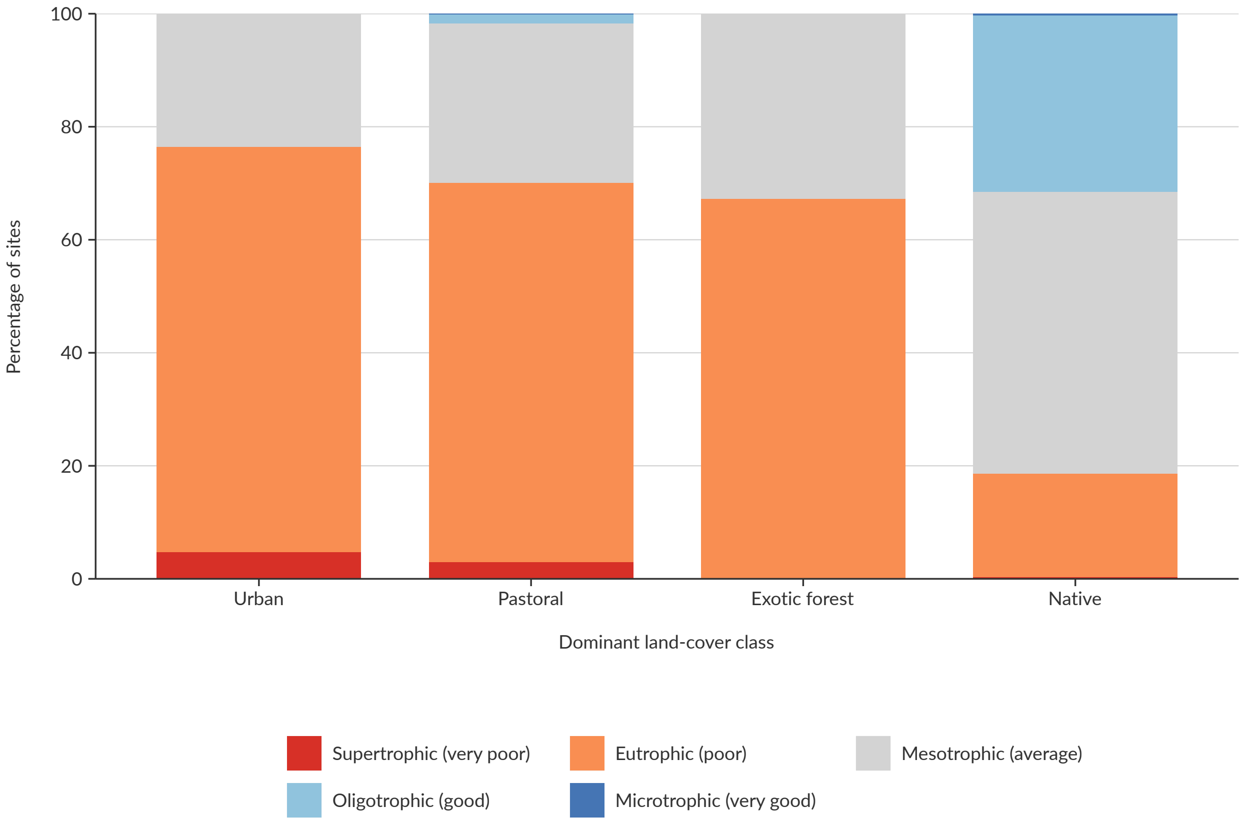
Since water quality is monitored in a very small proportion of our lakes, computer models are used to estimate water quality in 3,802 of the 3,820 lakes that are larger than 1 hectare (Schallenberg et al, 2013). The models estimate that total nitrogen concentrations in 28 percent of the lakes with upstream catchments in the pastoral land-cover class exceed the Freshwater NPS national bottom line – 47 percent of lakes larger than 1 hectare have upstream catchments in this land-cover class.

Lakes with upstream catchments in the urban land-cover class are available to the highest proportion of New Zealanders. For the 2 percent of lakes with upstream catchments in this land-cover class, models estimate that 44 percent exceed the national bottom line for total nitrogen concentration. Only 19 percent of lakes with upstream catchments in the exotic forest land-cover class and 8 percent of lakes with upstream catchments in the native land-cover class have modelled total nitrogen concentrations that exceed the national bottom line.

The models also estimate that 77, 70, and 67 percent of lakes with upstream catchments in the urban, pastoral, and exotic forest land-cover classes respectively are in poor or very poor ecological health, due to frequent algal blooms and murky water caused by high nutrient concentrations. By comparison, the models estimate that 19 percent of the lakes with upstream catchments in the native land-cover class (which can contain up to 15 percent urban and up to 25 percent pastoral land cover) are in poor or very poor ecological health (see figure 7, see The health of our freshwater ecosystems is variable). (See indicator: Modelled lake water quality.)

Trends in lake water quality (either nationally or specific to land-cover classes) cannot be reported due to insufficient monitoring data.

Figure 7: Modelled trophic level index ratings for lakes by dominant upstream land cover in catchment, 2013–17



Data source: LAWA

Note: Excludes lakes with upstream catchments in 'other' land-cover class, which are dominated by gorse, broom, surface mines, dumps, exotic shrubland, or transport infrastructure. Catchments in the native and exotic forest land-cover classes can contain up to 15 percent urban and 25 percent pastoral land cover. Also, for some lakes with upstream catchments in the native land-cover class, naturally nutrient-rich soils can be the cause of high nutrient concentrations and eutrophic (poor) or supertrophic (very poor) water quality conditions.

GROUNDWATER QUALITY IS MIXED BUT IS IMPROVING IN MANY PLACES

The quality of groundwater varies across New Zealand. For 2014–18, 44 percent of 424 monitored sites across the country had median nitrate-nitrogen concentrations that indicate that groundwater in these locations has been influenced by industrialised agriculture and is highly likely to have been impacted by human activity (Morgenstern & Daughney, 2012; Daughney & Reeves, 2005). The natural concentrations expected for other groundwater contaminants (like phosphorus or *E. coli*) have not yet been defined.

For nitrate-nitrogen, ammoniacal nitrogen, and dissolved reactive phosphorus, 49, 55, and 60 percent of sites respectively had improving trends and 38, 28, and 28 percent of sites respectively had worsening trends for 2009–18. For *E. coli*, 18 percent of sites had improving trends and 50 percent of sites had worsening trends for the same period.

Groundwater quality monitoring sites are not categorised according to land cover, so the specific effects of land use on groundwater quality cannot be estimated. (See indicator: Groundwater quality.)

FRESHWATER CONTAINS SOME EMERGING CONTAMINANTS BUT MOSTLY AT LOW CONCENTRATIONS

Emerging contaminants are being found more often in New Zealand but are not yet monitored routinely (Close & Humphries, 2019; Moreau et al, 2019; Stewart et al, 2016). In a national survey of 29 different emerging contaminants in groundwater, the plasticiser bisphenol-A, active ingredients of sunscreen, and sucralose (an artificial sweetener) were detected most often, but all were at low concentrations (Close & Humphries, 2019).

A survey of 723 emerging contaminants in groundwater at 51 sites in Waikato found at least one type of emerging contaminant at 91 percent of the sites. Pesticides, pharmaceuticals, industrial waste, and food additives were the most common (Moreau et al, 2019).

PFAS (per- and poly-fluoroalkyl substances) have been found at low concentrations in groundwater and streams below several sites where fire-fighting foam containing PFAS were used in the past (see 'Emerging contaminants' box) (Conway & Perwick, 2018; Walker & Callander, 2018).

Emerging contaminants

The term 'emerging contaminants' is used for non-natural chemicals in the environment when we know little about them or their effects on human health and the environment. More than 950 different compounds are classified as potential emerging contaminants and include pharmaceuticals, cleaning products, pesticides, animal and personal care product additives (like shampoo preservatives), and industrial compounds such as flame retardants (NORMAN Network, 2016). Some have been in the environment for a long time.

The New Zealand drinking water standards do not specify health limits for these compounds. Ecological guidelines are in place for a small range of emerging contaminants to manage their potential effects on ecosystems.

PFAS (per- and poly-fluoroalkyl substances) are a group of more than 3,000 compounds that have been used in homes and industries since the 1950s for food packaging, non-stick cookware, and in water-resistant products. PFAS can remain in the environment for many decades and accumulate in plants and animals. They are now common contaminants in soil and water and were identified as an environmental concern in the 1990s.

PESTICIDES HAVE BEEN DETECTED IN GROUNDWATER AT MANY SITES

Pesticides have been used in New Zealand for many decades over large areas of land (Manktelow et al, 2005; Chapman, 2010; Rolando et al, 2016). Many pesticides (which include insecticides, herbicides, and fungicides) stay in the environment for long periods and can enter waterways.

Nationwide, groundwater has been surveyed for pesticides every four years since 1990. The 2018 survey detected at least one type of pesticide in 24 percent of the wells tested but at levels that posed no significant risk to human health. Herbicides were found most often, with 17 different compounds detected (Close & Humphries, 2019).

A 2017–18 survey of 36 agricultural streams found several pesticides at most sites, but no comprehensive survey of pesticides in our rivers and lakes has been undertaken (Hageman et al, 2019).

What has contributed to this issue?

WASTEWATER AND STORMWATER INFRASTRUCTURE

Wastewater, which includes sewage, comes from drains in houses, businesses, and industrial processes and must be treated before it can be released into freshwater. Most wastewater is treated by the 321 publicly-owned wastewater treatment plants in New Zealand (DIA, 2018). Almost half (47 percent) of wastewater treatment plants discharge treated wastewater to rivers and lakes, while the remainder discharge it into the sea or onto land.

Septic tanks are used to partially treat domestic wastewater in many suburbs and towns. They discharge partially treated wastewater underground where it can reach shallow lakes, rivers, or groundwater (see figure 8).

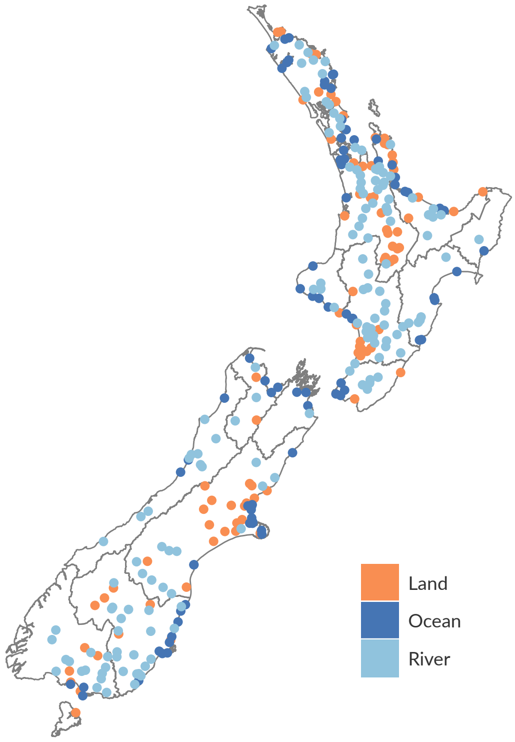
Wastewater treatment is not standardised across New Zealand and the performance of septic tanks is variable, so the quality of treated water is likely to vary. Also, not all contaminants are removed by treatment. Treated wastewater may contain pollutants (like medicines and microplastics) that contaminate land, waterways, and groundwater when it is released (see figure 8) (Petrie et al, 2015; Blair et al, 2017; OECD, 2019).

Stormwater is rainwater that comes off solid surfaces like roofs, roads, and asphalt and is piped into waterways or the sea. It is almost always collected separately from wastewater and is not generally treated. Stormwater can pick up pollutants and carry these into freshwater, and is likely to transport more pollutants if more of the land in a catchment is covered by solid surfaces. Heavy metals are one example that come from vehicles (copper from brake pads and zinc from tyres), metal roofing, and industrial yards (Gluckman et al, 2017; Kennedy & Sutherland, 2008). Stormwater can also be polluted with nutrients from fertilisers used commercially and in home gardens (*Environment Aotearoa 2019*), as well as hydrocarbons from exhausts, leaking vehicles, and industrial yards (Kennedy et al, 2016).

Nationally, a quarter of our water, wastewater, and stormwater infrastructure is more than 50 years old, with 10–20 percent of the network estimated to require significant renewal or replacement (LGNZ, 2014). Older treatment infrastructure may be less effective, and older pipes are more likely to be damaged and leak untreated wastewater onto land or into freshwater and groundwater.

Overwhelmed or blocked wastewater networks and septic tanks can back up and overflow. This allows untreated wastewater to flow onto the ground, into the stormwater network, then into waterways. Cross connections between waste and stormwater systems also contribute to freshwater pollution.

Figure 8: Wastewater treatment plant discharge locations, 2018



Data source: Department of Internal Affairs

CLEARING AND CONVERTING LAND, AND DRAINING WETLANDS

Establishing cities, towns, and farms in New Zealand involved clearing native forests and scrub, and draining wetlands. These large-scale changes dramatically affected how our soils and water function. Removing or replacing native forest, scrub, and wetlands with pasture or solid surfaces results in higher run-off volumes and flows. Dense vegetation and wetlands slow water down so it can soak into the ground and be absorbed by plants – this helps to prevent flooding and to capture sediment and other contaminants before they reach rivers and lakes (Tomscha et al, 2019; Mackay, 2008).

With less native land cover in their catchments, streams in urban and pastoral areas receive more sediment from run-off, particularly when vegetation beside rivers and streams has been removed. Run-off from pasture may also be a risk when grazing animals compact the soil or damage stream banks, channels, and riparian areas (McDowell et al, 2003).

Farm animals are a source of freshwater pollutants (dissolved nitrogen, phosphorus, and pathogens). Fertiliser and animal dung and urine are important sources of phosphorus (Selbie et al, 2013). A 2012 study showed that the high concentration of urine in spots on pastures was a major source of dissolved nitrogen (Parfitt et al, 2012). Another 2012 study showed that livestock dung also made a major contribution to the faecal contamination of waterways in the farming areas studied (Cornelison et al, 2012).

FELLING AND REPLANTING FORESTS

Once they are established, plantation forests stabilise the soil and reduce erosion, particularly on steep land. When the trees are being cut down and replanted, however, forestry can cause sediment and nutrients to enter waterways (Julian et al, 2017). Clear felling (the method used to harvest forests in New Zealand) exposes and disturbs soil, including from the construction of roads used for vehicle access during harvesting. This increases erosion and the sediment in rivers and lakes (*Environment Aotearoa 2019*).

Clear felling in some Nelson catchments caused a five-fold increase in the rate of soil loss to nearby waterways. In a Hawke's Bay catchment, an eight-fold increase has been documented. The higher rates of soil loss typically returned to pre-harvest levels or declined markedly within 2–3 years of harvest (Basher et al, 2011; Baillie & Neary, 2015; Fahey & Marden, 2006).

The concentrations of nitrogen and phosphorus in nearby waterways can also increase during harvesting and when fertiliser is applied during replanting (Julian et al, 2017).

WHAT WE FARM HAS CHANGED

From 1994 to 2017, the number of dairy cattle in New Zealand increased by 70 percent (from 3.8 million to 6.5 million). During the same period, the number of sheep decreased by 44 percent from 49.5 million to 27.5 million, and the number of beef cattle decreased by 28 percent from 5 million to 3.6 million. The increase in dairy cattle has been most pronounced in the South Island (see figure 9), notably in Canterbury, Otago, and Southland.

The area of land used for dairy farming has also increased. In 2016, 2.6 million hectares was used for dairy production (a 42 percent increase from 2002), while the area used for sheep and beef farming was 8.5 million hectares (a 20 percent drop in the same time). (See indicator: Agricultural and horticultural land use.)

This shift from sheep and beef farming to dairy farming is associated with increased leaching of nitrogen from agricultural soils. Leaching occurs when the concentration of nitrogen in the soil (from animal urine and fertiliser) is greater than the amount that soil and plants can absorb.

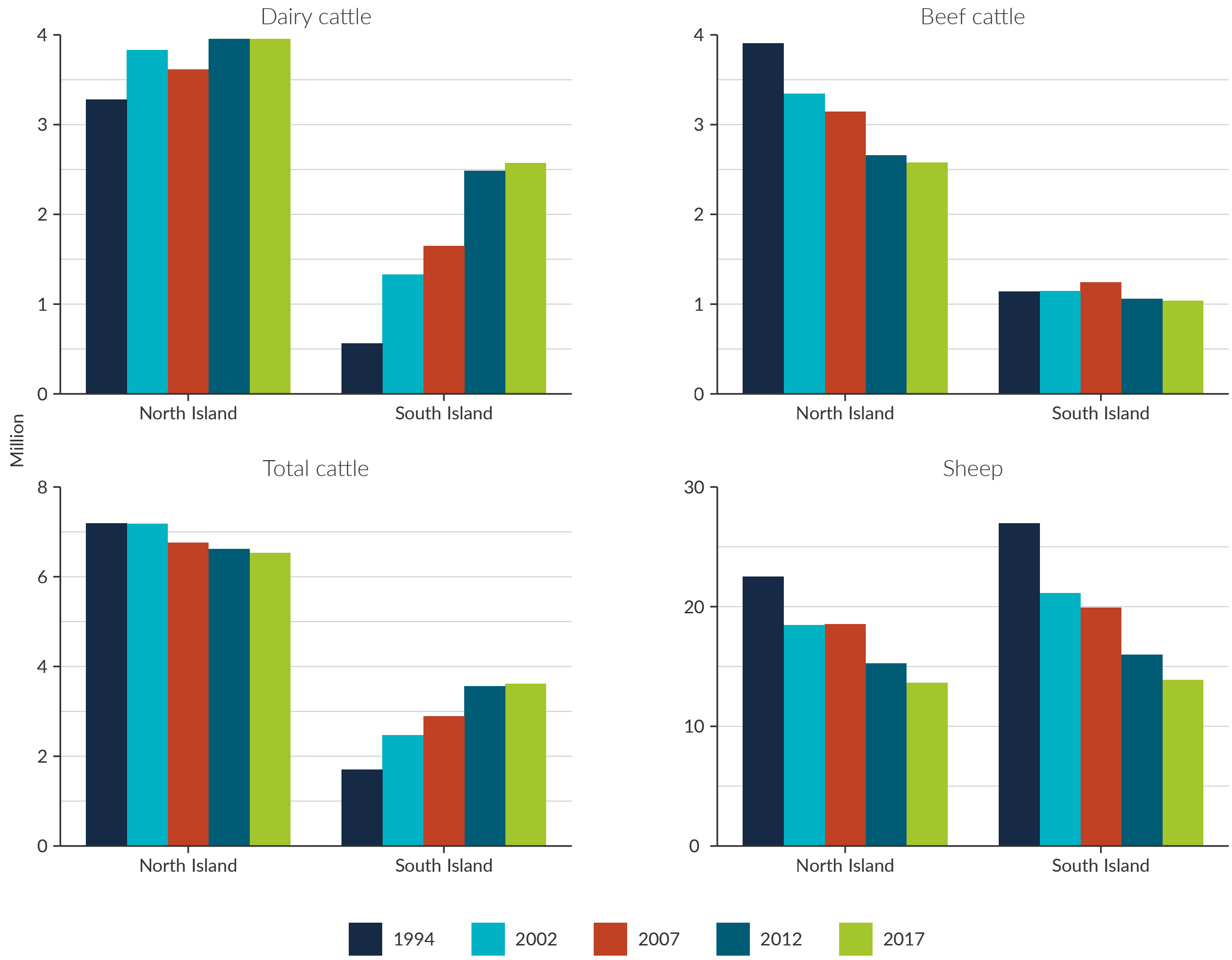
Models of the total amount of nitrate-nitrogen leached from livestock show an increase nationwide from 189,000 tonnes per year in 1990 to about 200,000 tonnes per year in 2017. The amount of leaching in specific places has also changed as a result of shifts in the number and type of livestock. According to the model, the highest nitrate-nitrogen leaching from livestock in 2017 occurred in Waikato, Manawatū-Whanganui, Taranaki, and Canterbury (see figure 10).

The model also shows that dairy cattle make a proportionally higher contribution to nitrogen leached from agricultural soils than other types of livestock. Cattle excrete more nitrogen per animal than sheep (as cows produce more urine, which has a higher nitrogen concentration), so nitrogen from cattle is more likely to leach through soil than nitrogen from sheep (MfE, 2018a; Pacheco et al, 2018).

Nationally in 1990, 39 percent of modelled nitrate-nitrogen leaching came from dairy cattle, 26 percent from beef cattle, and 34 percent from sheep. By 2017, dairy cattle contributed 65 percent of the modelled leached nitrate-nitrogen, with 19 percent from beef cattle, and 15 percent from sheep. (See indicator: Nitrate leaching from livestock.)

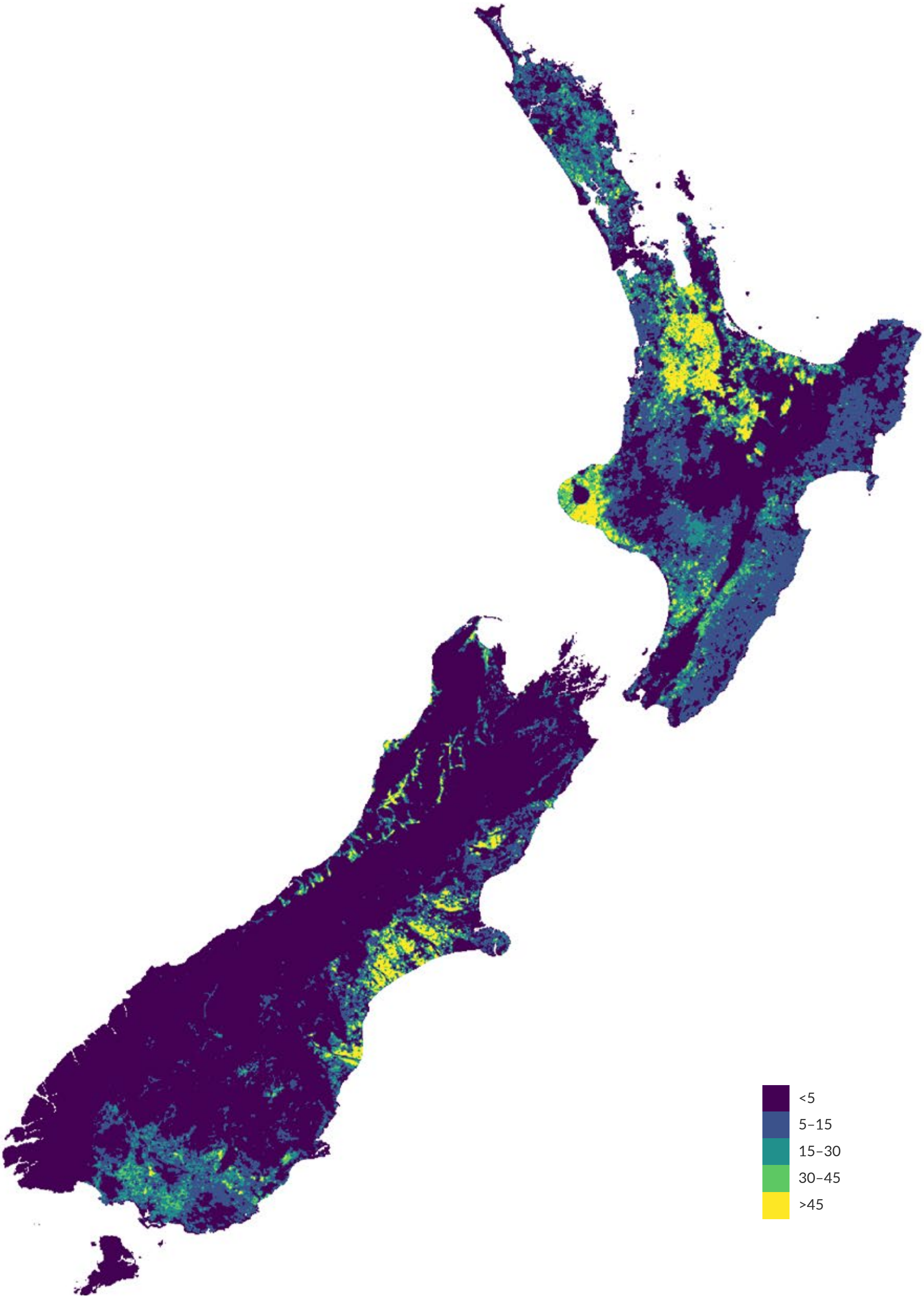
A 2005 study estimated that nationally, 37 percent of the nitrogen load entering the sea came from dairy farming despite dairy farming occurring on less than 7 percent of our land at that time (Elliot et al, 2005).

Figure 9: Livestock numbers in the North and South islands, 1994–2017



Data source: Stats NZ

Figure 10: Modelled nitrate-nitrogen leached from livestock, 2017 (kgN/ha)



Data source: Manaaki Whenua – Landcare Research

FARMING HAS INTENSIFIED

The number of cattle per hectare increased in some parts of the country between 1994 and 2017. (See indicator: Livestock numbers.) More animals per paddock can increase the amount of nitrogen released into the environment (Julian et al, 2017). When animals are closer together, urine patches are more frequent and overlap, and a greater likelihood that the absorption of nitrogen by soil and plants will be overloaded (Ledgard, 2013).

High animal stocking rates can compact the ground, particularly when the soil is wet (Drewry et al, 2008). Compaction closes up the small air spaces in the soil and reduces the drainage and leaching of nitrogen from the soil. Nitrogen on the surface of the soil can contribute to greenhouse gas emissions (as nitrous oxide) more easily (van der Weerden et al, 2017) or be washed directly into waterways.

Also, the use of nitrogen fertiliser has increased. The amount of nitrogen applied in fertiliser has increased more than six-fold since 1990, from 59,000 tonnes in 1990 to 429,000 tonnes in 2015. The amount of phosphorus applied as fertiliser peaked at 219,000 tonnes per year in 2005 but has reduced to about 150,000 tonnes per year in the last decade (155,000 tonnes in 2015). (See indicator: Fertilisers – nitrogen and phosphorus.)

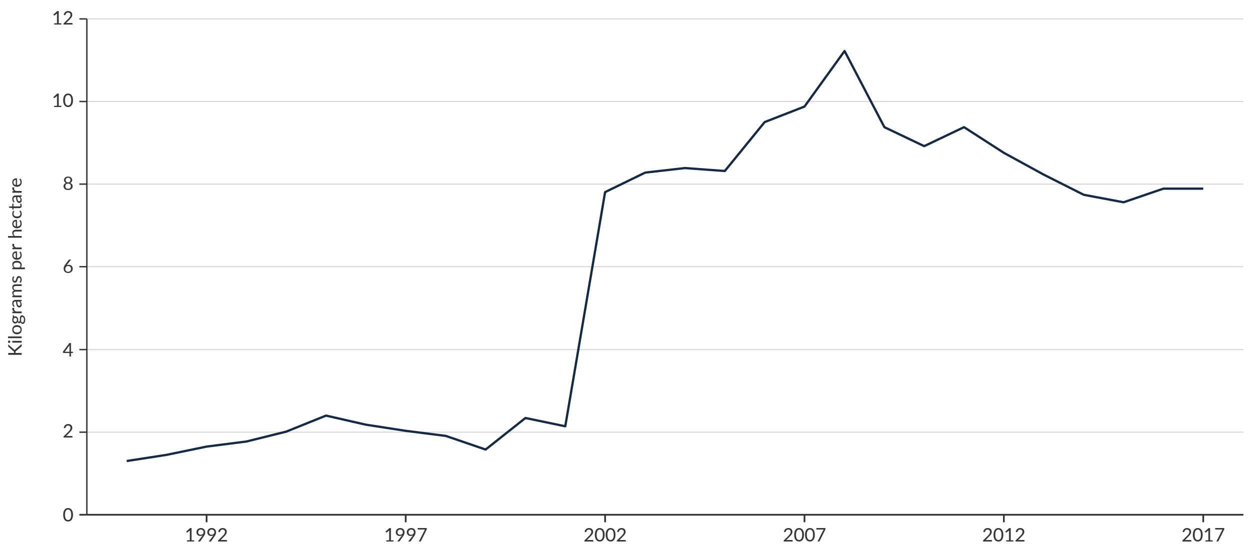
USE OF PESTICIDES

Pesticides have been used to control unwanted organisms in agricultural, forestry, conservation areas, and in our homes and gardens for many years. In 2005, the farming and forestry sectors used the most herbicides and the horticultural sector used the most fungicides and insecticides as measured by volume (Manktelow et al, 2005).

From 1990 (when data on the quantity of pesticide imports was first available) to 2009, our annual imports of pesticides, herbicides, and fungicides for agricultural use increased by nearly 70 percent. During the same period, the total annual application of pesticides per unit area of agricultural land increased from 1.3 to 9.4 kilogrammes per hectare. From 2009 to 2017 pesticide imports remained stable and were applied at 7.6–9.4 kilogrammes per hectare annually (FAO, nd, see figure 11).

The negative environmental effects of pesticides are relatively well known (Champeau & Tremblay, 2013), and such a large increase in the use of pesticides for agriculture is likely to have led to more of these chemicals reaching the freshwater environment. However, no data confirms this. Although pesticide use has increased, there has been a shift to the use of less toxic chemicals and more responsible application practices, particularly in the horticultural sector (Mankelow et al, 2005).

Figure 11: Agricultural use of pesticides in New Zealand, 1990–2017



Source: FAO

What are the consequences of this issue?

NUTRIENTS CAN DESTROY FRESHWATER HABITATS AND HARM FRESHWATER SPECIES

As their concentrations increase, nutrients begin to affect whole ecosystems. Nutrients cause harmful algal blooms that deplete the water's dissolved oxygen. Dissolved oxygen is essential for healthy ecosystems and fish need it to breathe. Some fish, particularly the young of species like īnanga, rainbow trout, common smelt, and common bullies are more sensitive to low levels of dissolved oxygen than others (Franklin, 2014; Landman et al, 2005). Īnanga are not good at detecting and avoiding water that contains ammonia at levels that could be toxic to them (Richardson et al, 2001).

At very high concentrations, nitrate-nitrogen and ammonia become toxic to freshwater species. Such conditions would rarely pose a risk because high nutrient levels would normally have already made the ecosystem unliveable for species through algal blooms and depleted oxygen.

Modelled concentrations of nitrate-nitrogen and ammonia in most rivers in catchments in the urban and pastoral land-cover classes are high enough to present a toxicity risk to freshwater species (if any were present) based on the National Objectives Framework bands for ecosystem health. (See indicator: River water quality: nitrogen.)

The risk of toxicity from nitrate-nitrogen and ammonia in groundwater ecosystems cannot be accurately assessed because the effects of excess nutrients are not well known in those systems, but it is assumed they would have a similar risk to surface water ecosystems (such as rivers and lakes) (Fenwick et al, 2018).

Safe to swim?

Regional councils monitor popular swimming sites, including rivers, lakes, and coastal areas to assess the health risk of swimming at that site (see LAWA website). Faecal contamination from humans and animals is the main reason that swimming can become unsafe.

To manage the different health risks of faecal contamination from various sources, several regional councils have begun tracking and analysing the contamination using DNA and other methods to find its source. Results from Northland Regional Council, Gisborne District Council, and Christchurch City Council showed that it came from geese, swans, seagulls, dogs, cows, and sheep, as well as humans (Gilpin et al, 2011; Reed, 2011; Moriarty & Gilpin, 2009).

See Towards a better understanding of our environment.

MORE FREQUENT AND INTENSE ALGAL BLOOMS DEGRADE ECOSYSTEMS AND HAVE HEALTH RISKS

Communities of algae and cyanobacteria (photosynthesising bacteria) occur naturally in rivers and lakes. Algal and cyanobacterial blooms occur when the environmental conditions change and allow these microorganisms to reproduce rapidly. High concentrations of nitrogen and phosphorus, along with warmer temperatures, promote their growth so they proliferate into a bloom. Based on models of nutrient concentrations, most rivers and lakes with catchments in the urban, pastoral, and exotic forest land-cover classes have a higher risk of algal blooms.

Algal blooms degrade the recreational and cultural uses of waterways. They reduce the water quality for swimming and other activities, the number of fish (including trout and salmon), and opportunities for mahinga kai (food gathering) (see Poor water quality reduces cultural use, beliefs, and practices). Some cyanobacteria produce toxins that can be harmful to ecosystems and contaminate water for drinking and swimming. Dogs are particularly susceptible because they are attracted to the odour of some cyanobacteria. More than 70 dog deaths have been reported since 2006 across New Zealand as a result of consuming cyanobacteria from rivers (*Our fresh water 2017*).

POLLUTION CAN HAVE HEALTH RISKS

A number of pollutants have human health risks when consumed in drinking water or food from polluted water, or from exposure while swimming.

Seven main waterborne illnesses are notifiable in New Zealand: campylobacteriosis, salmonellosis, shigellosis, yersiniosis, *E. coli* infection, giardiasis, and cryptosporidiosis (Ball, 2007; Ministry of Health, 2020). In 2017, there were 427 notifiable illness cases of campylobacteriosis, 250 of giardiasis, 219 of cryptosporidiosis, 135 of salmonellosis, and 88 of *E.coli* infection for cases where people reported contact with recreational water (river, lake, or sea). About 100 cases of two other notifiable waterborne diseases were also reported (ESR, 2019).

The presence of *E. coli* above a certain limit is used to indicate the health risk from the pathogen *Campylobacter* in rivers and lakes. Computer models estimate the average *Campylobacter* infection risk from swimming in any New Zealand river (Whitehead, 2018). For 2013–17, 94 percent of the river length in catchments in the urban land-cover class, 76 percent of the river length in catchments in the pastoral land-cover class, and 27 percent of the river length in catchments in the exotic forest land-cover class was not suitable for activities such as swimming. (This estimation is based on a predicted average *Campylobacter* infection risk of greater than 3 percent, National Objectives Framework bands D and E respectively – the two highest risk categories). Only 5 percent of the river length in catchments in the native land-cover class exceeded the same threshold.

Heavy metals and other pollutants in the freshwater environment (including pesticides) can accumulate in food sources like fish and shellfish, and making them unsafe to eat. Data from monitored sites indicates that this is a low risk for most New Zealanders. However, some Māori communities may be exposed to a higher risk than average because more eels and other wild-caught freshwater species are included in their diets. A 2011 risk assessment showed that contaminants in eels, trout, and flounder may lead to a higher risk of cancer and other chronic health issues for members of Arowhenua in South Canterbury (Stewart et al, 2011).

If freshwater pollution is high enough to risk contaminating wild-caught species, the local council will caution people to limit or stop eating certain species for health reasons. For Māori communities, these limits can restrict mahinga kai.

Most of New Zealand's drinking water comes from rivers and underground aquifers, and is tested and treated by local authorities (district or city councils) to ensure it is safe. Many households and communities source their own drinking water from nearby rivers, lakes, and aquifers (via wells), and are responsible for its safety. If these sources are contaminated and the water is not properly treated, it can make people ill.

Many aquifers across New Zealand are periodically tested for water quality, using groundwater wells. Information is not available about which groundwater wells are used for drinking water and whether treatment is in place to remove pathogens and nitrate-nitrogen from well water.

Monitoring untreated water in aquifers for 2014–18 found that 68 percent of 364 sites failed to meet the drinking water standard for *E. coli* on at least one occasion. This indicates a potential risk of illness if untreated water is consumed. The drinking water standard of 11.3 grams per cubic metre of nitrate-nitrogen was also exceeded on at least one occasion at 19 percent of 433 sites tested. At these concentrations, nitrate-nitrogen has a potential risk of causing methaemoglobinaemia (blue baby syndrome) in bottle-fed infants.

The concentrations of pesticides in lakes and rivers are not measured routinely. Groundwater monitoring shows that the concentrations of pesticides in monitored aquifers currently pose a low health risk (Close & Humphries, 2019).

Many emerging contaminants that can be found in freshwater are suspected or known to present risks to human health, but are not commonly monitored in New Zealand. One example is PFAS – the extent of contamination and safe concentrations have not been fully established (see 'Managing the risks of PFAS contamination' box).

Managing the risks of PFAS contamination

In 2018, several environmental investigations were undertaken at airfields and fire training sites where firefighting foams (used on high temperature fuel fires) have been sprayed onto the ground during incidents and exercises for decades. Many of these foams used to contain per- and poly-fluoroalkyl substances (PFAS). PFAS was identified as an emerging contaminant in the early 2000s, and the import, manufacture, and use of PFAS was banned in 2011.

The investigations found low concentrations of PFAS in groundwater, streams, and freshwater species near some sites (Walker & Callander, 2018; Shaw & King-Hudson, 2019). Because safe concentrations of PFAS in drinking water and food had not been confirmed at the time of the investigations, local councils took a precautionary approach to protect people in the affected areas.

Several town-supply and private water bores in Marlborough tested above the interim health guidelines for PFAS in drinking water that were recommended at the time of the investigation. The use of these bores was discontinued and water from other sources was used.

PFAS were detected in eels in the Oaonui Stream in Taranaki, which raised concerns that the eels were not safe to eat. Based on the best available advice, South Taranaki District Council erected warning signs at the stream mouth advising people not to eat fish or eels from the stream until the human health risks could be fully investigated.

POOR WATER QUALITY REDUCES CULTURAL USE, BELIEFS, AND PRACTICES

Changes in water quality can significantly affect the mauri (life force), mana, and wairua (spirituality) of waterways (Morgan, 2006). The health and capacity of our waterways to provide, is a significant part of expressing ahikāroa (connection with place) and kaitiakitanga (guardianship).

Customary practices associated with mahinga kai contribute significantly to manaakitanga (acts of giving and caring for), whanaungatanga (community relationships and networks), te ahurea o te reo (growth and evolution of language), and whakaheke kōrero (opportunities for intergenerational knowledge transfer) (Harmsworth & Awatere, 2013; Lyver et al, 2017a; Timoti et al, 2017).

Some iwi and hapū monitor freshwater using cultural indicators to record changes. Although healthy rivers have natural growth (periphyton) on the rocks of a riverbed, too much can reduce the diversity and number of invertebrates and fish, and make swimming and fishing unpleasant (Biggs & Kilroy, 2000). How the bottom of a swimming hole feels on your feet is an indicator based on waipara (the sediment and periphyton in a waterway) used by some whānau to test swimmability (Coffin, 2018; Tipa & Teirney, 2006). Other characteristics of a place like the sound, smell, and clarity of water are also used as indicators of cultural health.

Our fresh water 2017 used a cultural health index (CHI) to assess water quality for sites at 25 rivers and five lakes in New Zealand. (See indicator: Cultural health index for freshwater bodies.) It was made up of three elements:

1. site status (the association that tangata whenua have with the site and whether they would return)
2. mahinga kai status (range and quantity of species present)
3. cultural stream health status (water quality and land use).

For the 41 sites where a CHI was assessed between 2005 and 2016, 11 sites had very good or good scores, 21 sites had moderate scores, and 9 sites had poor or very poor scores. (This indicator has not been updated for this report.)

ESTUARY AND COASTAL ENVIRONMENTS MAY BE AFFECTED

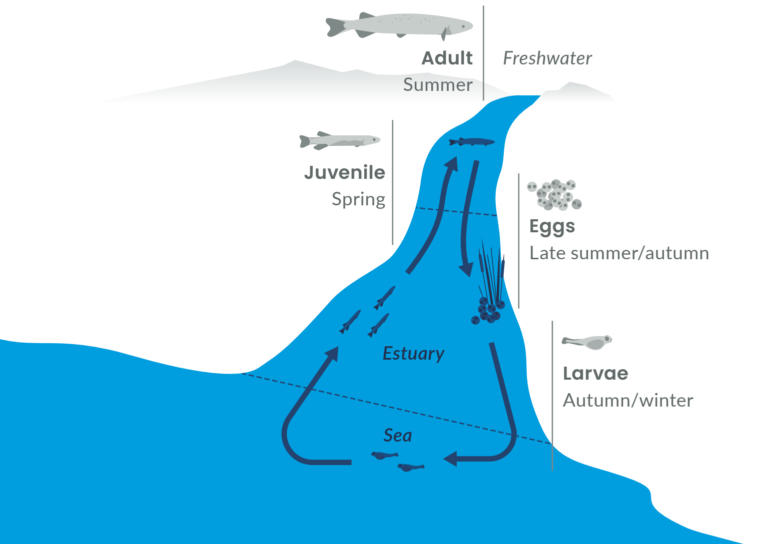
The quality of water around our coasts is directly affected by the polluting nutrients, pathogens, and sediment that rivers carry downstream (Dudley et al, 2017). Monitoring data for 2013–17 showed that high nitrogen concentrations and high levels of faecal bacteria were present at coastal monitoring sites that received large amounts of water from rivers, particularly shallow estuaries. Deep estuaries have the best water quality because seawater moves freely in and out, so freshwater that enters them is well diluted by seawater. Coastal areas near many of our biggest rivers are not monitored so the scale of effects on coastal waters is not known. (See indicator: Coastal and estuarine water quality.)

Heavy metals primarily reach estuaries via urban streams, apart from the exception of cadmium, which can also come from farming areas. Data at most monitoring sites in 13 regions for 2015–18 showed the concentration of heavy metals in estuarine and coastal sediment was below the levels expected to affect bottom-dwelling species. The proportion of nutrients, pathogens, and sediment delivered from urban areas (as opposed to pastoral, exotic forest, or native areas) to estuaries and the coast is not known. (See indicator: Heavy metal load in coastal and estuarine sediment.)

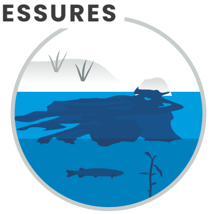
How our activities on land affect īnanga

Īnanga tolerate some water pollution but activities like urban development, farming, and forestry can affect them.

ĪNANGA LIFE CYCLE



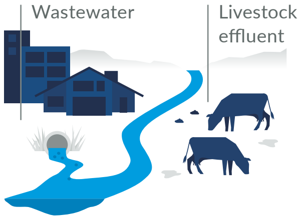
PRESSURES



Low dissolved oxygen

Īnanga are sensitive to water with lower levels of dissolved oxygen caused by nutrients like nitrogen.

Life stages affected



Increased ammonia

Adult īnanga aren't good at detecting and avoiding water that contains ammonia at levels that could be toxic to them.

Life stage affected

Where are the gaps in our knowledge about this issue?

EMERGING CONTAMINANTS AND MICROPLASTICS IN THE ENVIRONMENT

The behaviour and toxicity of a range of chemicals, industrial pollutants, and by-products from our activities are not fully understood. Time-series data that is long enough and high enough resolution to help build this knowledge is rarely available for emerging contaminants and microplastics.

New research programmes are beginning to collect data for emerging contaminants in our waterways, but their extent and potential effect on ecosystems are generally not known (Close & Humphries, 2019; Bernot et al, 2019; Stewart et al, 2016). The risk these contaminants pose to human health cannot be fully assessed without knowing if (or at what concentrations) they are present in drinking water or wild food.

SOURCES OF POLLUTANTS

Catchments can contain a mix of land-cover types and land uses. Each land use can generate pollution that can affect water quality in different ways. Pollution can come from one place and a single activity, like a pipe, drain, or culvert. It can also originate from a range of activities across a wide area, and therefore be harder to trace to a particular source.

Our overall understanding of the causes, effects, and cumulative impacts of pollution is improving but is still limited. Particularly in urban catchments, the complexity of human activities and potential sources, including emerging contaminants, are barriers to better understanding.

Water quality trends are also poorly understood. Some trends may be caused by variations in climate or other natural processes that are currently not accounted for, so the contribution of human activities is difficult to determine. At some locations, it may be challenging to isolate the input of nutrients from their source, for example, from farming or treated wastewater.

EFFECT OF OUR ACTIVITIES AND MANAGEMENT PRACTICES

In the urban environment, wastewater and stormwater networks are complex, and parts can fail for a variety of reasons. We know such failures can contribute to poor water quality, but the scale of these contributions is not known as no comprehensive investigations of the effects of these failures on the environment have been undertaken.

In the rural environment, data clearly shows that water quality in pastoral farming areas is degraded across New Zealand. At a local scale, we lack sufficient information about exactly where, when, and what activities and management practices (like tilling soil, stock density, fertiliser use, and managing stock effluent and access to waterways) have contributed to or reduced water pollution in farming areas (McDowell et al, 2019). Having no national-scale database or map of farm management practices is one cause of the information gap.

In places with long lag times, today's water quality may be the result of past management practices rather than what we are doing now. More information is also needed about the flow and natural absorption of pollutants as they move through catchments. This includes variations between catchments, including their geology and soils, climate, and ecosystems, as well as where and how groundwater and surface waters (lakes and waterways) interact.

Because of these large knowledge gaps, it is difficult to assess the full impacts of land management practices on water quality, or measure improvements in water quality from actions like planting beside waterways.

HOW CHANGES IN WATER QUALITY AFFECT THE THINGS WE VALUE

We don't yet know how changes in water quality affect the overall health of ecosystems. A framework to describe ecosystem health more holistically has been developed (Clapcott et al, 2018) but choosing the parameters to evaluate it is still underway (see Towards a better understanding of our environment).

National datasets are lacking for some of the variables relevant to ecosystem health (like deposited sediment, physical habitat, continuous dissolved oxygen, and algal biomass). Biodiversity and native fish populations, including taonga species, also have insufficient information (*Our fresh water 2017*). Very little is known about the freshwater ecosystems that require a connection to groundwater to function. Also, the interacting and cumulative effects of water pollution and other pressures on ecosystem health are not well understood (Larned et al, 2018).

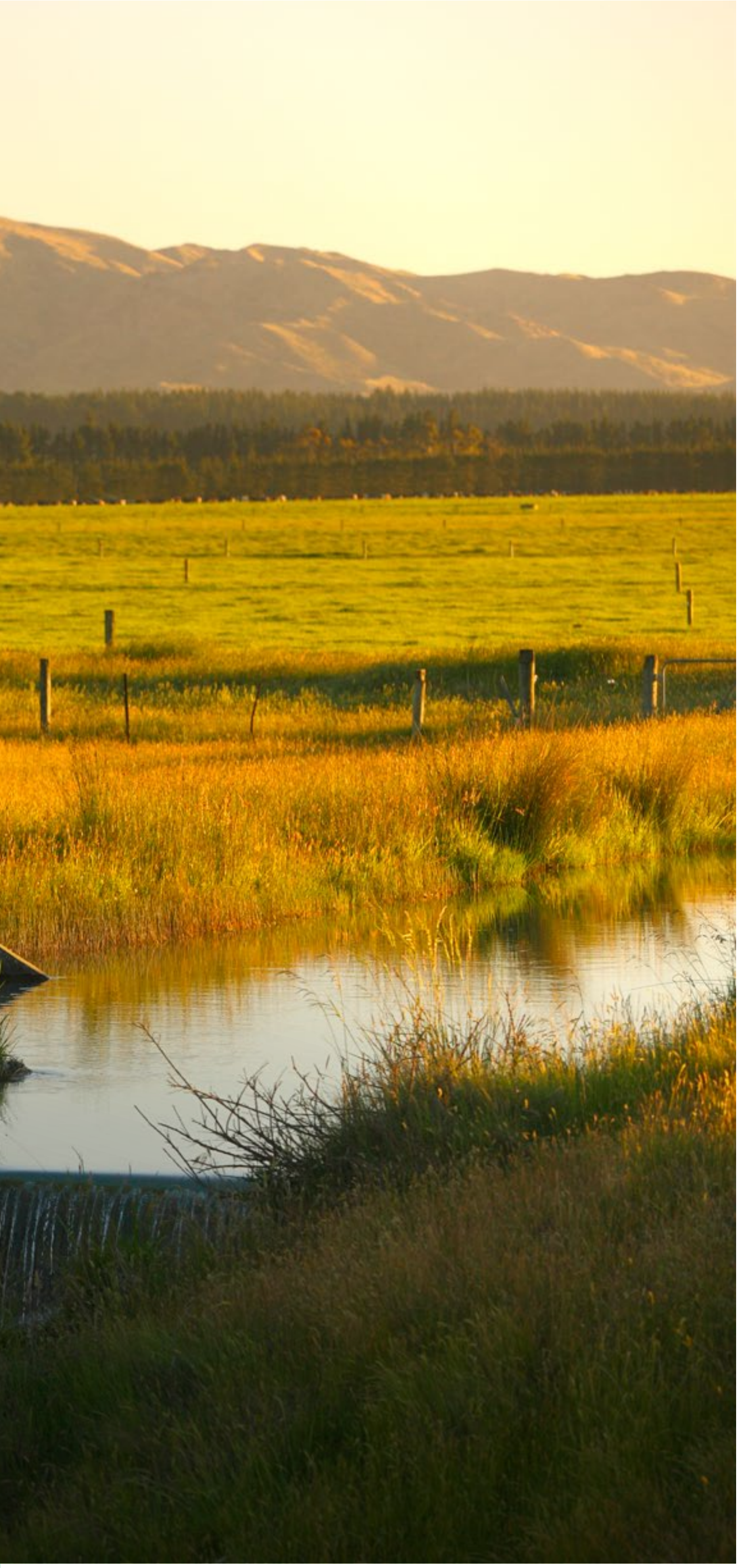
Our knowledge contains critical gaps about the impacts of water pollution on te ao Māori, including how mātauranga Māori, tikanga Māori, kaitiakitanga, customary use, and mahinga kai are affected. Although some relevant data is available (see Kusabs et al, 2015), we lack information about how changes in land use affects Māori freshwater-dependent values (Larned et al, 2018).

Information about the impacts of water pollution on human health is also poor. Regional councils monitor water quality at approximately 150 of New Zealand's lakes, but *E. coli* is monitored at very few of these (Larned et al, 2018).

New research programmes are beginning to collect data on emerging contaminants in our waterways. These include pesticides, pharmaceuticals, nanoparticles, and other chemicals that are now often found in waterways overseas (Petrie et al, 2015). The negative effects of emerging contaminants on freshwater ecosystems are not well understood, and very few studies have assessed their impacts on New Zealand's native species (Stewart et al, 2016). Data to assess the risk to human health from most emerging contaminants in fish or shellfish is also not available.

ISSUE 3

Changing water flows affect our freshwater



▸ Irrigation water canal on Amuri Plain, Canterbury.

Photo: Nature's Pic Images

This issue explores the effects of the changes we have made to the water levels, flows, and courses in our rivers and aquifers. The changes have supported our need for water to live and make a living, generate electricity, grow food, and protect ourselves from floods.

Although Aotearoa New Zealand has plenty of freshwater, we also use and store large quantities for irrigation and hydroelectricity generation, and in our homes.

To support our needs, water courses have been altered and water has been taken out of the freshwater system. This has reduced or changed the timing of water flows in many rivers. Low river flows reduce the habitat for freshwater fish and other species (including threatened birds). Essential fish movements up and downstream are made more difficult (or impossible) by low flows and artificial barriers (like dams and weirs) in rivers and streams.

Reduced or less variable flows can increase the temperature and the concentration of nutrients and pathogens (disease-causing microorganisms) in a waterway and increase the chances of harmful algal blooms.

Growing demand to irrigate more land (for 2002–17) coincided with less rain in 2000–14: lower rainfall was experienced in nine of the years between 2000 and 2014 compared with average rainfall for 1995–2014 (see **What has contributed to this issue**; Stats NZ, 2018).

Together, these changes affect the mauri of waterways and how we relate to and use them. Changing water flows can make our waterways unfit for recreational and cultural uses.

NEW IN THIS REPORT

This issue contains updated information since *Environment Aotearoa 2019* including new or updated data from these measures and indicators:

- barriers to fish passage
- consented freshwater allocation.

Using aquifers to manage water supply and quality issues is discussed in this issue, and a local story from the Manuherekia River is also included. In an infographic, īnanga demonstrate the effects of in-stream barriers and changing water flows on a native fish species.

WHAT WE DON'T KNOW

We know how much water is consented for use, but we don't know how much water is actually taken from the freshwater system, how much we have, or the full effects of taking too much water on river habitats and water quality.

CONNECTIONS TO OTHER ISSUES

The other issues highlighted in this report are also affected by changes to water flows.

- Issue 1: Our native freshwater species and ecosystems are under threat – a reduction of habitat from changing water flows threatens our freshwater species and ecosystems.
- Issue 2: Water is polluted in urban, farming, and forestry areas – low river flows can increase the effects of pollution in rivers.
- Issue 4: Climate change is affecting freshwater in Aotearoa New Zealand – changing rain and snowfall patterns are expected to affect major lakes and rivers that we use for hydroelectricity generation.

Why does this issue matter?

SPATIAL EXTENT

Taking water for irrigation occurs nationwide but at a larger scale in Canterbury and Otago. Hydro dams have been built throughout the country.

DEPARTURE FROM NATURAL CONDITIONS

Many waterways have been significantly modified by channelling their flow. In some catchments the water allowed to be taken for other uses is greater than the expected river flow.

IRREVERSIBILITY

It is difficult to reverse because farming is important for our economy and often requires irrigation. Hydro dams are important for renewable electricity generation and reduce our use of fossil fuels.

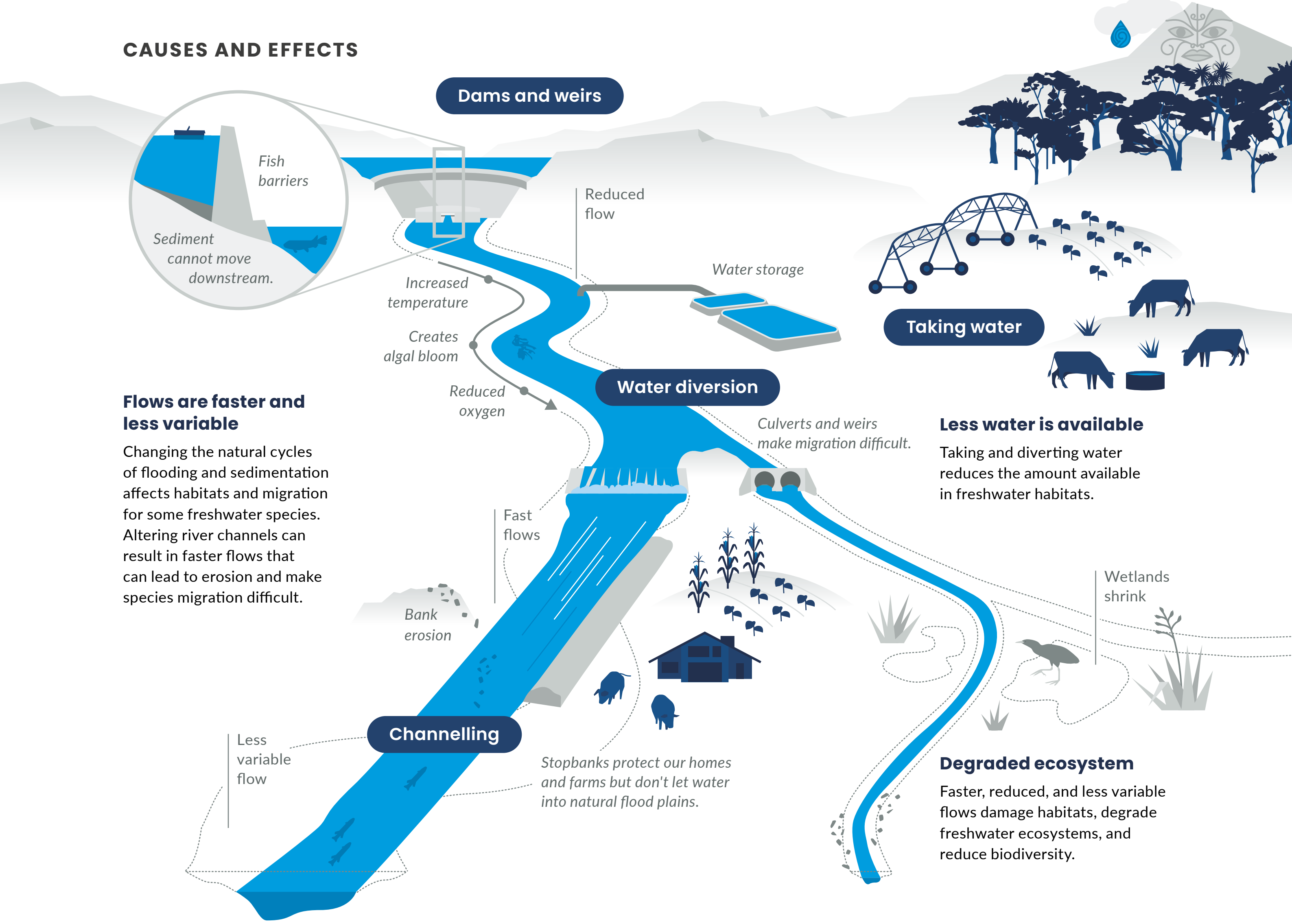
IMPACTS ON WHAT WE VALUE

Using water and modifying waterways can affect ecosystems and our cultural uses, beliefs, and practices, and limit our access to freshwater.

Effects of using water and modifying waterways

The natural flow of water is changed by modifying waterways for urban and rural development, flood control, and by taking water for drinking, irrigation, and electricity generation.

CAUSES AND EFFECTS



Flows are faster and less variable

Changing the natural cycles of flooding and sedimentation affects habitats and migration for some freshwater species. Altering river channels can result in faster flows that can lead to erosion and make species migration difficult.

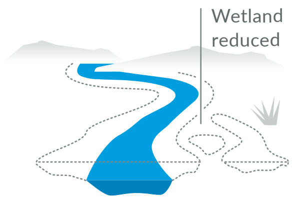
Less water is available

Taking and diverting water reduces the amount available in freshwater habitats.

Degraded ecosystem

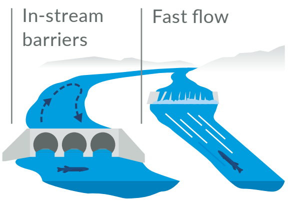
Faster, reduced, and less variable flows damage habitats, degrade freshwater ecosystems, and reduce biodiversity.

IMPACTS



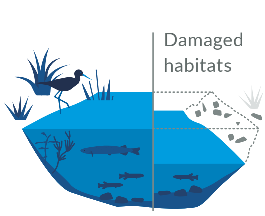
Habitat shrinks

Rivers become less dynamic and have fewer channels. Taking water from aquifers can reduce the water flow in rivers and vice versa.



Fewer fish migrate

In-stream structures and altered river channels and flows make it difficult or impossible for fish to move up and down stream.



Less biodiversity

Many of our native freshwater fish and birds are threatened with or at risk of extinction. Loss and degradation of habitat increases this risk.

Cultural impact

Altering natural flows can reduce the mauri of the environment. This reduces the ability of tangata whenua to exercise kaitiakitanga of wetlands, rivers, and lakes.

What is the current state of this issue and what has changed?

WE HAVE PLENTY OF WATER AND ARE HIGH USERS

New Zealand has plenty of freshwater. Approximately 440 billion cubic metres flow in our rivers and streams (Collins et al, 2015). Our aquifers also contain about 711 billion cubic metres of groundwater, of which 73 percent is located in Canterbury (519 billion cubic metres in 2014). (See indicator: Groundwater physical stocks.)

We are also heavy users of freshwater. For 2014, New Zealand's consented water allocation per person was 2.2 million litres (OECD, 2020).

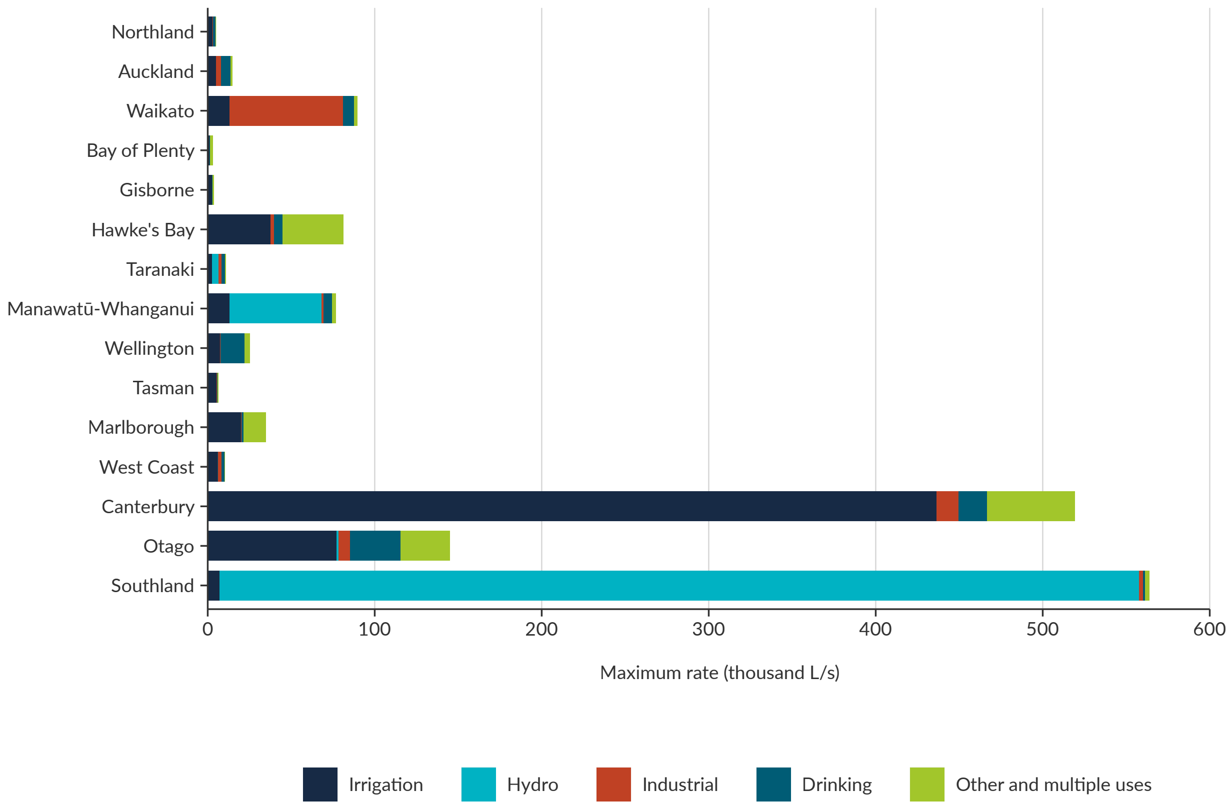
CONSENTED WATER TAKES ARE MAINLY FOR HYDROELECTRICITY AND IRRIGATION

Consents (permits) to take water are managed by regional councils and other authorities that allocate water for hydroelectric generation, irrigation, drinking water, industrial, and other uses. Individual consents to take water have specified conditions, such as how much water can be taken, from where, at what rate, and at what times. Regional councils also limit the total amount that can be taken from catchments or water management zones. In 2010, 10 of the 29 allocation zones in Canterbury were fully allocated and six were above 80 percent of the allocation limit (Kaye-Blake et al, 2014).

Hydroelectric generation is a major consented use of freshwater. Hydroelectricity is generated at about 100 sites nationwide including several large power stations (MBIE, 2018). Some of our big rivers like Clutha, Waikato, and Waitaki have multiple hydro dams. Most hydroelectric schemes store water without consuming it, but some (like the Manapouri in Southland) remove water from a catchment or move it from one catchment to another. In these cases it is considered a consumptive use.

Of all surface water uses nationally, hydroelectric generation had the largest consented allocation for consumptive use by total maximum rate (45 percent), followed by irrigation (37 percent) in the 2017/18 water reporting year (see Data service; see figure 12). No large hydroelectricity infrastructure has been built in the past two decades but a number of schemes have been proposed.

Figure 12: Maximum rate of consented consumptive freshwater takes by primary use
By region, 2017–18



Data source: NIWA

There were also 5,140 consents to take surface water and 11,573 consents to take groundwater in the 2017/18 water reporting year. Surface water made up 76 percent of the total volume of water allocated, with the rest from groundwater. Irrigation had the largest consented allocation by volume (58 percent). Household consumption (including water for drinking and sanitation) made up 17 percent, and industrial use was 10 percent (see figure 13). (See indicator: Consented freshwater takes.)

WATER COURSES AND FLOWS HAVE BEEN CHANGED EXTENSIVELY

In many of our rivers, the way water moves downstream has been changed by altering the channels, building dams and stopbanks, and diverting whole streams. This confines rivers to well-defined channels and protects nearby land from floodwater that could damage houses and infrastructure. However, these changes have consequences on the volume of water in a river, how fast it flows, how the flows vary, and the connections between waterways.

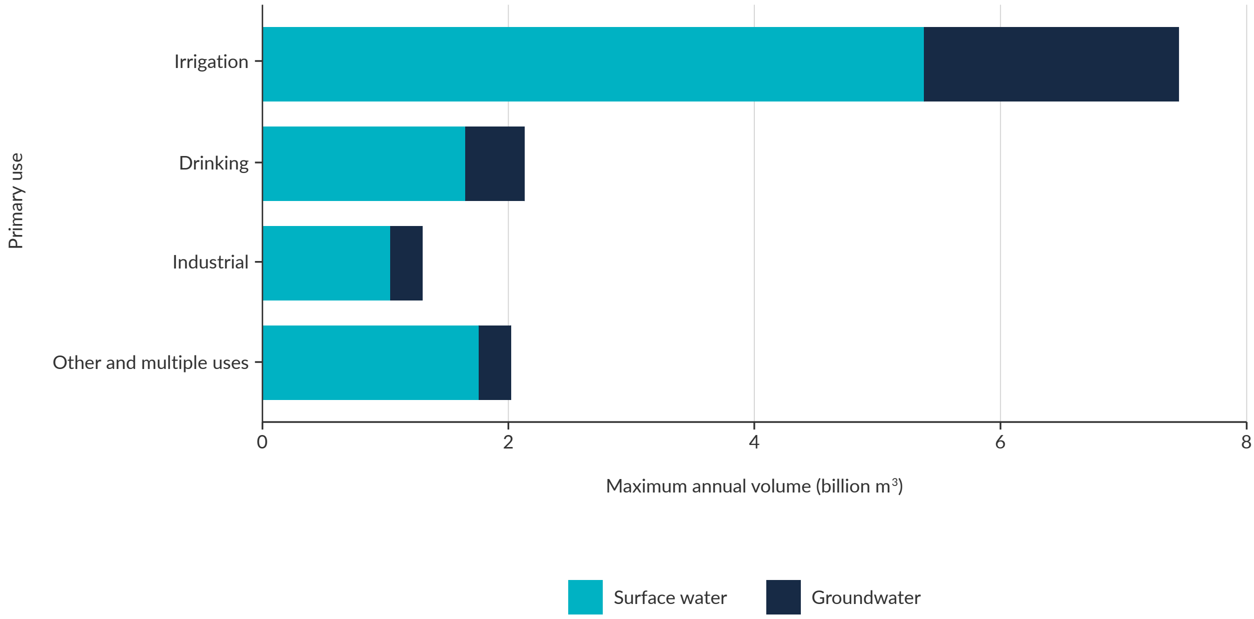
River channels can be made deeper, straighter, or wider, and riverbanks protected with groynes and rocks (Hudson & Harding, 2004; Holmes et al, 2018). Channelling rivers alters their natural character and can also erode riverbanks and increase the amount of sediment deposited downstream (Maddock, 1999; Fuller et al, 2011). It also reduces the ecological connections between a river and the land, lakes, and wetlands in its catchment. For example, if flooding is constrained, the ability for rivers to scour and deposit sediment, and cycle nutrients can be lost (Catlin et al, 2017).

Some hydroelectric schemes reduce the water flowing in one river by adding it to another. The Waikato River, for example, receives water diverted from the Whanganui and Whangaehu Rivers. Taking water for hydroelectricity can significantly reduce the flow in some rivers, like the Waiau River in Southland and the Tekapo River in Canterbury.

Irrigation schemes change the natural flow of a river. Thousands of kilometres of water races have been built to supply water for irrigation, stock watering, mining, and other purposes. For example, in the Rangitata South Irrigation Scheme, some of the water from the Rangitata River is diverted at times of high flow and stored in a system of ponds. This is then added to water supplies at times of scarcity (NIWA, 2015). There is growing interest and development of these kinds of water storage schemes (NIWA, 2018).

Land has been drained to make it more suitable for agriculture (Pearson, 2015; Manderson, 2018). About 10 percent of New Zealand's land is estimated to be artificially drained (Manderson, 2018) (see figure 14).

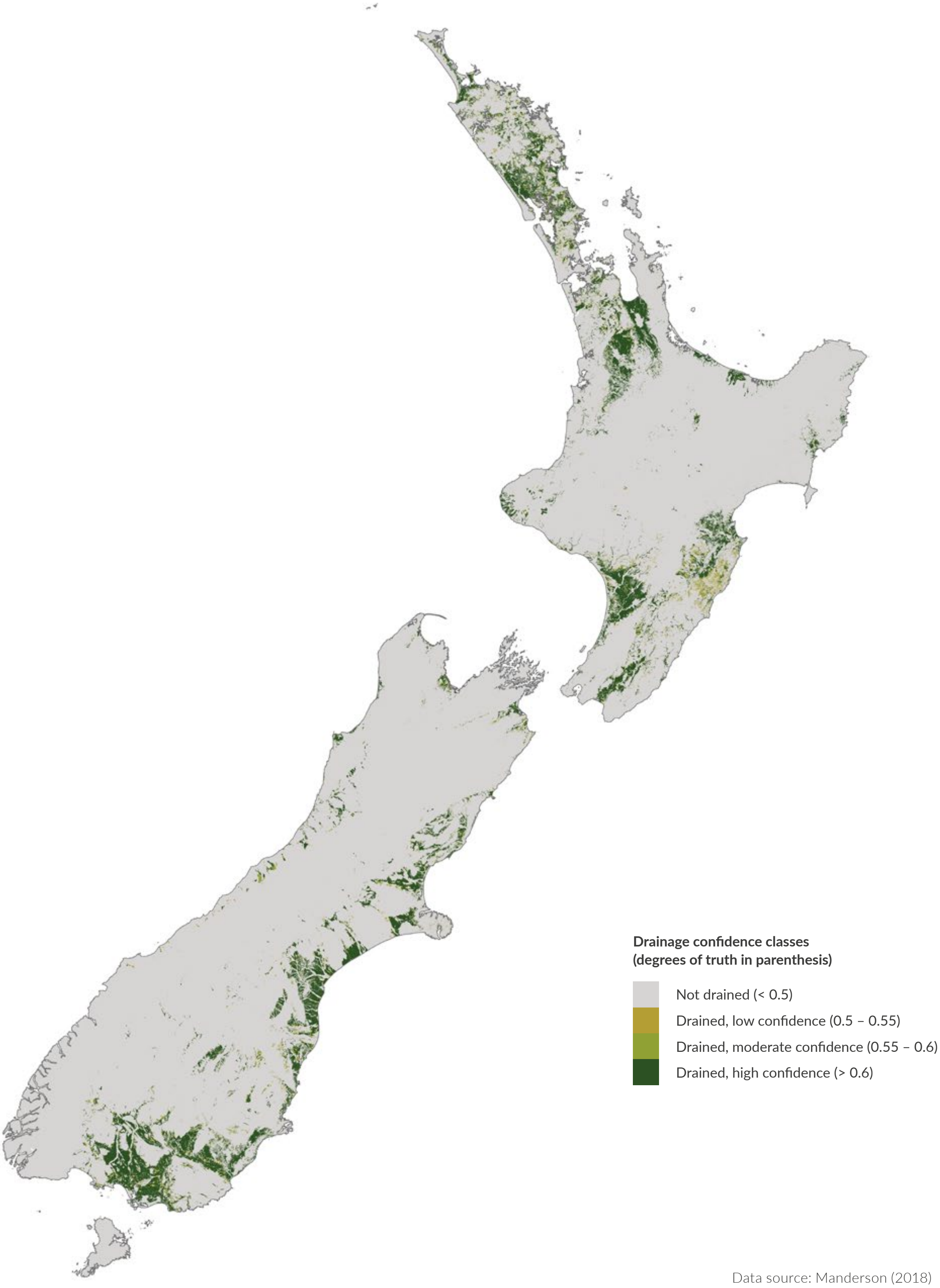
Figure 13: Maximum annual volume of consented freshwater takes for consumption
By primary use and source, 2017–18



Data source: NIWA

Note: Hydro use is generally non-consumptive and has been excluded from volume comparison. Drinking use includes household, town, and rural water supply; industrial use includes commercial, industrial, mining, and aquaculture uses; other and multiple uses includes frost protection, stock, storage, and consents for multiple uses.

Figure 14: Estimated extent of artificially drained land in New Zealand, 2018



Data source: Manderson (2018)

New Zealand has thousands of dams. While most are small and built to supply water to farms, more than 400 dams store large quantities of water (more than 18 million litres). About 100 of our large dams are used for hydroelectric generation, with the others used for irrigation, flood control, domestic and industrial water supply, or a combination of uses (NIWA, nd; MBIE, 2018). Depending on the design and operation of the dam, it may create a lake upstream and cause the flows downstream to be more constant, with less frequent high and low flows.

Weirs, culverts, and other structures may affect the water flow and the connections between waterways in a catchment (Franklin et al, 2018). Although there is no national inventory of these in-stream structures, their type and location can be recorded in a public database (see Fish Passage Assessment Tool).

What has contributed to this issue?

DEMAND FOR WATER FOR IRRIGATION HAS INCREASED

A shift from sheep and beef farming to dairy farming, and an increase in the number of animals per hectare, have increased the demand for water. (See indicator: Livestock numbers.) These changes in livestock have been especially marked in the South Island, particularly in Canterbury and Southland (see What we farm has changed).

The area of irrigated agricultural land in New Zealand almost doubled between 2002 and 2017 from 384,000 hectares to 747,000 hectares. Irrigated land area rose in every region during this time, but the total increase was largely due to the almost doubling of irrigated land in Canterbury (241,000 to 478,000 hectares). In 2017, 64 percent of irrigated agricultural land was in Canterbury.

Dairy farming accounted for 59 percent of irrigated agricultural land area in 2017, with other types of livestock farming accounting for 17 percent. The production of grain, vegetables, fruit, and other horticulture made up 24 percent of irrigated agricultural land. (See indicator: Irrigated land.)

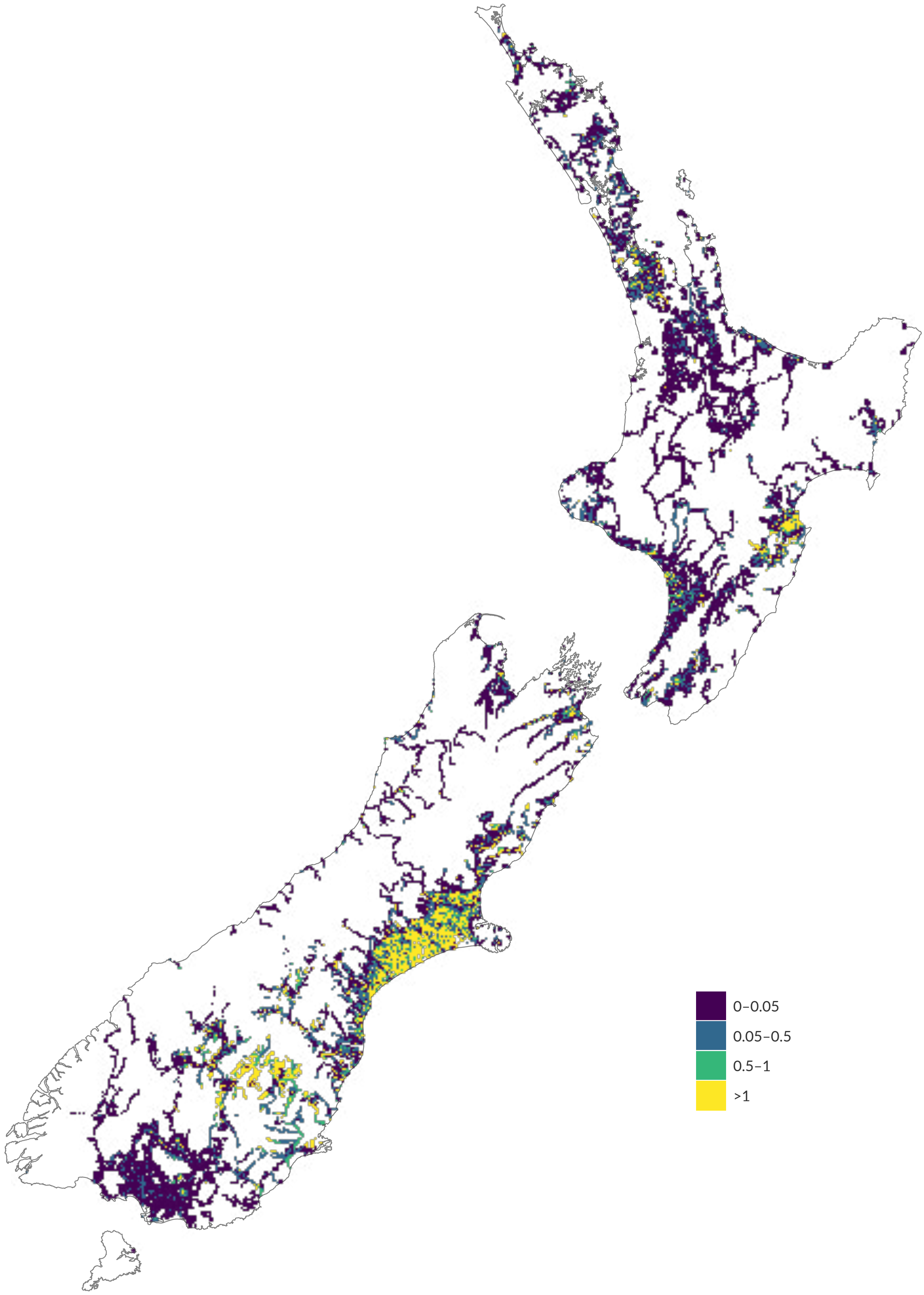
The effects of taking water on river flows can be predicted using computer models. For 2017/18, taking water for irrigation was predicted to have the greatest potential to cause widespread reductions in river flows across the country when compared with other uses (Booker & Henderson, 2019). The models showed that the total volume of water consented to be taken from a catchment (apart from use for hydroelectric generation) was greater than the estimated natural median river flows in some parts of Canterbury, Hawke's Bay, and Otago (see figure 15). (See indicator: Consented freshwater takes.)

DEMAND FOR WATER IS GROWING AS OUR POPULATION INCREASES

The water we use in our homes (including for drinking and sanitation) made up 17 percent of the country's allocated water use in 2017/18. Industrial use made up 10 percent. Data for the use of water over time is not available nationally but is known for two regions (Booker et al, 2019) and some urban areas.

In 1980, Auckland used about 280 million litres of water per day for home and industrial uses and tanker fills (including leaks from the supply network) – a rate of more than 400 litres per person (Watercare, 2011). As the city's population has grown, water use has increased to about 379 million litres per day but the volume used per person was 271 litres per day in 2019 (Watercare, 2019; Watercare, nd).

Figure 15: Modelled potential river flow reduction, due to upstream consented water takes for non-hydro consumption, as a ratio of the natural median flow, 2017–18



Data source: NIWA

Water bottling in New Zealand

Our water bottling industry is very small. Approximately 135 million litres per year were bottled for the local market in 2018, and 27.9 million litres were bottled for export. This is 0.001 percent and 0.0002 percent respectively of the total amount of water consented to be taken annually for consumption, excluding hydroelectricity generation. (See indicator: Consented freshwater takes.)

As of 2018, 79 consents allowed for 71.6 million litres per day to be extracted for bottling, but only 45 of those consents were used to take 20.4 million litres per day (Deloitte, 2018).

Consents have been granted that would enable recently established businesses to take and export almost 400 times more water than current exports (Deloitte, 2018). Data is not available to establish the potential effects of increased water bottling at a local and regional scale.

RAINFALL WAS LOWER NATIONALLY

Between 1995 and 2014, the average annual volume of precipitation (rain, hail, sleet, and snow) that fell in New Zealand was 549,392 million cubic metres. The annual precipitation was below average in nine of the years between 2000 and 2014 (with regional variations), probably because of natural climate patterns (Stats NZ, 2018, see SEEA water physical stock account).

Rain and snowmelt feed our rivers and streams, but their total volume is reduced by evaporation from lake and river surfaces, transpiration from plants, and the water we take and use. Precipitation varies naturally from year to year, but in dry years more water may be needed to sustain our cities, towns, and farms. Taking more water in these years could make issues related to low river flows worse or cause less groundwater to be available.

Climate changes are projected to affect the seasonality and regional variation of precipitation in New Zealand, which will affect water flows and the demand for water (MfE, 2018b; Gluckman et al, 2017) (see Issue 4: Climate change is affecting freshwater in Aotearoa New Zealand).

What are the consequences of this issue?

MODIFYING WATERWAYS CAN REDUCE OR PREVENT FISH MOVEMENT

Many of our native fish move significant distances up and downstream to feed, reproduce, and hide (Franklin et al, 2018). Species that move between sea and freshwater include whitebait species (īnanga, shortjaw kōkopu, giant kōkopu, kōaro); kanakana/piharau (lamprey); and tuna (longfin and shortfin eel) (McDowall, 2000) (see Issue 1: Our native freshwater species and ecosystems are under threat).

Altered river channels and flows can make it difficult or impossible for fish to make these journeys. Culverts, for example, are often narrower than natural channels and can have faster and more uniform water flows. The ability of fish to move through fast-flowing water depends on a species' swimming ability and the distance to travel as well as the presence of slower-flowing water for resting along the way (Williams et al, 2012).

In-stream structures like dams, weirs, fords, flood gates, and overhanging (perched) culverts can also disrupt or block fish migrations, and are a significant and ongoing threat to our native fish, including īnanga (*Our fresh water 2017*; Franklin et al, 2018; Goodman, 2018). Of the 240 in-stream structures surveyed in Hawke's Bay between 2002 and 2010, one-third were barriers to fish passage in some or all flow conditions. (See indicator: Selected barriers to freshwater fish in Hawke's Bay.)

REDUCED AND LESS VARIABLE FLOWS AFFECT THE AMOUNT AND QUALITY OF HABITAT

Low river flows reduce the quantity of habitat for freshwater fish, invertebrates (like snails and kōura), and other species (*Our fresh water 2017*; Booker et al, 2014; James et al, 2008; Storey & Quinn, 2007; Storey, 2015).

Lower flows and seasonal variations can affect whitebait species because their reproduction is closely tied to water levels. Īnanga lay eggs in the vegetation beside rivers and streams during the highest (or king) tides in late summer and autumn (Goodman, 2018) but the eggs must be submerged on the next king tide to stimulate hatching (McDowall, 2000). In braided rivers, lower flows can reduce the number of channels and consequently the amount of habitat available for threatened birds like wrybill and black stilt (kakī) (O'Donnell et al, 2016).

Reduced flows may increase the concentration of nutrients and other pollutants in a waterway (Nilsson & Malm-Renöfält, 2008). Drains for surface water can also transport contaminants from land to freshwater (Manderson, 2018). These factors, combined with fewer floods, can increase algal blooms (Storey, 2015) (see Issue 2: Water is polluted in urban, farming, and forestry areas).

The effects of taking water are greater when larger volumes of water are taken from multiple locations, particularly in dry periods. Reduced and less variable flows can increase water temperatures, especially in streams without shade (Nilsson & Malm-Renöfält, 2008). Temperatures above 20°C in higher-altitude streams or above 25°C in streams on lower-lying land threaten sensitive native species (Olsen et al, 2012). Macroinvertebrate community index scores that measure ecosystem health tend to decrease with increasing water temperature (Storey, 2015) (see 'Macroinvertebrate community index' box).

Taking water from rivers can affect aquifers and vice versa, since groundwater and surface water are part of the same system. Wetlands are connected to lakes, rivers, and aquifers, so taking water can reduce the water in these ecosystems (White et al, 2001; Cameron & White, 2004). Low river flows can also affect estuaries and their biodiversity (Gillanders & Kingsford, 2002).

CHANGING WATER FLOWS AFFECT US

Using freshwater changes the flows in rivers and aquifers, which affects the mana (status) of water and the ways we relate to and use our waterways. Waterways are an integral part of Māori identity – when a whakapapa (genealogy) is told, significant landscapes (including mountains and rivers) within a tribal area are acknowledged.

Some Māori communities feel aggrieved by water takes and the effects on the mauri (life force) of waterways. Building artificial structures like dams in rivers and taking water from one catchment and releasing it into another can be particularly offensive to Māori, because the cultural and spiritual connection to the waterway is disrupted (Jones & Hickford, 2019). Decreased or altered flows can also affect the availability of traditional and customary resources and access to mahinga kai areas. The cultural health and wellbeing of a site can therefore be deeply affected by changed flows. (See indicator: Cultural health index for freshwater bodies.)

Decreased river flows can limit our ability to use rivers, lakes, and estuaries for swimming and other recreation, and may make them more susceptible to algal blooms (see Issue 2: Water is polluted in urban, farming, and forestry areas).

Extracting too much groundwater lowers the water table. Near the coast, this can allow seawater to enter aquifers and make the groundwater unfit for irrigation and drinking (see 'Maintaining the water supply from our aquifers' box). On the Waimea Plains in Nelson in 2001 for example, taking too much groundwater contaminated urban water supply bores with salt water. Two bores had to be shut down to keep seawater from entering the aquifer, which limited water take by up to 60 percent in some areas (Callander et al, 2011). As a consequence, a dam is being built on the Lee River to prevent the aquifer being overused in the future (MPI, 2015).

Maintaining the water supply from our aquifers

Aquifers are large underground water reservoirs where groundwater fills in the gaps between rock, gravel, sand, and silt particles. Water from some aquifers comes to the surface naturally through springs but is usually pumped up in wells.

We use aquifers for drinking water and irrigation throughout New Zealand. In many areas, aquifers are the main source of water and, when used sustainably, provide a reliable supply of high-quality water.

But when water is taken out faster than it can be replenished naturally (from rain or water seeping underground from rivers and lakes), the water levels in aquifers decrease and less water is available. Seawater can also enter aquifers near the coast if their water levels are too low, or from rising seas. This can require the use of alternative water sources either with lower quality or that require significant engineering works and investment to access.

One solution is to refill (or recharge) aquifers using water diverted from rivers. Natural or artificially built basins hold river water and allow it to seep down into an aquifer. This practice is common overseas and several schemes have been investigated or trialled in New Zealand. Despite its cost, interest in the practice is growing, especially as we respond to changes in rainfall and sea-level rise associated with climate change.

Aquifer recharge can reduce the water in a feeding river, so the benefits of a scheme must be weighed against any consequences of lower flows. Mixing different types of water reduces the mauri of the receiving water and changes the age and temperature of groundwater (Ngāi Tūāhuriri Rūnanga et al, 2013).

Juggling with water: the Manuherekia River and its catchment

Central Otago summers are hot and dry and the winters are cold, with temperatures ranging from 35 to minus 20 degrees Celsius. It's the closest anywhere in New Zealand comes to a continental climate.

The Manuherekia River runs south from the Hawkdun Range to its confluence with the Clutha River / Mata-Au. In its catchment, water is gold. It sustains the area's sheep, deer, beef, and dairy farming; crops like barley and wheat; and fruit growing industries.

Several dams and reservoirs were built in the 1930s to capture and store water in areas where the rainfall is higher. Water is released in the summer months and transported using water races and natural watercourses to irrigate land. A small hydroelectric station also uses water.

Above Falls Dam (the catchment's largest dam), the river is up to 1 kilometre across and braided into natural channels. Below the dam, the river becomes constrained by hills and enters a gorge. Banks have been stabilised by the planting of willows and other introduced trees, but this prevents channels from naturally changing after floods.

Birds recorded here – particularly in the upper braided sections of river – include banded dotterel and wrybill (both are nationally vulnerable), black-fronted terns (nationally endangered), and pied stilts. The gorse and broom growing in the lower channelised riverbeds has reduced the habitat for birds.

The area is a popular trout fishery and also contains several threatened native fish: Clutha flathead galaxias are nationally critical, and Central Otago roundhead galaxias and alpine galaxias (Manuherikia River) are nationally endangered.

The catchment's low rainfall and high demand has led to river water being overallocated and reduced flows. Between 2013 and 2017, flows below Falls Dam were 23–69 percent of their modelled natural seasonal low flows. In times of low rainfall, some tributaries dry up naturally, but taking water out makes these periods longer and more frequent. Extreme low flows and higher water temperatures are unfavourable for trout and native fish, but trout are especially disadvantaged because they are larger. Having fewer trout can benefit some of the native species they compete with or eat.

Manuherekia River downstream of Falls Dam.

Photo: Isaac Bain

Contaminants from agriculture (including nitrogen, phosphorus, sediment, and disease-causing faecal bacteria) pollute the catchment's water, especially in farmed areas. A study in 2011 found that at one part of the river dissolved inorganic nitrogen, dissolved reactive phosphorus, and *E. coli* concentrations at a site downstream of irrigated land were four, nine, and 39 times higher respectively than upstream. In some places, poor water quality has led to bans on swimming. Adding the dammed water back in summer can make the flow more regular; increase water depth, width, and velocity; reduce the temperature; and could dilute pollutants.

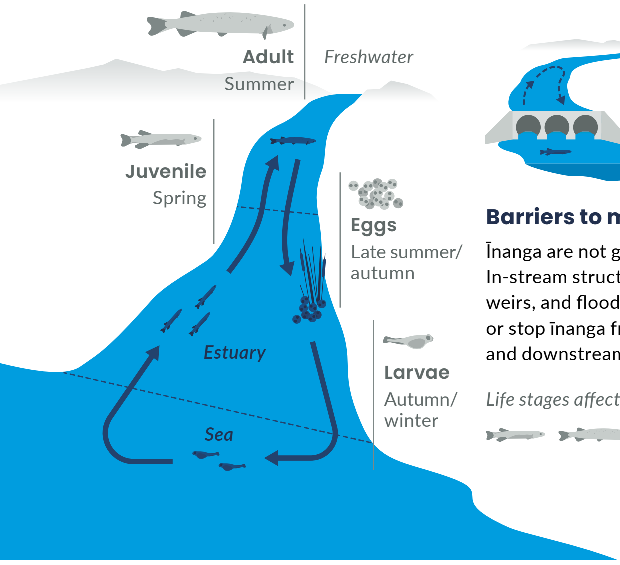
Balancing the need to protect the environment, provide for recreation and cultural values, and allow water to be taken for private or commercial uses is a huge challenge. There is also pressure to increase water storage and the area of irrigated land in the catchment.

Otago Regional Council intends to set allocation limits, and minimum flows and water levels for rivers and groundwater, as required by the National Policy Statement for Freshwater Management. Community consultation on the Council's proposals ran from August to September 2019, and the Council intends to announce its plan change that sets flow and allocation limits by November 2020.

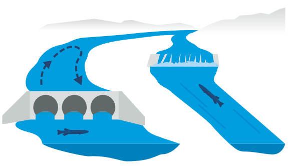
How changing water flows affect īnanga

Taking water and the ways we have modified rivers and streams can make it harder for īnanga to complete their life cycle.

ĪNANGA LIFE CYCLE



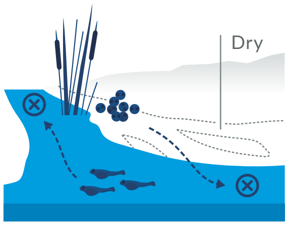
PRESSURES



Barriers to migration

Īnanga are not good climbers. In-stream structures like dams, weirs, and floodgates disrupt or stop īnanga from moving up and downstream.

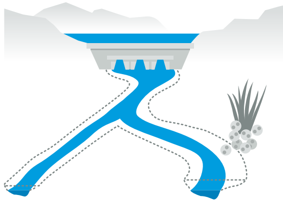
Life stages affected



Less variable flows

Artificially reducing the volume or frequency of floods makes it harder for larvae to reach the sea. It can also delay or reduce the number of juvenile īnanga moving upstream.

Life stages affected



Reduced flows

Less water in rivers means less habitat is available for īnanga. Lower flows also make spawning sites harder to reach and stop eggs hatching.

Life stages affected

Where are the gaps in our knowledge about this issue?

INFORMATION ABOUT WATER USE AND AVAILABILITY IS LIMITED

The quantity of water taken from all our rivers, lakes, and groundwater is not known – and neither is the amount of water available. This makes it difficult to know if our freshwater resources are over-exploited and how long they will continue to meet our needs. Given our economic reliance on agriculture, especially dairy farming, this is a significant management issue.

Detailed maps of the locations, volumes, and properties of our aquifers are not available so the volume, quality, and availability of water stored in aquifers is not known. The effects of climate change on the flow of water in rivers and aquifers is also poorly understood.

The Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 require water meters to be installed (when consented water take is more than 5 litres per second) to provide a continuous record of use. Case studies of actual water-use data, however, show that some users took less water than the volume they were consented to take, some consistently took more, and other users did not supply records of their water use (Booker et al, 2017).

Data for the actual volume of water taken was collected by Horizons and Greater Wellington Regional Councils from July 2015 to July 2018. One study showed the volume of water taken varied seasonally, and river levels were lower in different places at different times (Booker et al, 2019). This information could be useful in estimating the actual reductions in river flow from our water use.

THE FULL RANGE OF IMPACTS FROM REDUCED WATER FLOWS AND POLLUTION ARE POORLY UNDERSTOOD

Changing water flows can have significant effects on river habitats and water quality but we lack information about the extent and scale of these impacts on our ecosystems. Other water issues like pollution also have an effect, but the cumulative impact of these changes on our cultural, social, and economic values is difficult to determine.

Substantial sources of information about the impacts of water use on cultural values, beliefs, and practices have been recorded as evidence for regional plans, Waitangi Tribunal claims, Treaty of Waitangi settlements, and water take or diversion consents. Also, some new methods for whānau to describe their flow preferences have been developed (Crow et al, 2018). Using ngā tohu o te taiao (environmental indicators) and drawing on mātauranga Māori can provide a better understanding of the effects of changing water flows on te ao Māori than western science methods (Tipa & Severne, 2010).

ISSUE 4

Climate change is affecting freshwater in Aotearoa New Zealand

▸ Dried-out dam in Wairarapa.

Photo: Dave Allen, NIWA

This issue explores how the changes to our climate being caused by greenhouse gas emissions are expected to affect our freshwater.

Changes to our climate are already being observed. Climate change is expected to affect when, where, and how much rainfall, snowfall, and drought occur. This may change the amount of water in our soil and in glaciers, lakes, rivers, and groundwater.

The frequency of extreme weather events is expected to increase. The flows, mixing, and temperature of water in lakes, rivers, and groundwater is also projected to change.

Ultimately, all these changes will affect what we do (including where and how we produce food), our economy, and how and where we live. The things we value, including our health, culture, and opportunities for recreation may also be affected.

NEW IN THIS REPORT

This issue contains updated information since *Environment Aotearoa 2019* including new or updated data from these measures and indicators:

- freshwater ecosystems
- projected impacts of climate change on freshwater flows.

Information about how climate change can affect water mixing in lakes is included. In an infographic, īnanga demonstrate the different ways that climate change may affect a native fish species.

WHAT WE KNOW AND DON'T KNOW

How much our climate warms and changes depends on global emissions, but how emissions will change into the future is unknown.

The effects of climate change are variable across the country. While some – glacier ice extent and sea-level rise – are already obvious, others are less certain.

CONNECTIONS TO OTHER ISSUES

The other issues highlighted in this report are likely to be intensified by climate change:

- Issue 1: Our native freshwater species and ecosystems are under threat – climate change is expected to have far-reaching consequences for the health and distribution of species and ecosystems.
- Issue 2: Water is polluted in urban, farming, and forestry areas – extreme weather events are likely to increase pollution, erosion, and sedimentation in our waterways.
- Issue 3: Changing water flows affect our freshwater – more frequent and intense droughts are likely to increase the demand for water to irrigate land and increase competition for this resource.

Why does this issue matter?

SPATIAL EXTENT

Climate change is affecting all parts of New Zealand, with varying impacts on different species, ecosystems, regions, and sectors of the economy.

DEPARTURE FROM NATURAL CONDITIONS

Some changes are significantly different from pre-industrial conditions (temperature, glacier ice extent, sea level), while others (extreme rainfall) are not yet consistently detectable.

IRREVERSIBILITY

Many impacts are permanent or irreversible on a human timescale. Others are reversible but depend on the level of greenhouse gases in the atmosphere, which may stay high for thousands of years.

IMPACTS ON WHAT WE VALUE

Environmental, cultural, and economic systems are already affected. Impacts on other values like health and recreation are expected to increase.

What is the current state of this issue and what has changed?

OUR CLIMATE IS CHANGING

As reported in *Environment Aotearoa 2019*, many significant changes in New Zealand's climate have already been observed across the country. Regional variations can also be seen, particularly for rain and snowfall.

For some impacts, such as changes in extreme rainfall events, changes to the baseline have not yet been detected. Other impacts, such as rising sea levels, are already significantly different from pre-industrial conditions.

The effects of climate change will intensify with time.

Many effects are irreversible on a human timescale. Some, like species extinction are permanent. Stopping further emissions will not return us to a normal climate because carbon dioxide remains in the atmosphere for centuries to millennia. As long as greenhouse gas concentrations stay elevated, the risk from extreme events like heat waves, droughts, and storms will be elevated.

There is also a lag of up to several decades between when greenhouse gases are added to the atmosphere and when changes occur. This means that the climate will continue to warm and effects will intensify for many years after global emissions are reduced.

The following points illustrate the wide-ranging changes affecting our freshwater that have already been observed (for details see *Our atmosphere and climate 2017*).

Rainfall

From 1960 to 2016, most locations did not record changes in rainfall intensity. As at 2016, the proportion of annual rainfall occurring in intense events decreased at four of 30 locations (Auckland, New Plymouth, Rotorua, and Taupō) but increased at Napier and Timaru. (See indicator: Rainfall.) The inability to detect trends in rainfall intensity at most locations may be partly due to the relatively short time for which there is data and because intense events are infrequent.

Studies have identified climate change as a factor in flooding events in Golden Bay in 2011 (Dean et al, 2013) and Northland in 2014 (Rosier et al, 2015), and as contributing to the cost of floods in the last decade (Frame et al, 2018).

Temperature

New Zealand's annual average temperature has increased by 1 degree Celsius since 1909. (See indicator: Temperature.)

Soil moisture

Since 1972/73, soils at a quarter of the monitoring sites around New Zealand have become drier. (No change was detected at about three-quarters of sites, but where change was detected, it was skewed toward what would be expected in a warming climate – soil moisture decreased at seven sites and increased at one. (See indicator: Drought.)

Glacier ice

From 1977 to 2016, glaciers are estimated to have lost almost 25 percent (13.3 cubic kilometres) of their ice. The maximum volume of ice was recorded in 1997 and from then until 2016, 15.5 cubic kilometres of ice was lost, enough to fill Wellington Harbour 12 times. (See indicator: Annual glacier ice volumes.)

Sea level

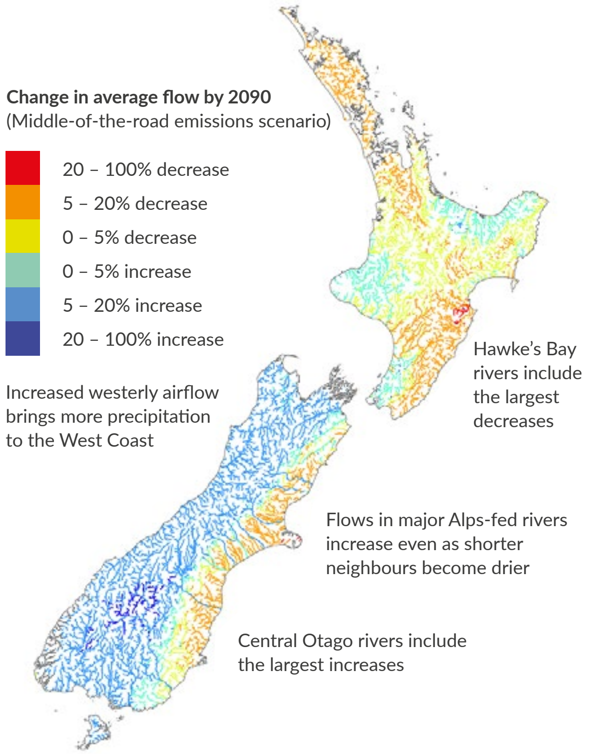
New Zealand's mean relative sea level has risen by 1.81 (±0.05) millimetres per year on average since records began. (See indicator: Coastal sea-level rise.) The rate of sea-level rise has increased in recent decades – the mean rate in the past 58 years (1961–2018) was more than twice the rate in the approximately 60 years before that.

Regional measurements show consistent increases but are largest in Wellington, partly because land is subsiding and seas are rising. Some places, including Nelson, have experienced flooding during the highest high tides even in calm weather (MfE, 2017b).

NATURAL WATER FLOWS ARE PROJECTED TO CHANGE

Computer models can be used to predict future changes in river flows across the country. These models show that flows are likely to increase on the west coast of the South Island and in rivers that drain the eastern side of the Southern Alps. Flows are predicted to decrease on the east coast of the North and South Islands, and in Waikato and Northland but these predictions are less certain (Gluckman et al, 2017; Collins et al, 2018) (see figure 16).

Figure 16: Projected change in mean annual river flows between 1990 and 2090



Data source: NIWA (2016) adapted from Collins (2013)

Note: Based on the A1B emissions scenario from IPCC AR3 and general circulation models.

Snowfall is projected to decrease in the future. Computer models predict a 3–44 percent reduction at 1,000 metres by 2040. The projected decreases in snowfall will alter the flows in rivers and streams that originate in alpine areas. This could affect the large rivers and lakes we use for hydroelectricity and irrigation (Hendrikx et al, 2012).

Droughts will also have an impact on our river flows and groundwater, and affect parts of the country differently (Hendy et al, 2018). Extreme rainfall, drought, and sea-level rise may have cumulative effects that intensify the pressures of our activities on freshwater.

CHANGES TO THE NATURAL WATER MIXING IN LAKES ARE ALREADY BEING OBSERVED

The mixing of water layers is an important process for many lakes. Mixing moves nutrients within lakes, replenishes the oxygen dissolved in deeper water, and affects what types of species can live in a particular lake. The extent of mixing has seasonal patterns in many lakes.

Shallow lakes (less than 10 metres deep) are usually well mixed. Their surfaces are warmed by air, wind, and sunshine, which create currents and move water around. Deeper lakes (greater than 10 metres) are warmer near the surface but colder at the bottom. Denser cold water sinks to the bottom while warm water near the surface continues to be warmed by the sun. These effects combine to prevent mixing and result in layered or stratified water.

Long periods of stratification can cause a build-up of nutrients that may cause harmful algal blooms near the surface and stimulate the breakdown of organic matter in deeper water. These effects deplete the dissolved oxygen in a lake and reduce the water clarity. Lower clarity and less light reduce the amount of native aquatic plants, which provide habitat and replenish dissolved oxygen (Schallenberg et al, 2013; Canfield & Langeland, 1985; Gallegos, 2001). Fish that are trapped in low-oxygen conditions use more energy to breathe, and their behaviour, growth, and reproduction can be adversely affected (Franklin, 2014). Many bottom-dwelling species, including kōura and kākahi, cannot survive in low-oxygen conditions.

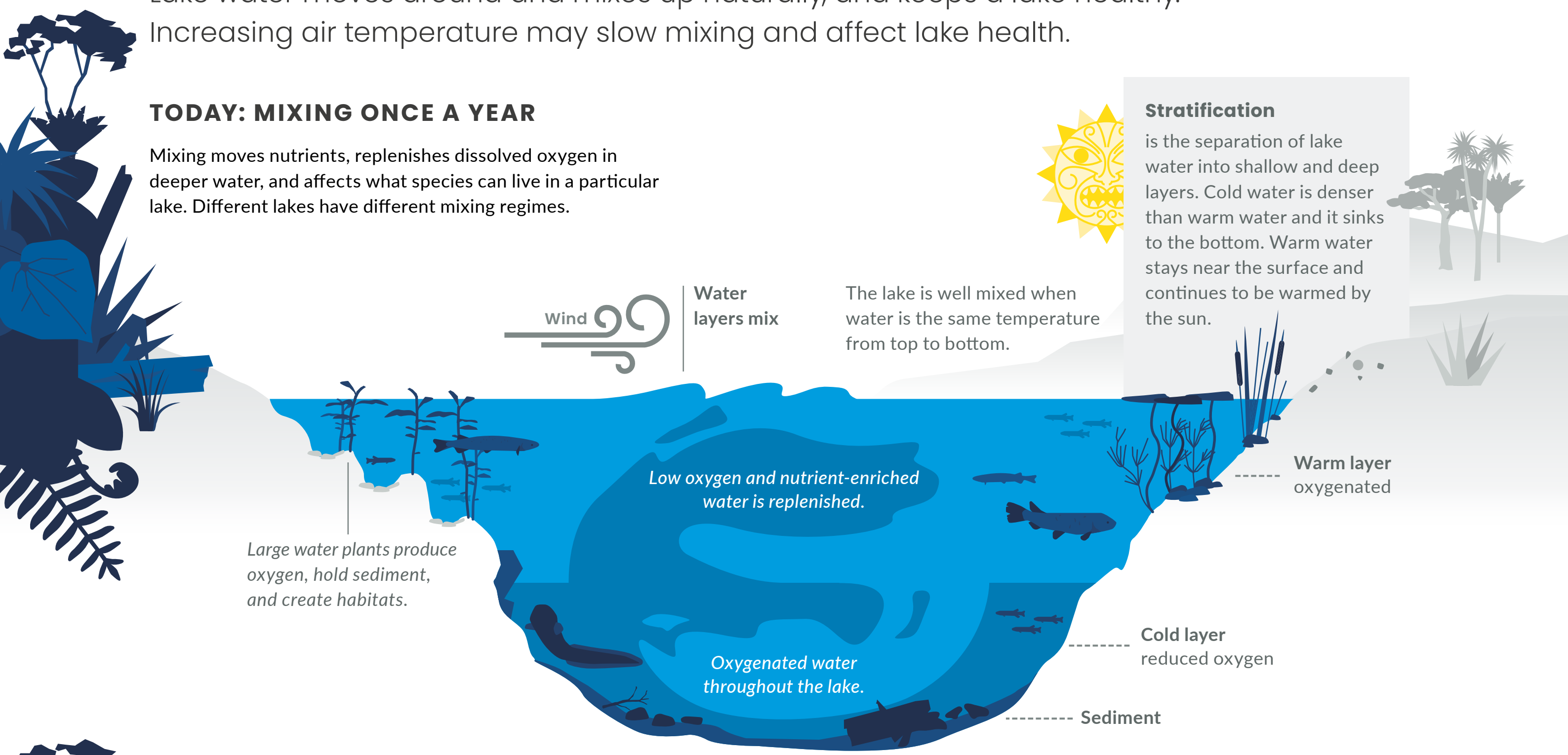
New Zealand's lakes have experienced more intense stratification in recent decades (Verburg et al, 2010). Stratification is expected to become more pronounced as our climate warms, and will have the greatest effect on our many shallow and coastal lakes, with temporary periods of stratification becoming longer and more frequent (Hamilton et al, 2013).

Climate change and lake health

Lake water moves around and mixes up naturally, and keeps a lake healthy. Increasing air temperature may slow mixing and affect lake health.

TODAY: MIXING ONCE A YEAR

Mixing moves nutrients, replenishes dissolved oxygen in deeper water, and affects what species can live in a particular lake. Different lakes have different mixing regimes.



WARMER FUTURE: PARTIAL OR NO MIXING IN A YEAR

Lakes may stay stratified for longer, with depleted dissolved oxygen. The species and mixing regimes vary in different lakes.

What has contributed to this issue?

GLOBAL GREENHOUSE GAS EMISSIONS HAVE INCREASED

The concentration of greenhouse gases in the atmosphere is increasing because of our use of fossil fuels (oil, coal, and gas) for heat, transport, and electricity generation. The rate of emissions is also rising (see *Environment Aotearoa 2019*). Global emissions have increased dramatically: half of all human-generated carbon dioxide emissions since 1750 have occurred since 1970. From 2000 to 2010, global greenhouse gas emissions increased by about 2.2 percent per year, compared with 1.3 percent per year from 1970 to 2000 (IPCC, 2014). Global carbon dioxide concentrations have risen by about 20 parts per million per decade since 2000. This rise is up to 10 times faster than any sustained rise during the past 800,000 years (Lüthi et al, 2008; Bereiter et al, 2015).

New Zealand's greenhouse gas emissions contribute a small proportion to the total global emissions, but we have high emissions per capita, mainly because of methane and nitrous oxide emissions from agriculture, our high rate of car ownership, and our aging vehicle fleet.

The sources of our greenhouse emissions and changes over time were reported in *Environment Aotearoa 2019* and *Our atmosphere and climate 2017*. Agricultural industries contribute the most (49.7 percent) to our total emissions. Household emissions increased by 19.3 percent between 2007 and 2017 (Stats NZ, 2019).

What are the consequences of this issue?

SPECIES DISTRIBUTION AND NUMBERS, AND ECOSYSTEMS WILL BE AFFECTED

Climate change is likely to shift where some native and introduced species are found. Higher water temperatures could cause species to be found further south but be lost from the northern parts of their current ranges. Affected species may include stream invertebrates like kōura, and native fish, trout, and salmon (Ryan & Ryan, 2006). Warmer temperatures could also reduce the number of young eels migrating upstream from the sea (August & Hicks, 2008).

Some native fish that migrate to the sea and back during their life cycle (including those caught as whitebait) are sensitive to several climate-driven changes. Water temperature influences their growth. Drought affects the survival of their eggs and the ability of hatched larvae to move downstream. Floods can wash out and destroy eggs that are laid in the vegetation beside a waterway (Goodman, 2018; Hayes et al, 2019). Floods are also a signal for these fish to migrate, so changes in the height and variability of floods could also affect these species (Goodman, 2018). Sea-level rise could affect the success of īnanga spawning by forcing the fish into upstream areas that do not have appropriate vegetation for egg-laying (Kettles & Bell, 2016).

Climate change is likely to cause major changes in ecological communities and interactions between species. The extent of these changes is unknown (McGlone & Walker, 2011). Climate change could also make ecosystems and organisms more susceptible to other stresses like pollution and fire.

Estuaries, lagoons, and wetlands near the coast are especially sensitive to climate change – they are exposed to changes in freshwater flows downstream as well as rising sea levels (Rodríguez et al, 2017). Coastal erosion and rising seas (which moves salt water into freshwater environments) may cause these ecosystems and their diverse habitats to be reduced or lost. This process will change the make-up of communities if some species are less salt-tolerant (MfE, 2017b). Even small changes in salinity (saltiness) can affect freshwater species and habitats (Schallenberg et al, 2003; Cañedo-Argüelles et al, 2013; Neubauer et al, 2013). Īnanga, for example, only spawn when the salinity is within a specific range (Goodman, 2018).

IMPACTS TO TAONGA SPECIES WILL AFFECT MĀORI CULTURAL AND ENVIRONMENTAL VALUES AND PRACTICES

Climate change will negatively affect Māori cultural and environmental values and practices, including those that relate to freshwater (King & Penny, 2006). Some vulnerable and taonga species may lose parts of their habitats or become extinct (Hennessy et al, 2007).

Local kaitiaki, hapū, and whānau fishers are already noting seasonal shifts that affect their kaitiakitanga practices and harvest times, as well as the indicators that signal them (Deep South National Science Challenge: vision mātauranga, 2018). Iwi, hapū, and whānau are using cultural health indicators to understand the changes and guide their work to restore, protect, and enhance vulnerable taonga species and ecosystems.

EXTREME WEATHER AND RISING SEAS WILL AFFECT OUR CITIES AND TOWNS

Extreme rainfall events are likely to become more common in most areas and could cause increased flooding (Royal Society Te Apārangi, 2016). Flooding can damage housing and transport, energy, stormwater, and wastewater systems. About 675,000 New Zealanders are estimated to live in areas prone to flooding from rainfall and overflowing rivers (Paulik et al, 2019). Also, many marae and urupā (burial sites) are on river flood plains or coastal areas that could be vulnerable.

Longer or more frequent droughts will put extra pressure on water supplies. Communities and infrastructure that depend on rain to supply drinking water may be at risk of running out. The cost of treating water during a drought may also increase (Hendy et al, 2018). Droughts are also likely to cause food shortages (Royal Society Te Apārangi, 2017).

As sea levels rise and weather events like storm swells and extreme waves increase, freshwater environments near the coast will become more salty as sea water enters through ground and surface water. This can contaminate drinking and irrigation water supplies and damage stormwater, wastewater, and water supply networks. A sea-level rise of 0.5–1.2 metres is projected to occur by 2100 (Kopp et al, 2014). If seas were to rise 1.5 metres this would put more than 6,000 kilometres of our drinking, waste, and stormwater pipes at risk from salt water, and cause damage from waves and flooding (Simonson & Hall, 2019).

RISKS TO HUMAN HEALTH FROM DISEASES COULD INCREASE

The health risks from drinking or swimming in water contaminated with pathogens (disease-causing microorganisms) such as *E. coli* and salmonella may increase if extreme rainfall and floods become more frequent (Britton et al, 2010; Gluckman et al, 2017, Hendy et al, 2018; Bennett et al, 2014; Cann et al, 2013) (see Pollution can have health risks).

Some regions and communities, including northern and remote eastern areas of New Zealand, are particularly vulnerable because their water supply systems are less developed. This can limit the availability of reliable and safe drinking water (King et al, 2010; Henwood et al, 2019).

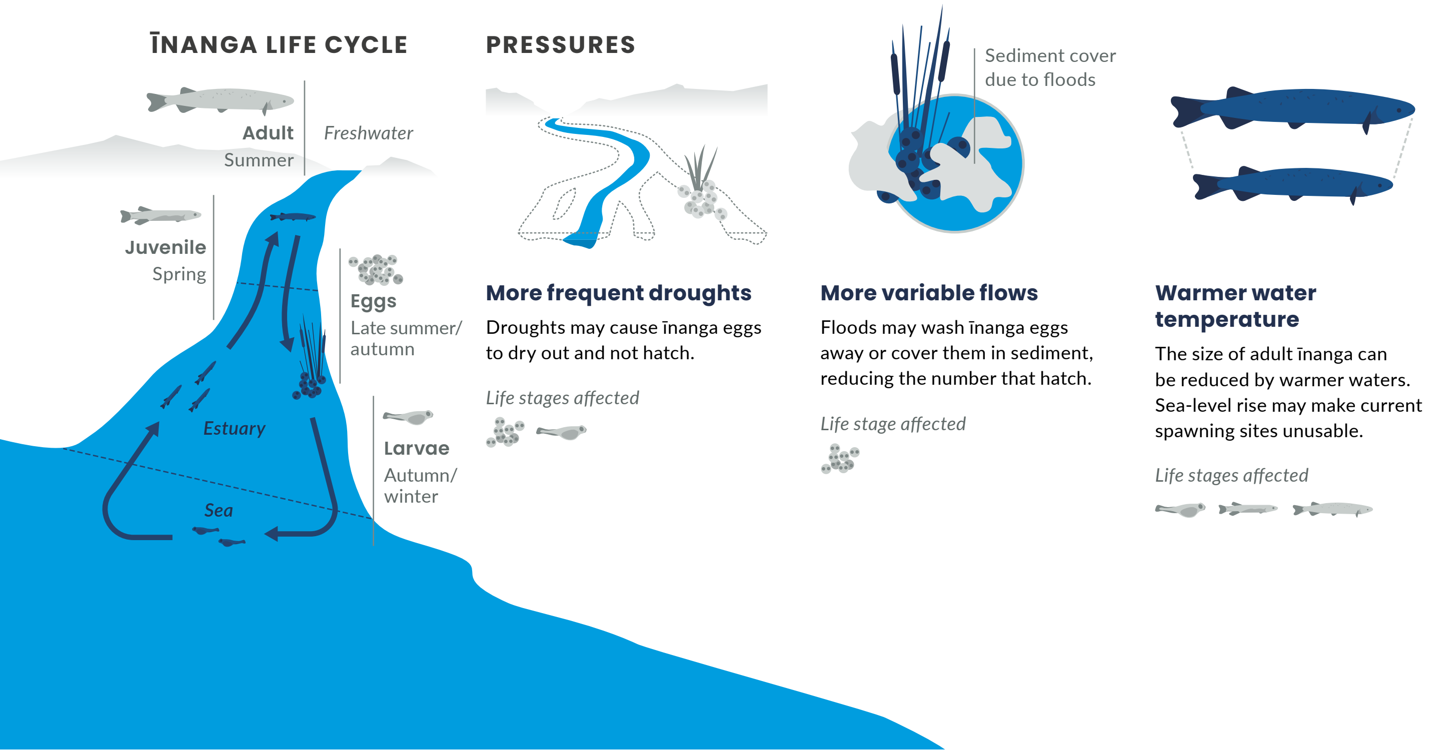
DEMAND FOR WATER IS LIKELY TO INCREASE AS AGRICULTURE IS AFFECTED BY DROUGHTS

A more variable climate will make droughts and floods more likely. Low rainfall and soil moisture reduce the growth and yield of crops, while long periods of drought can make plants wilt permanently. The timing of a drought makes a big difference to its effect. In late summer when plants have mostly finished growing for the season, a drought does not have the same devastating effect as a dry time in late winter or early spring, which cuts a plant's productivity (McGlone et al, 2010). Floods can also affect the growth and yield of crops, along with the distribution networks needed to move goods to market.

In dry years, more irrigation may be needed to make up for the lack of rainfall. Droughts are expected to increase the demand for water from agriculture and cause competition for this resource. The demand is likely to be greatest in regions that are already drought-prone because these regions are expected to experience more frequent and intense droughts (see Issue 3: Changing water flows affect our freshwater).

How climate change may affect īnanga

Different aspects of climate change are expected to affect īnanga during all their life stages.



Where are the gaps in our knowledge about this issue?

The science underpinning projections of the impacts from a warmed climate is increasing every day, but there are some areas where better knowledge is crucial to understand what we can expect.

HOW GLOBAL EMISSIONS WILL CHANGE IN THE FUTURE IS UNCERTAIN

The biggest gap in our knowledge is what the total amount of global emissions will be. The amount the climate and oceans warm, and the impacts on New Zealand from these changes, is dependent on the concentrations of greenhouse gases in our atmosphere. The uncertainty of the global emissions trajectory makes quantifying and planning for impacts difficult.

INFORMATION ABOUT THE COMPOUNDING EFFECTS OF CLIMATE CHANGE IS LIMITED

More information about the range of climate change effects on rivers, streams, lakes, and groundwater in catchments, and the interactions between them, is needed. This information would help us understand how and when changes in upstream areas affect downstream freshwater environments. A better understanding of the effects of changing temperatures on freshwater, and how warmer water affects lakes, rivers, and wetland ecosystems, is also needed.

Climate change is causing our oceans to warm and become more acidic. (See indicator: Ocean acidification.) However, there is currently limited information about how changes in the marine environment will affect freshwater fish (including taonga species like eels and īnanga) that spend some of their lives in the ocean. (See *Our marine environment 2019*.)

These issues have begun to be addressed, but a more thorough understanding of the many effects we can expect will improve our ability to plan for and adapt to the projected changes in our climate.

Towards a better understanding of our environment

▸ NIWA divers at Lake Brunner, West Coast South Island.

Photo: John Clayton, NIWA

Knowing enough to act

We face important choices about how to manage and respond to the combined impacts of our activities on the freshwater environment – including the consequences of climate change. When we understand our environment, we can manage it better by making decisions and adjusting our actions to reduce their negative impacts, stop further declines, and respond to unanticipated changes. The purpose of environmental reporting is to provide evidence to enable an open and honest conversation about those choices.

The data and science presented in this report is the best available. It has been both rigorously checked and peer reviewed. Inevitably gaps remain – and we continue to advance knowledge and fill them – but the gaps should not stymie or postpone action. Work is also underway to collect evidence to inform national policy statements and national environmental standards, and in time this evidence will also be available to support environmental reporting.

Improving our environmental reporting system

In his 2019 review of the environmental reporting system, the Parliamentary Commissioner for the Environment noted, "*If there is one thing that stands out from the first cycle of reports, it is the extent of what we don't know about what's going on with our environment.*" This report would be remiss if it focused only on reiterating the knowledge gaps that have been identified in previous reports. Instead, this section builds on the recommendations made in *Environment Aotearoa 2019* and highlights where future efforts should be targeted and where current initiatives signal hopeful advances.

Government agencies (including regional councils) are working together to develop a national environmental monitoring and reporting system, and a strategy to prioritise and fill important knowledge and data gaps. This needs time and investment, and will require addressing inconsistencies, bridging knowledge gaps, and listening to the voice of te ao Māori (as discussed below).

ADDRESSING INCONSISTENCIES

The commissioner wrote, "*When data is collected, attempts to construct a national-level picture can be thwarted because of inconsistencies in what, why, when and where something is measured.*"

Environmental data is collected for different reasons and by different people. Aggregating and synthesising that data to produce a consistent, nationally-representative dataset (and therefore assessment of the environment) is a significant challenge.

Consistency in data collection must continue to be a priority for monitoring and reporting on freshwater. Attempts to address systemic issues are underway in the form of the National Environmental Monitoring Standards that focus on developing standards for measured data. To date, a number of different standards and codes of practice have been developed, but more are needed (for recreational water quality, for example).

BRIDGING KNOWLEDGE GAPS

Our freshwater environment is a complex system where everything is connected. From the soils, rivers, lakes, wetlands, and groundwater to the plants and animals, and the people who live there. Both natural and human influences affect how water moves among these elements. Climate change is another influence – it is already affecting how much, when, and where rainfall, snowfall, and drought occur. Together, this dynamic combination makes it difficult to establish how our actions in one place affect other parts of the freshwater system over different time and spatial scales.

Knowledge is essential for unravelling this complexity and targeting what needs to be measured, how measures should be interpreted, and how to look ahead for the future. In our dynamic environment with emerging risks and new technologies, knowledge is also needed to advise what new data needs to be collected to keep pace with and anticipate change.

LISTENING TO THE VOICE OF TE AO MĀORI

Te ao Māori, a Māori world view, has a fundamental contribution to make to environmental reporting and environmental stewardship. Mātauranga Māori is a dynamic and evolving knowledge system that has qualitative and quantitative aspects. It also includes processes for acquiring, managing, applying, and transferring the knowledge it holds.

Mātauranga Māori has great potential for providing a system-wide view of the environment and people together. It offers a knowledge system that embraces the connectivity and complexity of freshwater as highlighted in Stepping into freshwater including the:

- concept of ki uta ki tai – from the mountains to the sea
- connections between people and place
- concept that small shifts in the mauri (life force) of any part of the environment can cause shifts in the mauri of related parts
- need for an intergenerational view over time.

When mātauranga Māori is used to inform reporting, appropriate emphasis must be given to information that is useful to Māori. This includes information about the state of taonga species and environmental resources, which is a commitment made by the Crown through the Treaty of Waitangi.

Bringing a stronger te ao Māori voice and using mātauranga Māori more centrally in environmental reporting must also ensure that Māori knowledge is respected, valued, and properly acknowledged. The need for appropriate long-term investment to build capacity and capability is also recognised.

Prioritising the knowledge we need most

Given the complexity of the environment and the number of gaps, the only practical way forward is to address gaps progressively or to target specific gaps.

Previous environmental reports (like *Environment Aotearoa 2019* and *Our marine environment 2019*) documented the priority knowledge gaps. In his 2019 review, the Parliamentary Commissioner for the Environment also recommended looking at past efforts (such as the *Environmental domain plan 2013*), using existing initiatives (like the Government's Data Investment Framework), and bringing in expertise from iwi and hapū, local and central government, and Crown research institutes.

At present, the environmental reporting system is based on what we know and what we already have. The Ministry for the Environment has initiated work to create a more integrated monitoring and reporting system as outlined in *Environment Aotearoa 2019*. This cross-sector initiative aims to set direction and agree some initial priorities such as core environmental indicators to start filling critical gaps in science, research, and data.

The basis of any prioritisation must also relate to the purpose of environmental reporting, which is to provide evidence on:

- what we have
- what we are at risk of losing (for its intrinsic value and in relation to our wellbeing)
- where and how we can make change.

To do this properly requires data that is measured at an appropriate scale to determine cause and effect relationships, and that is frequent and long term enough to enable issues and trends to be tracked over time. Data and knowledge is also needed for te ao Māori, to bridge the gap between people and place, and to understand the connections between the environment and our wellbeing.

How we could approach this task is set out in table 2.

Table 2: Addressing knowledge gaps

PURPOSE OF EVIDENCE	WHAT WE NEED TO KNOW	EXAMPLES OF PRIORITY GAPS
What we have (in the freshwater environment)	**Assess and monitor the extent, condition, trends, and ecological integrity (completeness) of freshwater habitats.**	▸ Improve the mapping and characterisation of the current state of freshwater species (including taonga species), habitats, and ecosystems. ▸ Improve reporting on freshwater trends so we know whether the health of a water body is declining, stable, or recovering. ▸ Use mātauranga Māori (like tohu, or seasonal signs and knowledge gathered over generations) in coordinated national monitoring systems.
What we are at risk of losing (in the freshwater environment)	**Understand and quantify the benefits of freshwater, including on wellbeing.**	▸ Develop indicators to measure the benefits of a freshwater ecosystem to us, including its intrinsic value. ▸ Develop indicators that reflect Māori values and customary practices and when they may be under threat.
	Understand rates of change and tipping points in freshwater so research and response work can be prioritised according to urgency.	▸ Understand the resilience of freshwater habitats to changes in land use. ▸ Understand how pollutants and other environmental variables interact (eg how changes in nitrogen, phosphorus, and flows affect algal growth). ▸ Understand where water bodies are approaching tipping points so there is time to act before a water body reaches a severely degraded state and recovery is long, expensive, or even impossible.
Where and how we can make enduring change (in our activities)	**Improve our understanding of the pressures on freshwater and their causes, including how they interact and intensify in places and over time.**	▸ Understand land-use changes and their effects over time, including variations in management intensity (eg stocking rate, fertiliser use) and seasonal variations. ▸ Understand how pollutants move through catchments, interact with different parts of the environment, and create legacy effects.
	Characterise the connections between the health of the freshwater environment and past, current, and future land uses in the short and long term.	▸ Quantify the effectiveness of existing and new land management interventions and technologies. ▸ Understand how climate change is expected to affect freshwater quality, quantity, and use over time.
	Investigate how mātauranga and tikanga Māori can help make change.	▸ Understand how Māori communities are putting kaitiakitanga into practice around New Zealand to restore freshwater.
	Understand how to build social cohesion and readiness for change.	▸ Explore ways to support and motivate behaviour change and resilience in people, communities, and society.

Future opportunities for improved reporting

NEW TECHNOLOGIES, SMART SENSING, AND CITIZEN SCIENCE

The evolution of environmental reporting is already underway. Each successive report in New Zealand's Environmental Reporting Series draws on data and knowledge that is more comprehensive and complete, as well as knowledge that is gradually enabling us to identify trends and focus our stewardship of the environment in the right places.

Worldwide, technology is advancing rapidly and offering step-changes in how we collect and analyse data. This includes new technologies such as aerial electromagnetic technologies to collect high-resolution data related to aquifers: where they are fed from, how they behave, and where they flow to. Land Information New Zealand is leading work to generate nationally consistent, high-resolution topography data through laser surveys (LiDAR). Smart sensors are being used to remotely capture data and monitor change, including multispectral cameras that monitor streams for algae. Remotely operated vehicles can observe changes in lakes and their shorelines, and satellite remote sensing can determine the colour of a lake or changing land use during the year.

Citizen science, where the public contributes to data collection and analysis (usually through the internet), has also extended our ability to gather data and monitor change. Examples include the Whitebait Connection that collects indicators to assess and monitor the health of streams, rivers, lakes, and wetlands, and NIWA's Fish Passage Assessment Tool where in-stream structures that could be barriers to fish are mapped across New Zealand.

INTEGRATING MEASUREMENTS FOR A HOLISTIC VIEW OF THE ENVIRONMENT

Freshwater ecosystems are complex, with water chemistry, water quality, physical habitats, different species, and diverse processes all interacting with one another. Environmental indicators offer a way of simplifying this complexity by measuring what is happening in specific parts of the environment. The concentrations of nitrogen, phosphorus, and sediment for example, are indicators that point to aspects of water quality in our rivers and lakes.

To understand a whole ecosystem requires an integrated measurement system that reflects its complexity, dimensions, and dynamics. The Ministry for the Environment's Framework for Assessing Biophysical Ecosystem Health (Clapcott et al, 2018) can help identify indicators and begin to understand how they fit together, as well as identifying data gaps. The framework requires testing to finalise how specific measures are integrated, so it is not currently used in environmental reporting. It does provide a glimpse into how reporting on the environment as a system could be achieved in the future.

INNOVATIVE APPROACHES TO ENVIRONMENTAL RESEARCH

Advanced modelling is improving our understanding of overlapping issues and cumulative effects in the freshwater environment. For example, models are being developed that allow the effects of several pressures (such as changes in land use and climate) to be considered together (Elliott et al, 2017).

New research programmes are contributing valuable freshwater-related data and knowledge. Each initiative is helping to build a richer understanding of our complex freshwater environment. Some examples (and there are many more) include:

- Using sediment cores and environmental DNA to assess the health of 380 New Zealand lakes and the causes of change in the past 1,000 years: Lakes380.
- Work to better understand how lakes respond to pressures and land management: LERNZ Lake resilience programme.
- Research to identify the risks of emerging contaminants in freshwater and marine ecosystems to native species: Cawthron Institute.
- Options to improve land-use planning by making the consequences of our land management clearer and more predictable: Our Land and Water National Science Challenge.
- Identifying potential sources of faecal contamination in our waterways and the presence of naturalised *E. coli:* Our Land and Water National Science Challenge.

Environmental reporting series, Acknowledgements, and References

Hutt River, Kaitoke Regional Park.

Photo: Ministry for the Environment

Environmental reporting series

PREVIOUS REPORTS

- Our marine environment 2019
- Environment Aotearoa 2019
- Our air 2018
- Our land 2018
- Our atmosphere and climate 2017
- Our fresh water 2017
- Our marine environment 2016
- Environment Aotearoa 2015

ENVIRONMENTAL INDICATORS

New and updated for *Our freshwater 2020*:

- Conservation status of indigenous freshwater species
- Lake submerged plant index
- Deposited sediment in rivers
- Freshwater physical habitat
- Consented freshwater takes
- Modelled lake water quality
- River water quality: heavy metals
- Groundwater quality

Indicators updated for *Environment Aotearoa 2019*:

- Fertilisers – nitrogen and phosphorus
- River water quality: nitrogen
- River water quality: phosphorus
- River water quality: clarity and turbidity
- River water quality: *Escherichia coli*
- River water quality: macroinvertebrate community index
- Nitrate leaching from livestock
- Livestock numbers
- Irrigated land

Indicators last updated for *Our fresh water 2017*:

- Selected barriers to freshwater fish in Hawke's Bay
- Freshwater pests
- Cultural health index for freshwater bodies
- Groundwater physical stocks

OTHER INDICATORS REFERENCED IN THIS REPORT:

- Predicted pre-human vegetation
- Exotic land cover
- Indigenous land cover
- Urban land cover
- Wetland extent
- Agricultural and horticultural land use
- Rainfall
- Temperature
- Drought
- Annual glacier ice volumes
- Coastal sea-level rise
- Coastal and estuarine water quality
- Heavy metal load in coastal and estuarine sediment
- Ocean acidification

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INFOGRAPHICS

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