Environment Aotearoa 2019

New Zealand's Environmental Reporting Series

Ministry for the Environment
Manatū Mō Te Taiao

Stats NZ
Tatauranga Aotearoa

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Cover photo: Whangaruru Harbour, Northland. Credit: photonewzealand

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Message to our readers

We are proud to present *Environment Aotearoa 2019,* our three-yearly report on the state of the environment in New Zealand.

Our ministries work together to produce environmental reports every six months, focussed on a domain such as air, marine, or land. This report, by contrast, takes a broader view of the environment as a whole by reporting on nine priority issues for us in 2019. The issues typically involve more than one domain.

To identify the nine issues, our scientists and data analysts reviewed the most recent domain reports and worked with an independent, expert science panel.

The data and science presented in the report is up to date, fully explained, and rigorously checked to the highest standards. The information is factual and trustworthy, and links to the analysis and data sources are provided throughout the report.

Taken together, the issues clearly show that the choices we have made about the way we live and make a living are having a significant impact on our environment and therefore on the things we value. They highlight areas where we need to pay close attention.

Choosing and making appropriate responses to the issues is not straightforward: the New Zealand economy has been built on our environment, our population continues to grow, and climate change is amplifying many current pressures. These are complex challenges that require serious consideration.

We believe now is the time to engage in conversations as a country about what we value, what consequences we are prepared to accept, and the kind of country we want our children and mokopuna to inherit. *Environment Aotearoa 2019* will add value to those conversations.

The report also points out how much we don't know about many aspects of our environment. While we have considerable knowledge in many areas, understanding our environment as a whole – and its many interactions – is a much bigger challenge. *Environment Aotearoa 2019* suggests some steps that could be taken to improve our knowledge and reporting system so we are better equipped to understand the effects of our actions, and what we need to do about it.

Whatever your interest or connection to the environment, we trust that reading this report or its summary will support you to ask questions and be empowered in conversations about how to enjoy, protect, and prosper in our Aotearoa New Zealand.

Vicky Robertson
Secretary for the Environment

Liz MacPherson
Government Statistician

PART 1

About Environment Aotearoa 2019

This part of the report sets the scene and explains the approach – including how the nine priority issues were chosen. Scope, context, and governing legislation are also presented here.

Photo credit: photonewzealand

The green of a kākāpō feather, scarlet pōhutukawa, summer cicada song, and a dolphin's silver flash – these are the colours and sounds of our Aotearoa New Zealand.

Aotearoa New Zealand

Our land and sea are unique and very special, having evolved so distinctly and separately from the rest of the world. From the time our ancestors first stepped onto its shores, the land of the long white cloud has provided nourishment, protection, and resources to its inhabitants. People have become part of the environment and shaped it, modifying the land to grow food, building houses, and establishing settlements, roads, and infrastructure.

The relationship and connection we have with the environment goes well beyond the goods and services we receive from it, like food, fuel, and clean water. Our environment is where we stand, our tūrangawaewae – where we live, learn, work and earn a living, play, and socialise. It is our home and our identity, and the foundation of our national culture and tradition.

As tangata whenua – people *of* the land – Māori have a distinct and special connection to the land. Māori identity, well-being, knowledge, and language systems, and the ways the culture is nourished, are indivisible from the health of Papatūānuku, the Earth Mother.

The whakapapa Māori have with the environment embeds humans in the environment. It ensures the unique connection of tangata whenua is respected and brings a way of thinking that helps us all see ourselves as a part of, not apart from, the environment.

Te ao Māori, the Māori world view, has an important place in environmental reporting in New Zealand and is intended to be a significant voice in this report. Wherever possible, it has been given space to speak about the state of the environment. We recognise that there is no one voice of Māori, nor are the voices presented in *Environment Aotearoa 2019* as strong as they could be.

The relationship New Zealanders have with the environment is dynamic, but the ways we are modifying natural ecosystems to meet our needs in 2019 are having profound effects. Some parts of our environment are in good shape, others less so.

How we go forward from here is up to all of us.

Background to this report

This report is different to the Ministry for the Environment and Stats NZ's regular six-monthly reports that cycle air, freshwater, marine, atmosphere and climate, and land domains. It is a synthesis report – bringing together all the domain reports to help us step inside and view our environment as a whole, in all its complexity.

The Environmental Reporting Act of 2015 (the Act) requires the Secretary for the Environment and the Government Statistician to produce such a synthesis state of the environment report every three years. Its purpose is to present 'a diagnosis of the health of our environment' to enable us as a nation, as iwi, as whānau, as communities, sectors, and individuals to understand the things that affect, or potentially affect the health of our environment. The last full report was *Environment Aotearoa 2015* (before the Act), and before that versions in 2007 and 1997.

So while not suggesting responses (which are out of scope under the legislation), *Environment Aotearoa 2019* provides 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.

The data used in *Environment Aotearoa 2019* is drawn from the most recent domain reports *(Our marine environment 2016, Our fresh water 2017, Our atmosphere and climate 2017, Our land 2018, and Our air 2018)*. The evidence base for this report is drawn from a set of environmental indicator web pages that are available on the Stats NZ website. Of the environmental indicators used in this report, 18 are new or have been updated since they were last used in a domain report, as new data has become available. (See the **Environmental indicators section** for links to all new and existing indicators referred to in this report.)

To provide the best picture in this report, including of emerging concerns, the report also draws on a body of evidence, such as government reports and peer-reviewed science papers. While the report tells a national story, it acknowledges important regional variations where possible.

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.

The timeframes used throughout the report are largely dictated by the data that is available. Where possible, data is used to highlight significant periods of change. The time before humans arrived is sometimes used as a benchmark when the concept of 'departure from natural conditions' is discussed, to help characterise the significance of change.

In this report we have used the term 'farming' to refer to pastoral farming (including dairy, beef, sheep, and other livestock), horticulture, and arable cropping. When quoting from the body of evidence, we have used the term 'agriculture' to describe the same activities, where it is a direct quote from the source document.

Although the report does not specifically address uncertainty in measurements or conclusions in most instances, it acknowledges that it is present in all data and analysis. Where there is enough uncertainty to significantly impact the understanding of an issue it is highlighted as a knowledge gap.

This report has three main parts:

- 'About Environment Aotearoa 2019' helps to orient us and explain our environment.
- The second part 'Themes and issues' uses five themes to present nine priority environmental issues.
- The last part 'Towards a better understanding of our environment' sets out the challenges we must overcome so future decisions about the environment are as effective as they can be.

A whole system approach

Our environment holds people, plants, animals, soil, fresh water, seas, and sky. In the domain reports, we explore just one element of the environment by considering its state, how it is changing, and the impacts these changes will have. In this synthesis report, however, five broad themes are used to look beyond single domains to the whole interconnected system.

Theme 1: Our ecosystems and biodiversity

An ecosystem describes a community of people, plants, and animals and how it interacts with a physical environment, like soil, water, and air. Ecosystems provide many benefits that are integral to our well-being. These include goods and services like food, recreation, pollination, and erosion control. Biodiversity is one of the main health indicators for ecosystems.

Theme 2: How we use our land

The way we use our land and what happens when we change from one land use to another can have significant effects on the health of our ecosystems, and the benefits we get from them. Effects can be on the land itself but also extend to connected streams, estuaries, and seas.

Theme 3: Pollution from our activities

Our environment is polluted when substances (waste, nutrients, contaminants) and energy (heat, sound, radioactivity) are added faster than they can be dispersed, recycled, decomposed, or stored. Since many ecosystem processes operate as cycles (nutrients, water) pollutants can have long-lasting effects on ecosystems and our well-being.

Theme 4: How we use our freshwater and marine resources

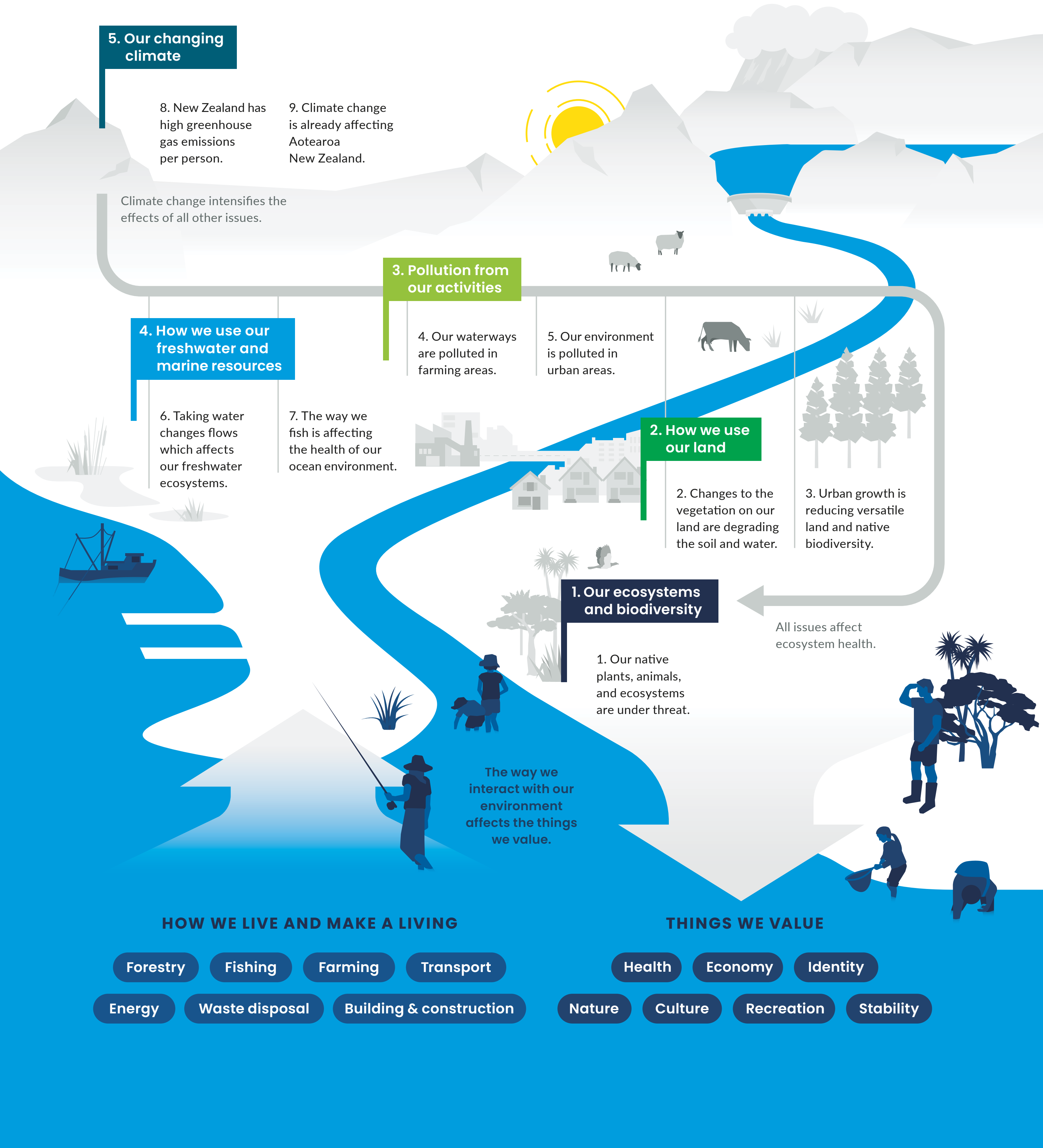
Our rivers, lakes, estuaries, and oceans are valued for their ecosystems and the services and resources they provide. The way we interact with these resources (taking water for irrigation, fishing for example) can compromise the health of the ecosystems and their ability to provide the cultural and socio-economic benefits we depend on.

Theme 5: Our changing climate

Climate, and changes in climate, are affecting every ecosystem and some of the things we value. Here, our role as both influencers and recipients of climate is explored. Placing climate change as the final theme is also a chance to show how this unprecedented global disruption will affect every other issue.

Environment Aotearoa 2019 themes and issues

The themes and issues in this report show how the way we live and make a living affects our environment and the things we value.



A focus on what matters

When reviewing *Environment Aotearoa 2015*, the Parliamentary Commissioner for the Environment (PCE) 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).

A focus on issues was adopted for this report. It has enabled different environmental concerns to be prioritised individually but it also demonstrates how a single issue can cross many domains.

There are many environmental issues in our country. To narrow down the issues to those included here, findings from each of the five most recent domain reports were reviewed, ranked, and prioritised. 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?

These criteria were informed by the suggestions of the PCE in *The state of New Zealand's environment: Commentary by the Parliamentary Commissioner for the Environment on Environment Aotearoa 2015* and are consistent with the selection criteria used to highlight the top findings in the domain reports.

The four criteria plus an indication of related knowledge gaps are used to summarise why each issue matters.

An independent panel of scientists verified the selection process to ensure criteria were appropriately applied against the issues. The relevance of the nine issues to mātauranga Māori, kaitiakitanga, and other cultural values was also considered by Māori researchers and practitioners.

The priority issues are not an exhaustive list of all the pressures our environment faces. Some have an impact on the environment but are not featured in this report as they do not rank as highly against the criteria as other issues. Mining for example, is not included because of its localised nature.

Building a scientifically credible report

This report and all the associated indicator pages, graphics, and summary have been compiled by a team of scientists and data analysts from the Ministry for the Environment and Stats NZ.

Early in the project an independent science panel, composed of four of New Zealand's top scientists, was established through a competitive process. The panel, chaired by the Departmental Chief Science Advisor, advised and provided independent review of the structure, all content, and findings.

Where limited national data was available, more information has been provided using a 'body of evidence' approach. This approach looks across the science system and draws on the scientific literature and the combined results of multiple scientific studies to support findings.

To keep pace with developments since previous reports, some new data is included and different methods for collecting and interpreting data is presented (eg measuring trends for water quality).

All data used, as well as the body of evidence references have been corroborated and checked for consistency.

A steering group, representing both Ministry for the Environment and Stats NZ, provided oversight to ensure *Environment Aotearoa 2019* was produced in a way that is transparent and robust, and can therefore be a valuable and trusted source of information.

As an issue is defined as a change in the state of the environment, caused by human activities (pressures) and having consequences (impacts), some environmental problems are not included. An example is plastic waste, which is considered as a pressure but not an issue, despite recently being ranked as the number one environmental concern by the public (Colmar Brunton, 2019).

Each issue addresses six questions:

- Why does this issue matter?
- What is the current state of this issue?
- 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?

PART 2

Themes and issues

Using five broad themes, this part of the report presents nine priority environmental issues for us as a nation in 2019. Each issue includes information about why it matters, what has changed, and the consequences.

Photo credit: Ministry for the Environment

THEME 1

Our ecosystems and biodiversity

Photo credit: iStock

The biodiversity of Aotearoa New Zealand is essential to our culture, identity, and well-being. Our biodiversity – the whole variety of native plants, animals, microorganisms, the genes they contain, and the ecosystems they create – is unique to New Zealand and irreplaceable.

Because of its evolution as a group of very isolated islands, New Zealand has a high proportion of native species that are found nowhere else in the world. Many lack defences or strategies for dealing with mammalian predators (like stoats or possums) and herbivores (such as deer), since they evolved almost completely without them. Our native species and ecosystems are therefore particularly vulnerable to introduced species and diseases, human activities, and changes to their habitat from climate, landscape changes, and pollution.

In this theme, the state of our biodiversity is reported, considering the loss and risk to species and ecosystems across land, freshwater, and marine environments. The main human activities that impact on ecosystems and species are also discussed, including what changes in biodiversity mean for our well-being.

Our native plants and animals, and the communities they form, are affected by all the issues identified in this report. When the pressure from these issues is combined with the effects of introduced species (a significant current pressure for terrestrial, freshwater, and marine environments) the compounding pressures intensify the impacts on animal and plant communities.

For other issues that impact biodiversity see:

- **Issue 2:** Changes to the vegetation on our land are degrading the soil and water
- **Issue 3:** Urban growth is reducing versatile land and native biodiversity
- **Issue 4:** Our waterways are polluted in farming areas
- **Issue 5:** Our environment is polluted in urban areas
- **Issue 6:** Taking water changes flows which affects our freshwater ecosystems
- **Issue 7:** The way we fish is affecting the health of our ocean environment
- **Issue 9:** Climate change is already affecting Aotearoa New Zealand.

ISSUE 1

Our native plants, animals, and ecosystems are under threat

Our unique native biodiversity is under significant pressure from introduced species, pollution, physical changes to our landscapes and coast, harvesting of wild species, and other factors. Almost 4,000 of our native species are currently threatened with or at risk of extinction.

Why does this issue matter?

SPATIAL EXTENT

All of New Zealand's land, freshwater, and marine environments are affected.

DEPARTURE FROM NATURAL CONDITIONS

There are major differences from what things were like before humans arrived.

IRREVERSIBILITY

Many aspects are irreversible – species extinction is forever. Many declines may be reversed with substantial effort.

IMPACTS ON WHAT WE VALUE

It can potentially have significant impacts on our well-being, identity, and cultural values.

KNOWLEDGE GAPS

Large gaps in knowledge on the state of our biodiversity and the condition of many ecosystems may limit our ability to understand and reduce future declines.

What is the current state of this issue?

The biodiversity of Aotearoa New Zealand is unique and vulnerable to changes we make to the environment. A high proportion of the species found here are found nowhere else in the world. Some of these irreplaceable species include:

- kākāpō, the world's only nocturnal flightless parrot
- lancewood/horoeka, a tree that has dramatically different young and mature forms
- giant wētā/wētāpunga, insects that can weigh more than a mouse
- Māui dolphin, the world's smallest dolphin.

Biodiversity in all our land, freshwater, and marine environments has declined significantly since the arrival of humans. This downward slide includes the extinction of numerous native species, an increased risk of extinction for many surviving species, and a reduced range of ecosystems, both by type and area. These changes represent a major departure from what things were once like.

The changes have sometimes been dramatic, with species becoming extinct and the degradation of entire ecosystems. Other changes, though less dramatic, are very serious, like non-native species becoming established here or a decline in the health of ecosystems.

While most measures show a loss or increased risk to our biodiversity, some intensive conservation efforts provide a few brighter points.

Measuring ecosystem health

An ecosystem describes the interrelationships between living organisms and the non-living environment. A healthy ecosystem contains a variety of native species, as would be found in that setting (eg river, forest, wetland, dunes) when it is in a pristine condition, unaffected by human disturbance.

Several components are assessed to describe ecosystem health. These include the abundance and diversity of species present (biodiversity), the availability and quality of habitats, and how completely the important ecological processes are sustained (eg decomposition, nutrient cycling, and connections between levels of the food chain).

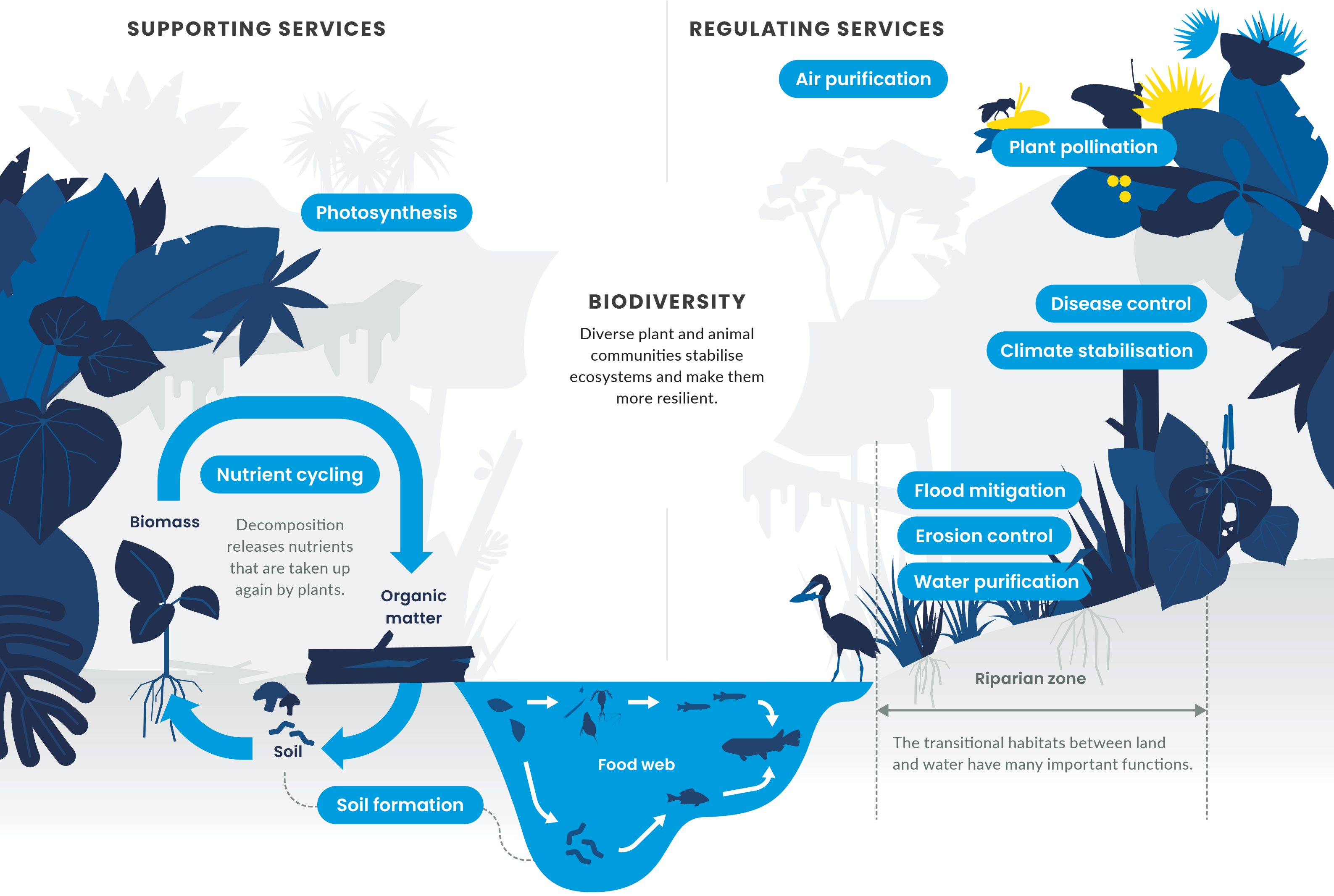
Measuring these components is complicated and varies for different types of ecosystems. In freshwater ecosystems, for example, five components are recognised as important for assessing health (Clapcott et al, 2018):

1. **Aquatic life:** The abundance and diversity of biota including microbes, invertebrates, plants, fish, and birds, and any invasive species present.
2. **Habitat:** The physical form, structure, and extent of the waterbody, its bed, banks and margins, riparian vegetation, and connections to the floodplain.
3. **Water quality:** The physical and chemical measures of the water, including the presence of pollutants (eg excessive nutrients).
4. **Water quantity:** The extent and variability in the level or flow of water, including connections between different water bodies.
5. **Ecological processes:** The interactions among biota and their physical and chemical environment.

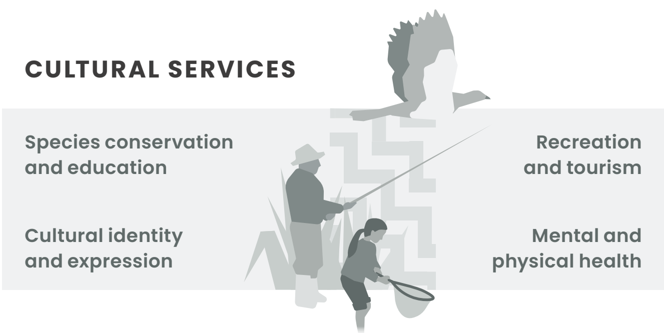
At present, sufficient high-quality data is generally not available to describe all the aspects of a healthy ecosystem. This means it is only possible to assess some aspects of ecosystem health, and not its entirety.

Ecosystems

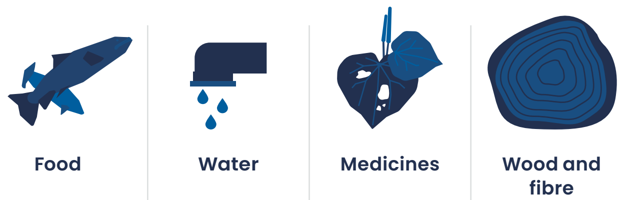
A healthy ecosystem provides many benefits (services) that are essential for native plants and animals as well as our own well-being.



CULTURAL SERVICES



PROVISIONING SERVICES



CULTURAL VALUE

A healthy ecosystem enables tangata whenua to connect with the environment and each other. It provides sustenance and materials for cultural practices and expressions like waiata, karakia, and wairua.

ECOSYSTEM HEALTH

Measuring the overall condition of our ecosystems is more than counting the number of different species. Ecosystems are complex and made of many interacting biological and physical components that can all be affected by environmental changes.

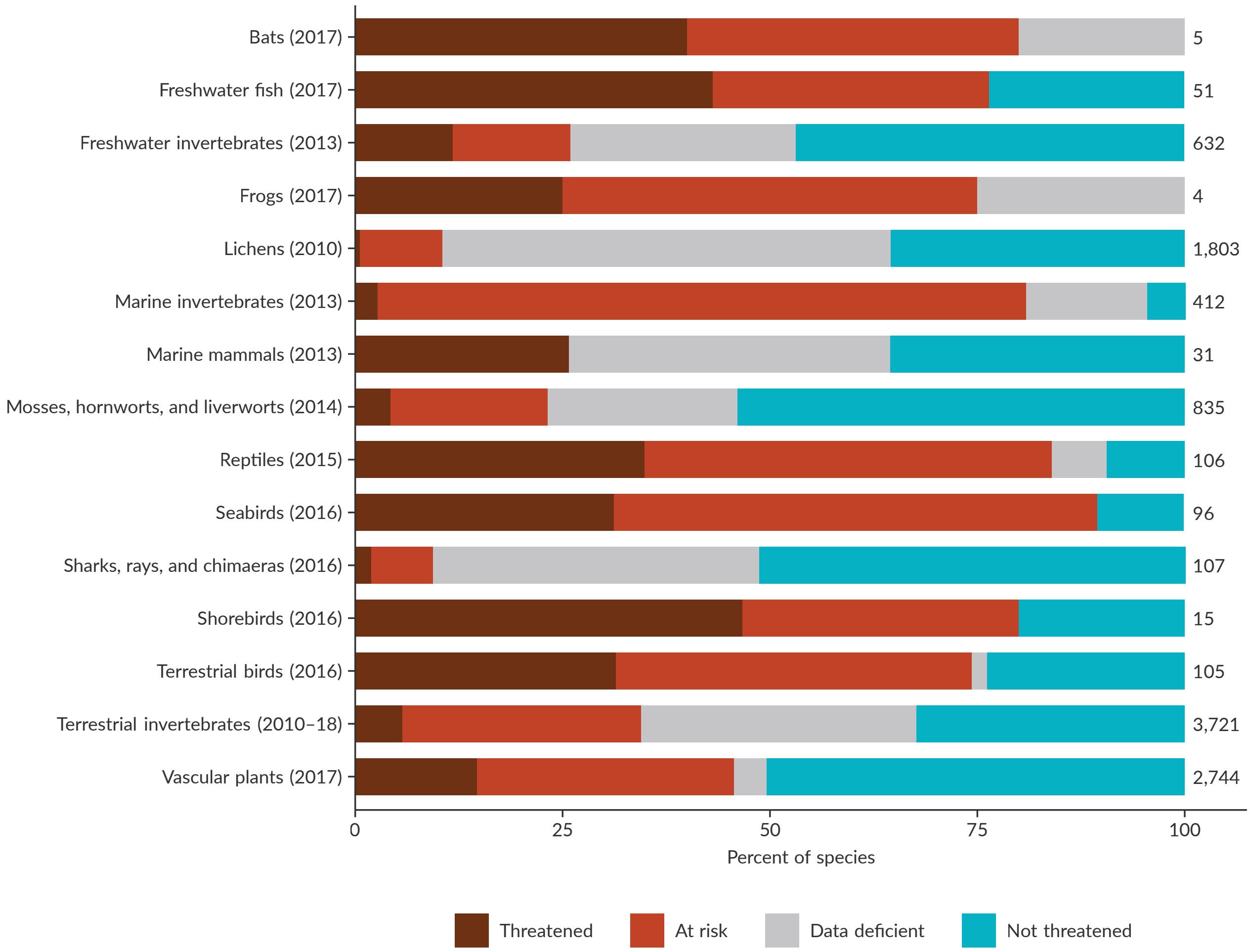
NATIVE SPECIES AND THEIR HABITATS HAVE BEEN LOST

At least 75 animal and plant species have become extinct since humans arrived in New Zealand. This includes 59 bird species (Robertson et al, 2017), 3 frogs (Newman et al, 2013), 2 reptiles (Hitchmough et al, 2016), 4 insects (Leschen et al, 2012), and 7 plants (de Lange et al, 2018). All moa species are now extinct – an event recognised as the most rapid extinction of a large animal species caused by humans (Allentoft et al, 2014)

The New Zealand Threat Classification System (NZTCS) is used to assess the risk of extinction of New Zealand species (in this context, species is used to refer to plant and animal species, subspecies, and varieties). The conservation status of about 10,667 native species is known, which is only a fraction of the total number of species thought to exist in our land, freshwater, and marine environments. The NZTCS showed that 3,747 of New Zealand's native species are either at risk or threatened with extinction (as reported between 2010 and 2018). (See indicators: Conservation status of indigenous freshwater species, Conservation status of indigenous land species and Conservation status of indigenous marine species.)

For our marine species, 90 percent of seabirds, 80 percent of shorebirds, and 26 percent of native marine mammals are either threatened with or at risk of extinction. The latest estimates (Baker et al, 2016) suggest that only 63 individuals of the endemic (found nowhere else in the world) Māui dolphin remain. In addition, 9 percent of sharks, rays, and chimaeras (ghost sharks) were also classified as threatened with or at risk of extinction extinction (see figure 1). (See indicator: Conservation status of indigenous marine species.)

Figure 1: Conservation status of native species by species group



Data source: Department of Conservation

Note: Only known, native, resident, living species are included. Total species are listed to the right of bars.

Freshwater species also face risks. In 2017, 76 percent of our native freshwater fish were either threatened with or at risk of extinction. More than 25 percent of native freshwater invertebrates had a threatened or at risk conservation status in 2013 (see figure 1). Almost 33 percent of the plant species that depend on fresh water are classified as threatened or at risk (Gerbeaux et al, 2016). Of these, almost 20 percent were in the highest risk category, ie nationally critical (Gerbeaux et al, 2016).

Many of our land species face extinction too. Eighty percent of bats, 84 percent of reptiles, 74 percent of terrestrial birds, and 75 percent of frogs are currently threatened with or at risk of extinction. This risk extends to land plants: 46 percent of vascular plants, 23 percent of mosses, hornworts, and liverworts, and 10 percent of lichens are threatened with or at risk of extinction (see figure 1).

Many of the habitats – land, freshwater, and marine – that our native species rely on have been reduced or damaged (see What has changed? and Issue 2: Changes to the vegetation on our land are degrading the soil and water). Such large-scale changes can make some species particularly vulnerable to extinction and lead to the degradation of entire ecosystems.

RARE ECOSYSTEMS ARE THREATENED OR DEGRADED

For a small country, we have a very diverse range of unique ecosystems. Some are naturally rare (there were only a few even before people arrived), while others are uncommon internationally. The braided rivers in Canterbury and Otago are one example (Grove et al, 2015; O'Donnell et al, 2016; Williams et al, 2007). Not only are these ecosystems rare, but they also contain unique plants and animals, many of which are threatened (eg O'Donnell & Hoare, 2011; O'Donnell & Moore, 1983).

Almost two-thirds of our rare ecosystems are threatened with collapse. The rate is higher for rare coastal ecosystems (like coastal turfs and shingle beaches), where more than three-quarters are threatened. (See indicator: Rare ecosystems.)

THE HEALTH OF OUR FRESHWATER COMMUNITIES IS MIXED

Assessing the health of an ecosystem is complicated and requires many different components to be evaluated. In most cases, the information that would allow an assessment of the overall health of all our ecosystems is lacking. However, some information that is useful for understanding the health of rivers and lakes, and the communities of plants and animals that live there, is available. The ecological health of rivers is partly informed by the macroinvertebrate community index (MCI), which is based on the presence or absence of different organisms (like mayflies and stoneflies) in a waterway.

More than three-quarters of New Zealand's total river length had excellent or good MCI scores for 2013–17 (see figure 2). The MCI results show a relationship between the health of macroinvertebrate communities and the land use of the area. Compared with areas with native land cover, median MCI scores are 31 percent lower in urban areas and 15 percent lower in pastoral farming areas. (See indicator: River water quality: macroinvertebrate community index.) (See Issue 4: Our waterways are polluted in farming areas and Issue 5: Our environment is polluted in urban areas for further information that influences the ecological health of our rivers.)

The submerged plant index (SPI) is one measure of a lake's ecological health and reports the diversity and extent of native and invasive plants. SPI data is only available for 210 lakes – a small percentage of the total number in New Zealand (there are 3,820 lakes greater than 1 hectare in size in New Zealand (Schallenberg et al, 2013).

Between 2007 and 2016, 33 percent of monitored lakes were in excellent or high ecological condition, 31 percent were in moderate condition, and 36 percent were in poor ecological condition or were entirely without submerged plants. Nearly all (90 percent) of the monitored lakes with vegetation had some non-native plant species present. (See indicator: Lake submerged plant index.)

Macroinvertebrate community index (MCI)

Macroinvertebrates (animals without a backbone that are visible with the naked eye, like insects or snails) spend much of their lifecycle in a relatively small portion of a stream. They respond differently to changes in conditions (like pollutants, water flows, and habitat), so the presence or absence of particular species can provide an indication of the health of the living species in a waterway.

Different species are assigned specific scores that relate to their level of tolerance to changes in the environment. A final MCI score for a site is based on the average score of the various macroinvertebrates found there.

Braided rivers: Gravel, water, birds, and farming

Lower reaches of the Waimakariri River.
Photo credit: Lloyd Homer, GNS Science

Like ribbons draped across the Canterbury Plains, braided rivers carry water eastwards from the Southern Alps to the sea. Traversing alpine, forest, farm, and coastal landscapes, these rare ecosystems are forever changing, with floods lifting gravel from temporary islands and depositing it further downstream. A completely different pattern of water channels and islands can be created by a large flood.

Braided rivers are rare internationally and 60 percent of New Zealand's braided rivers are found in Canterbury (Gray et al, 2018; Gray & Harding, 2007). More than 80 bird species feed and breed in braided rivers, including more than 20 wetland birds (O'Donnell & Hoare, 2011; O'Donnell & Moore, 1983). Some nest on the gravel islands – just a few speckled eggs protected only by their camouflage and watchful parents.

With almost no vegetation, braided river islands allow nesting birds to keep watch for predatory birds like southern black-backed gulls and swamp harriers. Being surrounded by water, islands also offer some defence from predators like rats and stoats, and a supply of food including mayflies, stoneflies, and small fish.

A number of these bird species are rare and also threatened: black stilt, wrybill, black-billed gull, and black-fronted tern all have nationally critical, vulnerable, or endangered threat classifications. Many of the fish, insects, spiders, and plants adapted to living in braided rivers are also rare and threatened (O'Donnell et al, 2016).

Relatively few braided rivers are in a natural condition today. Taking water from a river for other uses, including irrigation, alters the flow and causes significant changes to the river habitat. Dams also have an effect by making the flow more uniform and reducing floods.

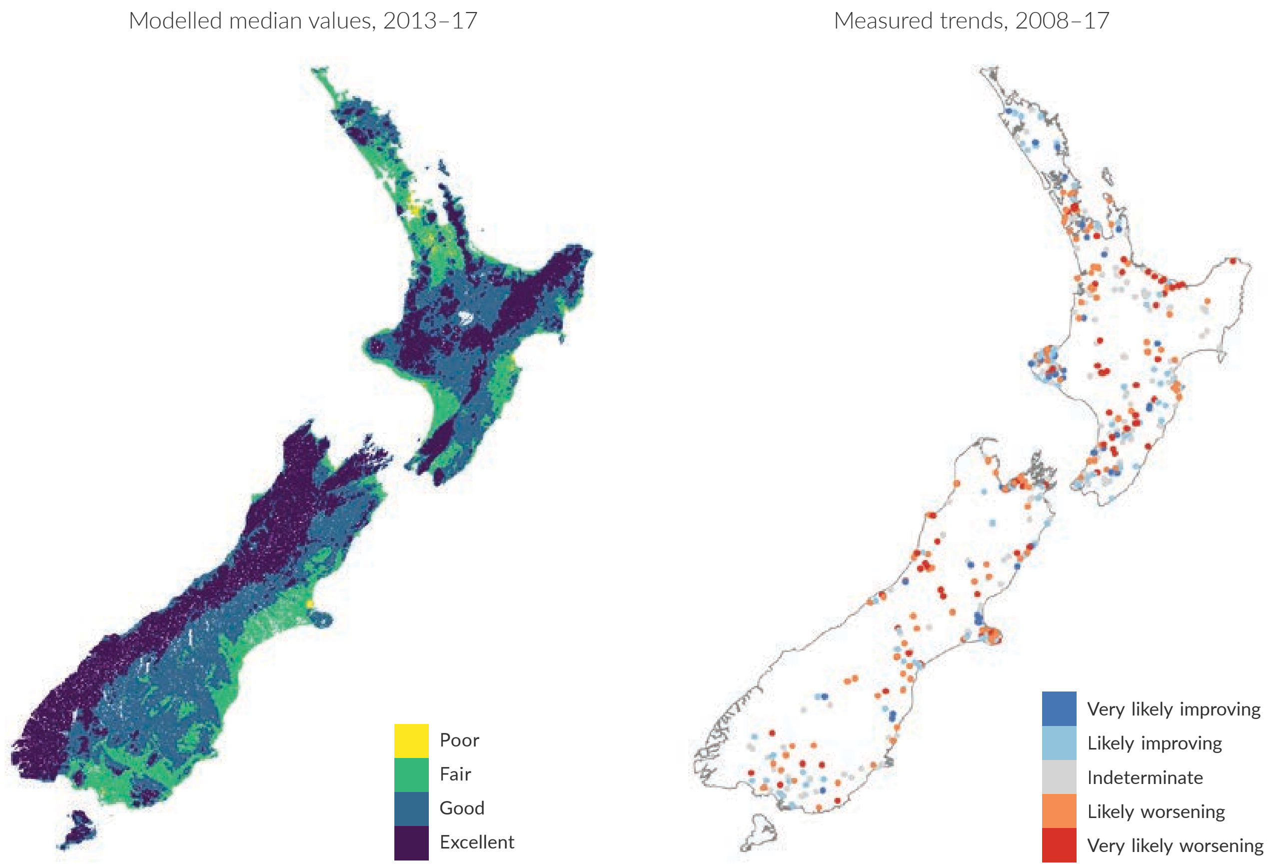
Lower river flows stabilise the gravel islands and make it easier for invasive plants like broom and gorse to take hold. These plants encroach on bird feeding and breeding habitats and give predators a place to hide. A 2011 study found that rivers where the number of black-fronted terns had declined had relatively low flows, and further reductions in flow were predicted to accelerate the population decline (O'Donnell & Hoare, 2011).

River margins are important for native species like geckos and skinks but this habitat is lost when land beside braided rivers is used for other purposes. From 1990–2012 more than 11,000 hectares of this type of land in Canterbury was converted to intensive agriculture (Grove et al, 2015).

Because of their importance, braided rivers are the only type of ecosystem to have their own set of targets in the Canterbury water management strategy (Environment Canterbury, 2009). These targets are to:

- maintain the upper catchments of alpine braided rivers as largely natural ecosystems and landscapes
- not build new dams on the main stem of major alpine braided rivers
- maintain active floodplains, flow variability, and sediment movement – including during river protection works, land-use change, or deliberate vegetation stabilisation
- support the dynamics of river mouth and coastal processes
- implement actions to correct the decline in useable braided river bird habitat.

Figure 2: River macroinvertebrate community index scores



Data source: NIWA

Chlorophyll-a, a measure of phytoplankton biomass, is another measure of lake health. Between 2013 and 2017, 35 percent of 63 monitored lakes had worse scores for chlorophyll-a than the National Objectives Framework (NOF) bottom line for ecosystem health. (For more about NOF pollution in our waterways, see Issue 4: Our waterways are polluted in farming areas.)

The ecological health of lakes is also assessed using the lake trophic level index (TLI), which is based on the total concentrations of nitrogen, phosphorus, and chlorophyll-a. Lakes with good or very good TLI ratings have clear water (unless they have natural colour or cloudiness) and low concentrations of nutrients and algae (eg Lake Pukaki in Canterbury). Lakes with poor or very poor TLI tend to be murky and have high concentrations of nutrients 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 Manawatu-Wanganui).

Only 58 lake monitoring sites had enough data to assess the TLI for 2013–17. The median TLI rating was very good or good at 16 percent, average at 28 percent, and poor or very poor at 57 percent of these sites. The small number of sites, the restriction to only a few regions, and the bias towards monitoring lakes with known water quality issues mean the data available do not represent New Zealand lakes in general. (See indicator: Lake water quality.)

The cultural health index (CHI) uses factors of cultural importance to Māori to assess the health of freshwater ecosystems. CHI scores consist of three components: site status, mahinga kai (food gathering area) status, and the cultural stream health. Of 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 4: Our waterways are polluted in farming areas.)

There is not enough data to directly assess the ecological health of all New Zealand's terrestrial and marine ecosystems, particularly at a national scale (see Where are the gaps in our knowledge about this issue?). Our ecosystems are, however, being affected by many of the issues discussed in this report (eg pollution in our rivers, expanding urban areas, changes to the land).

What has changed?

PAST ACTIVITIES HAVE AFFECTED OUR NATIVE ECOSYSTEMS

Before humans arrived in New Zealand, forests covered about 80 percent of the land (Nicholls, 1980), but it has been transformed in only 800 years (Wilmshurst et al, 2008). The first wave of settlers from Polynesia cleared many forest areas with fire, reducing the original forest by half. Next, European colonisers cut down and burned forest to make way for farming and settlements (McGlone, 1989).

Today, about one-third of the original native forest remains, mainly in mountainous and hilly areas. In 2012, native forest covered 26 percent of the land, native tussock grasslands 9 percent, and native scrub 7 percent (*Our land 2018*). (See indicators: Predicted pre-human vegetation and Land cover.)

Wetland areas have been reduced to only 10 percent of their estimated pre-human area and are continuing to decline in many regions. (See indicator: Wetland extent.) Active sand dunes, which were once widespread in New Zealand, declined by 80 percent between the 1950s and 2008. (See indicator: Active sand dune extent.)

Changes in biodiversity can be reported using Māori indicators of biodiversity and biophysical change (eg mauri – life force or essence). There are a number of examples where iwi have compiled narratives and interviews with kaumātua to inform the development of plans and strategies alongside councils and other organisations. One example includes estimates of change in the size of kererū flocks by Tūhoe Tuawhenua kaumātua in the past 100 years (Lyver et al, 2009).

> **No sooner had I finished my prayers I heard this thundering coming up the valley like a jet and I thought, "Oh! I'm in trouble here." Then I heard this sound, 'Whoooooosh!!!' By crikey, the trees are moving and they [kererū] were quite a distance away when they turned around and it was white everywhere. There was a constant cooing all over the place. I was in awe and shivering with fear. I was so afraid I could feel my hairs standing. Some time went by and my excitement finally settled.**
>
> *Poai Nelson, 2011, translated from Māori, Ruatāhuna (Timoti et al, 2017)*

SPECIES AND ECOSYSTEMS CONTINUE TO DECLINE

Recent assessments in the New Zealand Threat Classification System across all native, resident, and living species from land, freshwater, and marine environments showed that the extinction risk worsened for 86 species in the past 15 years. This included 61 plants, 10 land invertebrates, 5 land birds, 2 seabirds, 3 reptiles, 1 marine invertebrate, 3 freshwater invertebrates, and 1 freshwater fish (see figure 3). (Note: Change in conservation status is measured at the conservation status subcategory. For example, if a taxa (species) moved from threatened – nationally critical to threatened – nationally endangered, this is an improvement in conservation status.)

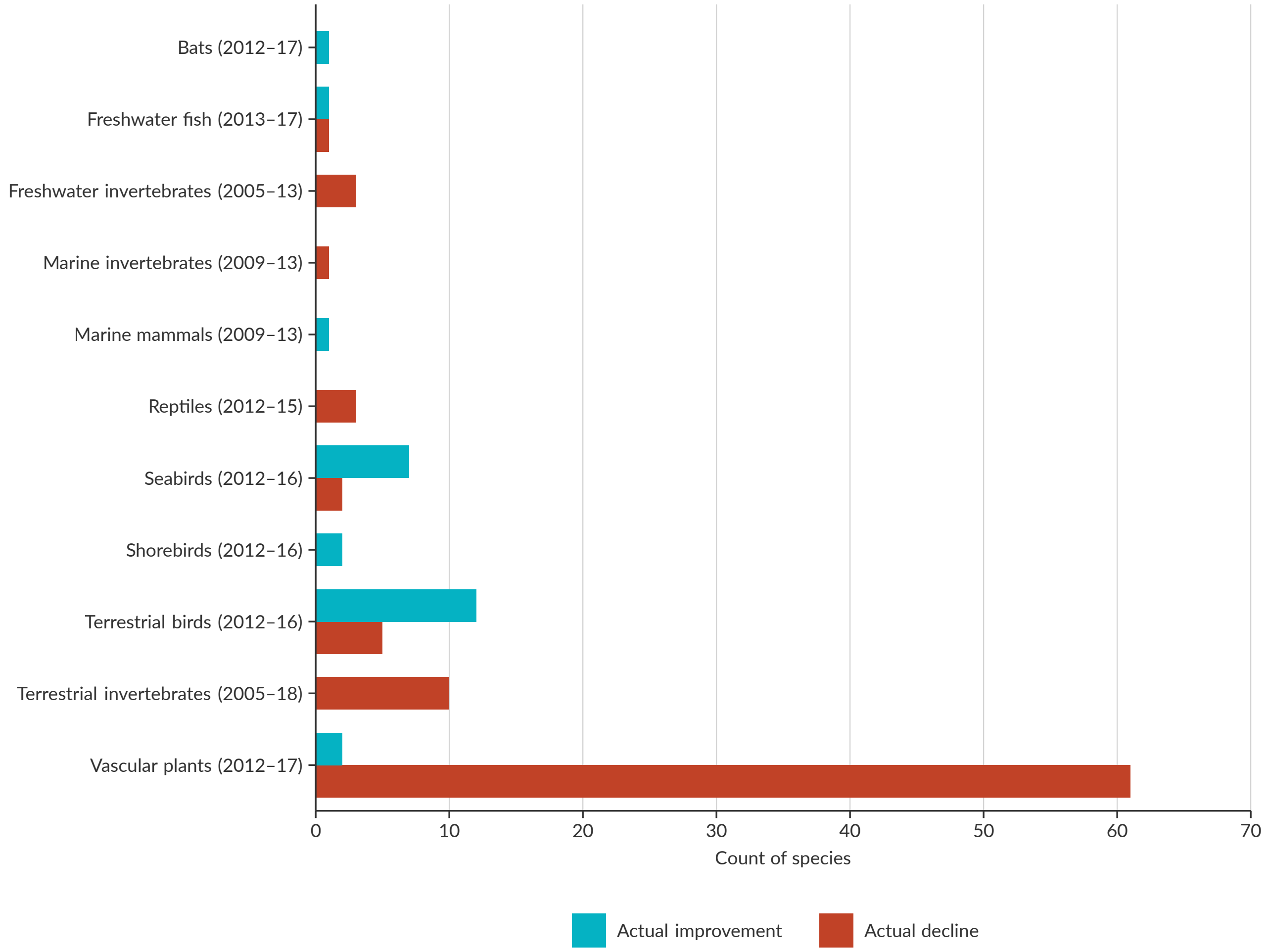
The conservation status of 26 species improved within the past 10 years. This included 2 plants, 1 bat, 1 freshwater fish, 2 shorebirds, 7 seabirds, 12 land birds, and 1 whale. The improvement was conservation-dependent for more than half (57.7 percent) of the species – meaning that if the management stopped, the species would be expected to decline to a worse conservation status over three of their generations. (See indicators: Conservation status of indigenous freshwater species, Conservation status of indigenous land species and Conservation status of indigenous marine species.)

Between 1996 and 2012, the total area of native forest was reduced by 16,108 hectares. Native scrub and shrubland declined by 24,187 hectares, and native tussock grasslands reduced by 30,928 hectares. (See indicator: Land cover.)

Wetland areas also continued to shrink, with at least 1,247 hectares lost between 2001 and 2016. (See indicator: Wetland extent.) The rate of decline in these precious ecosystems can be substantial – 157 hectares of wetland were lost *per year* in Southland between 1990 and 2012 (Robertson et al, 2018).

The volume of water in many of our rivers and lakes has been reduced by using water for activities such as irrigation and hydropower – including braided river systems. This can change the number of channels in a river and increase the spread of invasive plants (Caruso et al, 2013; O'Donnell et al, 2016). Changes in lake water levels also lead to the loss of native freshwater habitat near the shore (Thompson & Ryder, 2008). (See Issue 6: Taking water changes flows which affects our freshwater ecosystems.)

Figure 3: Change in conservation status subcategory of native species by species group



Data source: Department of Conservation

Note: Only known, native, resident, living species are included.

More river monitoring sites had declining MCI scores than improving scores from 2008 to 2017 – 59 percent had worsening trends and 41 percent had improving trends (see figure 2). For all these sites, trends were rated as likely (67–89 percent certainty in the trend) or very likely (90–100 percent certainty in the trend). This method of trend assessment differs from that used in previous environmental reports. The number of monitoring sites has also increased. These trend results are therefore not directly comparable to those in previous reports. (See **Issue 4: Our waterways are polluted in farming areas**.)

Nationwide, 62 lakes or fewer had sufficient data for trend testing. Of those that had sufficient data, more sites had improving than worsening trends for TLI, chlorophyll-a, ammoniacal nitrogen, and total phosphorus over the period 2008–17. Roughly the same proportion of lake monitoring sites had improving and worsening trends for total nitrogen and for water clarity in the same period.

What has contributed to this issue?

PEOPLE HAVE CHANGED THE LANDSCAPE

Farming and urban expansion have driven the clearing of forest and the draining of wetlands, with associated losses of habitat and decline in species. (See Issue 2: Changes to the vegetation on our land are degrading the soil and water.) Māori have seen large areas of their land degraded by such changes, which has greatly impacted species and habitats of particular significance to Māori customary values and resources.

Compounding this issue is that land clearance was accompanied by a change in ownership and management arrangements, which led to radical changes in the nature of the relationship Māori had with their whenua. In 1840, Māori had exclusive rights and ownership over 27 million hectares of land, but there are only about 1.4 million hectares of Māori freehold land today (plus small amounts of land returned through Treaty of Waitangi claims and agreements since 1975). (Asher & Naulls, 1987; Durie, 1998; Kingi, 2008; Ministry for Culture and Heritage, 2017; Ministry of Justice, 2017; Orange, 2004.)

On average, native vegetation makes up less than 2 percent of urban land and about 10 percent on the urban-rural boundary (Clarkson et al, 2007). Ecological studies show that dropping below 10 percent native vegetation cover can trigger a decline in many species (Drinnan, 2005; McIntyre & Hobbs, 1999), so urban expansion and the further loss of native vegetation could cause disproportionately large changes in the biodiversity that remains on city fringes. (See Issue 3: Urban growth is reducing versatile land and native biodiversity.)

On coastal edges, reclaiming land (by infilling swamps/wetlands and harbours) and building marinas and seawalls have resulted in the loss and degradation of coastal habitats, particularly in sheltered harbours (MacDiarmid et al, 2009). Many of these areas were critically important areas for iwi and hapū as sources of sustenance and mana. Seagrass meadows, for example, have declined significantly since the late 19th century. These meadows are important nursery areas for fish and often hotspots of coastal biodiversity (Morrison et al, 2014). (See Issue 3: Urban growth is reducing versatile land and native biodiversity.)

POLLUTION AFFECTS OUR BIODIVERSITY

The growth of urban centres can also increase pollution. Heavy metals entering waterways are of particular concern as they can be toxic to fish and invertebrates in both freshwater and coastal-marine environments. (See Issue 3: Urban growth is reducing versatile land and native biodiversity.)

Farming increases contaminants in our freshwater and coastal areas, posing threats to biodiversity because of their toxicity and associated habitat degradation. Soil washed from pastures and from forests after felling moves along waterways and settles as sediment on streambeds. It fills in the spaces used by fish and invertebrates for hiding and breeding, and makes their food harder to find or to eat. (See Issue 4: Our waterways are polluted in farming areas.)

INTRODUCED SPECIES THREATEN OUR NATIVE SPECIES

The animals and organisms that humans have brought to New Zealand islands (intentionally and unintentionally) pose significant threats to native biodiversity in land, freshwater, and marine environments. The threats are from competition, predation, and diseases.

New Zealand is considered one of the most invaded countries in the world (Kelly & Sullivan, 2010). Non-native plant species outnumber natives (Wilton & Breitwieser, 2000).

Stoats, possums, and rats were present on more than 94 percent of New Zealand land in 2014. (See indicator: Land pests.) Along with the impact that possums have on our native trees, these species pose significant threats to our native birds, lizards, and invertebrates. This is also an issue in populated areas due to predation by household pets (cats and dogs) and non-native animals that exploit urban environments (eg rats and mice). Exotic plants from gardens can be problematic, including the fast-growing pest plants tradescantia (wandering willie) and climbing asparagus.

New Zealand has many introduced freshwater fish, with 21 species now present in our freshwater ecosystems (Collier & Grainger, 2015). Nine of these (eg the bullhead catfish, goldfish, and koi carp), along with 11 introduced invertebrate species and 41 non-native algae and plant species, were identified as being pests of greatest concern in our freshwater environments. (See indicator: Freshwater pests.) These pests compete with native species for food and space, and damage existing habitats. The river algal species Didymo (*Didymosphenia geminata*) for example, is now in more than 200 waterways in the South Island, where it can form thick, dense mats over an entire streambed (Jellyman & Harding, 2016).

More than half of the 351 non-native species (plants, algae and animals) found in our coastal waters have established breeding populations. The number of known non-native species also increased by 10 percent between 2010 and 2015. (See indicator: Marine non-indigenous species.)

In Tuawhenua forests in Te Urewera, introduced species have contributed to the change in the language of the forest of Te Urewera (Lyver et al, 2017a, b). Tuawhenua kaumātua have observed declining populations of blowflies *(Calliporidae)*, and insects that pollinate a wide range of New Zealand plants (Heath, 1982; Heine, 1937; Howlett, 2012). Blowflies are attacked and eaten by introduced European wasps *(Vespula germanica)* (Doherty & Tumarae-Teka, 2015; Fordham, 1961).

OUR USE OF NATURAL RESOURCES IMPACTS OUR BIODIVERSITY

In the past, harvesting for food or commercial purposes contributed to the extinction of some species (such as moa and huia). Other harvests caused drastic population changes, leaving species close to extinction. (See Issue 7: The way we fish is affecting the health of our ocean environment for information about the impact of harvesting on whales, seals, and sea lions.)

Contemporary harvesting is also impacting our biodiversity. Commercial sea fishing impacts our marine ecology. The information we have does not show the whole picture but we do have data about the effects of fishing on protected marine species (from accidental catch) and on seabed habitats from trawling. (See Issue 7: The way we fish is affecting the health of our ocean environment.)

Mining, industrial processing, and manufacturing have had major effects on local ecology. In some places, activities from many decades ago have an enduring effect on the soil and water *(Our land 2018)*.

Taking water for irrigation, industry, and household use can reduce river flows and impact stream habitats and freshwater biodiversity (eg Caruso et al, 2013; O'Donnell et al, 2016). It can also damage our unique and rare ecosystems including braided rivers. (See Issue 6: Taking water changes flows which affects our freshwater ecosystems.)

DISEASES THREATEN SOME OF OUR NATIVE SPECIES

Virulent pathogens (disease-causing organisms) that are new to the country often pose serious threats to our biodiversity. Because our understanding of new diseases and pathogens is often limited, it may be difficult to put effective control measures in place.

Myrtle rust is a threat to plants in the Myrtaceae family including mānuka, pōhutukawa, and rātā. It is an aerially borne fungal disease that can kill plants and its microscopic spores are dispersed by the wind, making it very difficult to control. Myrtle rust was first detected in May 2017 and is now present throughout large parts of the North Island and in the north of the South Island. This distribution is related to climatic conditions and the presence of suitable host species (Beresford et al, 2018).

Our unique kauri forests are also seriously threatened by kauri dieback *(Phytophthora agathidicida)* – a disease for which there are treatments, but no cures.

CLIMATE CHANGE IS BEGINNING TO AFFECT SOME SPECIES

Evidence suggests that climate change is already starting to impact our native species. Increasing temperatures have shifted the distribution of some species and increased the numbers of invasive pests in some areas. (See Issue 9: Climate change is already affecting Aotearoa New Zealand.) More research is needed to fully understand the potential impacts of climate change on our biodiversity (see What are the gaps in our knowledge about this issue?).

What are the consequences of this issue?

Our unique native species and the environments they inhabit are irreplaceable. They have immense intrinsic value and wide-ranging values to people. Damage to our biodiversity affects us now and all future generations of New Zealanders.

A loss of biodiversity can be felt in cultural connections (like a sense of identity and belonging), in the resources available to us (like wild food sources), and in functions (such as pollination of plants or filtering of air pollution). Underneath these benefits are background supporting processes, including soil formation and nutrient cycling by soil organisms. The degradation or loss of biodiversity can affect these services, many of which are essential for our well-being (Dymond, 2013).

OUR WAY OF LIFE AND CONNECTION TO THE LAND COULD CHANGE

The ties between us and our biodiversity run deep – we call ourselves 'Kiwis' and proudly use the silver fern (ponga) for our national identity. Access to nature is an important component of the lifestyle we enjoy. In te ao Māori, people's well-being depends on the health of the environment. The reverse is just as true – the health of the environment is dependent on people's well-being.

Our identity as a people suffers when we experience damaged or lost native species and ecosystems, and recreational opportunities and the connections we have to nature are also degraded. Bird song is recognised by tangata whenua as significant in the language of the forest. Around Ruatāhuna 40–50 years ago, it was difficult to hear someone speak metres away from you because of the volume of noise from the bird chorus (Lyver et al, 2017a, 2017b).

It isn't like the old days when the beautiful thunderous sounds of the birds were consistently heard. It may well be that I have lost the skills of listening to the sounds of our forest? Nevertheless, I have noticed the great declines in our birds from the times when we grew up. There was always a consistent uproar of birds singing in our forests. When we journeyed into the forest with our father he would dismount to give his horse a rest and, he would tell us stories pertaining to the different species of birds and trees in our environment. I remember one particular time he says "Listen! Listen to what is going on in the forest. Can you hear the birds?" He would add, "You aren't listening to the language of the trees and the birds." I couldn't make any sense of it at the time and I would think to myself, now how would I know what the trees are saying? The language of the trees can be heard if you listen carefully. In those days I thought it was only the rustling of the leaves while the wind blew. But I do believe that the forest isn't as healthy as it used to be.

Menu Ripia, 2014,
translated from Māori, Ruatāhuna

Benefits from nature – ecosystem services

People have a special relationship with the environment. This relationship can be described in a number of ways including through a te ao Māori perspective. Another framework to describe our relationship with the environment is through the benefits that ecosystems provide to us and our society. This is referred to as an 'ecosystem services' approach. Benefits are categorised as provisioning (eg food and fibre), regulating (eg flood or climate regulation), supporting (eg photosynthesis and nutrient cycling), and cultural (eg wairua/spiritual, recreational) services.

New Zealand's native forests regulate the climate by storing carbon, prevent erosion, provide nursery habitats, and create nectar for honey production. They are also the backbone of our recreation and tourism activities (Dymond et al, 2015).

Natural wetlands also provide important ecosystem services. Wetlands are often called 'nature's kidneys' because they purify water by filtering out nutrients and sediments. Wetlands regulate water flow during storms and store carbon as peat. In New Zealand, they have a particular significance to Māori as taonga and for mahinga kai (Clarkson et al, 2013).

A reduction in biodiversity and ecosystem health reduces the ability to provide benefits and services (Cardinale et al, 2012). A loss of biodiversity can reduce the capacity of an ecosystem to produce biomass, decompose and recycle essential nutrients, and make it less stable and therefore more vulnerable to climate change.

Native biodiversity provides mahinga kai and other culturally important materials like raranga (weaving), and rongoā (medicinal uses) for Māori communities. In addition they represent important indicators for kaitiaki in their management of the environment, as well as being key to the maintenance and transmission of intergenerational knowledge. A loss of biodiversity – and the quantity of food and material available – limits the opportunities for tangata whenua to connect with and use the environment.

Customary practices that surround the use of biodiversity and natural materials can be vital in maintaining and reinforcing values like mana (authority and prestige), identity (ahikāroa), family ties and linkages (whanaungatanga), and knowledge systems (mātauranga), as well as the inter-generational transfer of knowledge (whakaheke kōrero) (Harmsworth & Awatere, 2013; Lyver et al, 2017a, 2017b).

Biodiversity also makes significant contributions to cultural expressions like prayer (karakia), songs (waiata, mōteatea, pao), instrumental music (taonga puoro), performances (kapa haka), products (tā moko, whakairo), and representations of traditional thought (wairua) (Harmsworth & Awatere, 2013; Timoti et al, 2017).

These expressions were often crafted to express whakapapa, relationships between the natural and human realms, and the responsibilities and reciprocity people have with the environment (Timoti et al, 2017; Walsh et al, 2013). The use of materials and engagement with the environment is critical for tangata whenua to compose, protect, maintain, regenerate, and apply knowledge and expressions of culture.

LEVELS OF BIODIVERSITY MAY INFLUENCE ECOSYSTEM RESILIENCE TO CLIMATE CHANGE

High levels of biodiversity increase ecosystem resilience to moderate to extreme climate events (Isbell et al, 2015). Declines in biodiversity, however, can have an opposite effect (Oliver et al, 2015). Species loss and habitat degradation can make ecosystems less resilient to environmental change (Isbell et al, 2015) leading to further declines in biodiversity.

Where are the gaps in our knowledge about this issue?

ASSESSING ECOSYSTEM CONDITION IS DIFFICULT AND COMPLEX

It is difficult to measure the overall condition of our ecosystems (Andreasen et al, 2001) because the systems themselves are complex, and climate and landscape variations are overlaid. Information is particularly limited for rare and naturally uncommon ecosystems.

Despite recent efforts to improve freshwater quality, we still have incomplete knowledge about the condition of our freshwater ecosystems, habitats, and their 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) and only around 150 of the nation's more than 3,000 lakes are regularly monitored by regional authorities (Larned et al, 2019).

OUR KNOWLEDGE OF SOME ECOSYSTEMS AND SPECIES IS VERY LIMITED

There are major gaps in our knowledge of the marine environment. We have one of the largest exclusive economic zones (EEZ) in the world and most of it has never been surveyed. While scientists have identified more than 17,000 species, many thousands more are yet to be discovered and identified.

Information is also missing at a species level – the conservation status of 2,805 species cannot be assessed because of a lack of data. Some groups of species are not well studied and many species are yet to be described. This is particularly true for invertebrates. For marine invertebrates, the number of species assessed for their conservation status (412) may only be 5 percent of the total number of species.

Introduced species are one of the greatest negative influences on our terrestrial biodiversity. We do not have accurate data about the location or number of introduced species or how they are changing.

THE FULL IMPACTS OF CLIMATE CHANGE ARE NOT KNOWN

Research and monitoring are needed to better understand the consequences of climate change on our native species and our biodiversity. It is likely to have significant impacts on our biodiversity like changing where species live and their reproductive behaviour as well as increasing their risk from invasive species. Climate change could also create mismatches in timing between species and their sources of food.

THEME 2

How we use our land

Photo credit: Photonewzeland

The way we use our land and the physical changes we have made to it affect our environment. Those effects continue to the waterways that drain the land, and include loss of ecosystems and habitat as well as reduction in the quality of our soil and fresh water. There are also consequences on our well-being, including the benefits (ecosystem services) we receive from nature, like flood control, water filtering, and soil retention.

This theme focuses on two major changes that have been made to the land:

1. **What we have removed:** Cutting down native forests, draining wetlands, and clearing land for farming and development have accelerated our naturally high rates of soil loss. This has also degraded a range of ecosystem services provided by native vegetation.
2. **What we have built:** Human-made structures and hard surfaces affect the natural systems we rely on. There is a particular focus in this issue on the spread of urban areas over versatile land (which can be used for many purposes, including farming) and scarce high-class soils.

Building structures and changing the way we use land enable us to move around the country and generate electricity, as well as support industries like farming and aquaculture. Local changes, however, can have significant impacts when they are considered as a whole. One example is the collective impact of barriers, like culverts and dams in waterways, on our native fish (Franklin et al, 2018; Gluckman et al, 2017). (See Issue 1: Our native plants, animals, and ecosystems are under threat.) Another is the effect on our coasts of infilling harbours and estuaries to reclaim land (*Our marine environment 2016*).

Other parts of this report present different issues related to changes to our land:

- **Issue 1:** Our native plants, animals, and ecosystems are under threat – how changes to native habitat affect biodiversity and ecosystem health.
- **Issue 4:** Our waterways are polluted in farming areas – how more-intensive agriculture is changing our soils, and how this pollutes waterways.
- **Issue 5:** Our environment is polluted in urban areas – how buildings and infrastructure affect the distribution of pollutants found in our cities and towns.
- **Issue 6:** Taking water changes flows which affects our freshwater ecosystems – how our waterways change when water is taken out for irrigation and hydroelectric generation.

ISSUE 2

Changes to the vegetation on our land are degrading the soil and water

Logging native forests, draining wetlands, and clearing land have degraded a range of benefits provided by native vegetation, accelerated our naturally high rates of soil loss, and affected our waterways.

Why does this issue matter?

SPATIAL EXTENT

About 40 percent of our land is now exotic grassland and is prone to erosion in susceptible areas.

DEPARTURE FROM NATURAL CONDITIONS

About 65 percent of our native forest has been removed and 90 percent of our wetlands have been drained.

IRREVERSIBILITY

It is difficult to reverse as vegetation was removed to support the way we live and sustain our economy.

IMPACTS ON WHAT WE VALUE

Loss of native forests and wetlands, and increased erosion are significant threats to our ecosystems, soil productivity, and the health of our freshwater, estuarine, and marine environments. This also impacts cultural practices and knowledge.

KNOWLEDGE GAPS

We lack monitoring data for erosion and information about the benefits of native vegetation and how well any interventions are working.

What is the current state of this issue?

MODIFIED LAND COVER HAS INCREASED

Land cover describes the types of vegetation and features that cover the land's surface, like native and non-native (exotic) vegetation, water bodies, built environments, and bare natural surfaces (eg gravel and rock). National surveys of Aotearoa New Zealand's land cover were carried out in 1996, 2002, 2008, and most recently in 2012. (See indicator: Land cover.)

As of 2012, just under half of our land area (49 percent) was covered by natural land-cover types (see figure 4). Native forest covered 26 percent of our land area, mostly in mountainous and hilly areas. Other native vegetation (like tussock grassland, scrub, and shrubland), water bodies, and naturally bare ground together accounted for the other 23 percent.

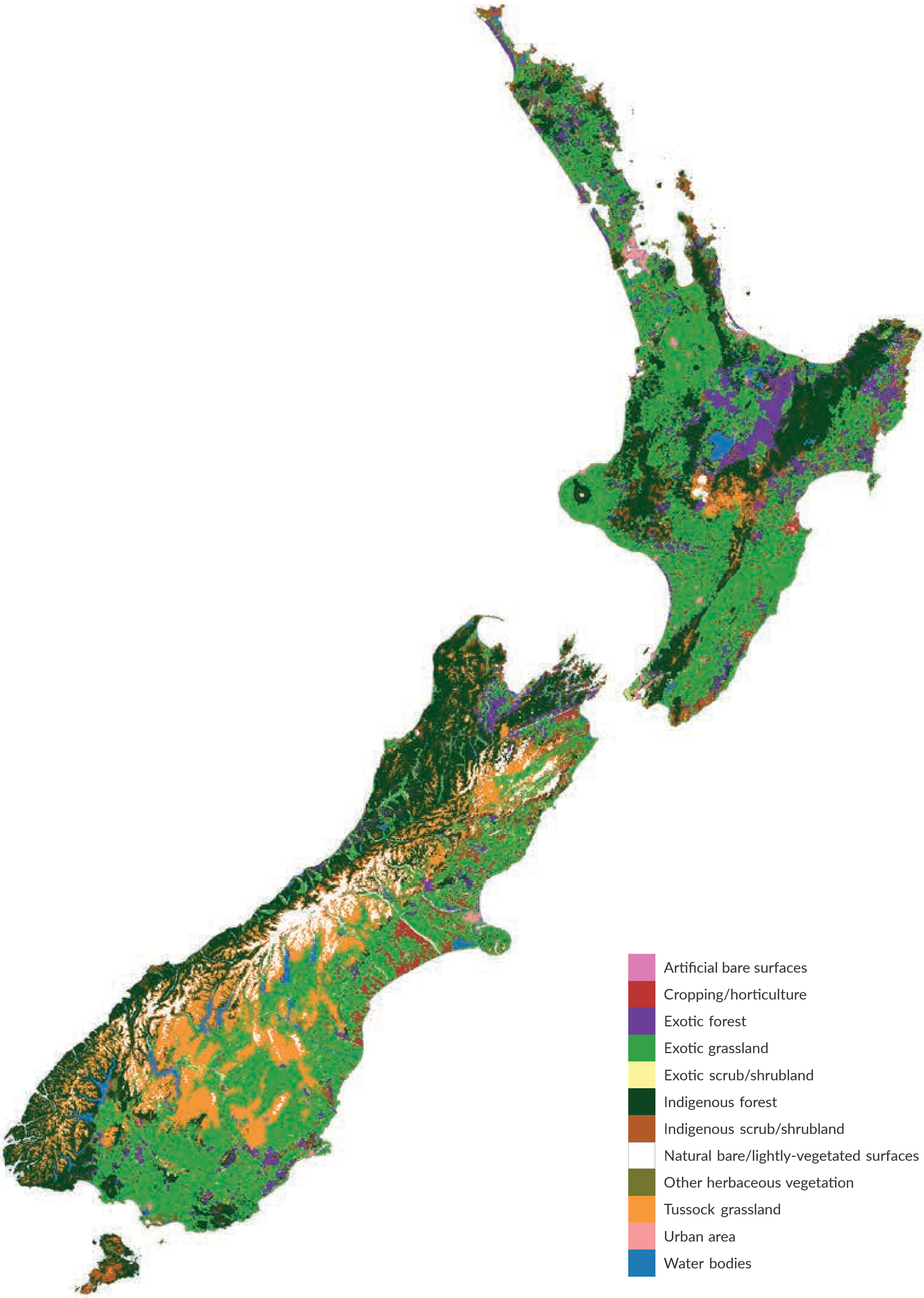
By contrast, 51 percent of our land area had modified land cover, like urban areas and exotic vegetation. Exotic grassland (pasture) was the largest single type of land cover in New Zealand and accounted for about 40 percent of our total land area. Exotic (plantation) forest covered about 8 percent of our land area, concentrated in the central North Island.

Forestry and logging's contribution to our economy

- $1.74 billion
- 0.6 percent of gross domestic product (GDP)
- 6,080 (0.2 percent) people were employed in forestry and logging as their main income source.

Note: All gross domestic product (GDP) figures are from the *National accounts (Industry production and investment): year ended March 2017*. These figures exclude manufacturing or processing of primary products. They are in current prices, ie not adjusted for the effect of changing prices over time. The people employed information is from linked employer-employee data (LEED). The measure is main earning source, by industry using New Zealand standard industry output categories.

Figure 4: Land cover, 2012



Data source: Manaaki Whenua – Landcare Research

EROSION RISK VARIES

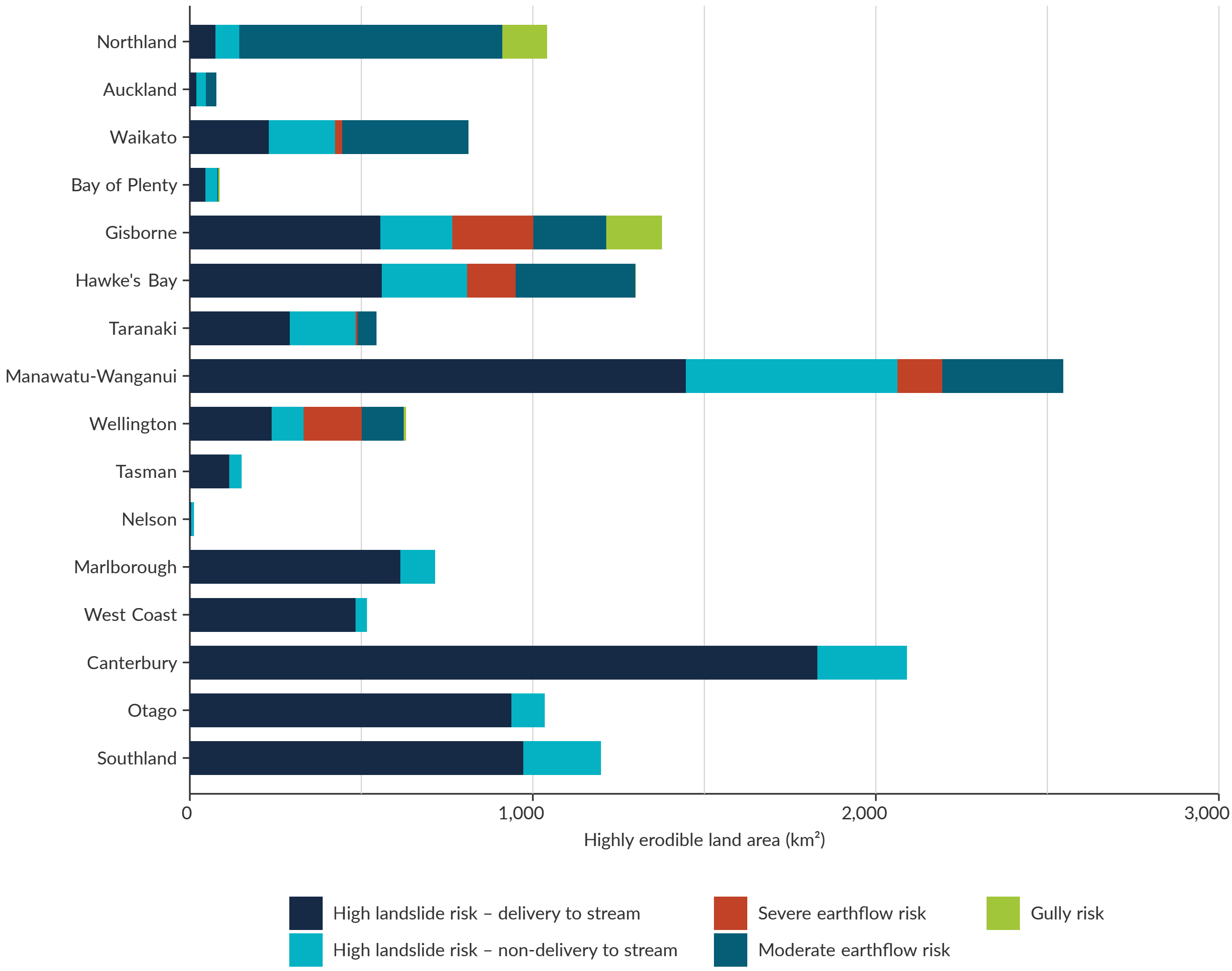
Erosion risk varies from place to place, reflecting things we influence (land cover) and naturally variable factors like soil types, geology, topography (shape of the land), and rainfall.

As of 2012, approximately 5 percent of our land area was classified as highly prone to erosion, and 60 percent of highly erodible land was in the North Island. (See indicator: Highly erodible land.)

Seven regions (Gisborne, Manawatu-Wanganui, Canterbury, Hawke's Bay, Southland, Northland, and Otago) had more than 1,000 square kilometres of highly erodible land in 2012 (see figure 5).

Erosion can happen in various ways. Landslide erosion occurs when a soil slope is destabilised during storm rainfall. Gully erosion begins at a gully head and expands up hillsides over decades. Earthflow erosion is the slow downward movement (approximately 1 metre per year) of wet soil slopes towards waterways. As at 2012, landslide risk applied to 77 percent of the highly erodible land in New Zealand.

Figure 5: Highly erodible land area by region and risk type, 2012



Data source: Manaaki Whenua – Landcare Research

What has changed?

EXTENSIVE LOSS OF NATIVE LAND COVER CONTINUES TODAY

The vegetation on more than half our country has changed significantly since human settlement. (See Issue 1: Our native plants, animals, and ecosystems are under threat.) Native forests once covered about 80 percent of New Zealand's land area – all but the tops of mountains and the wettest lowlands (Nicholls, 1980). About 65 percent of our original native forest has been removed.

Wetlands once covered about 10 percent of New Zealand's land area, especially in coastal areas and lowlands. About 90 percent of these original wetlands have been drained. (See indicator: Wetland extent.)

The native vegetation cover has continued to decline, even in recent years – being converted to land cover like exotic grassland (pasture), plantation forestry, and urban areas. Between 1996 and 2012 there was a 1.3 percent loss of tussock grassland (reduced by 31,000 hectares), a 1.3 percent loss of indigenous shrubland (reduced by 24,000 hectares), and a 0.2 percent loss of native forests (reduced by 16,000 hectares). (See indicator: Land cover.)

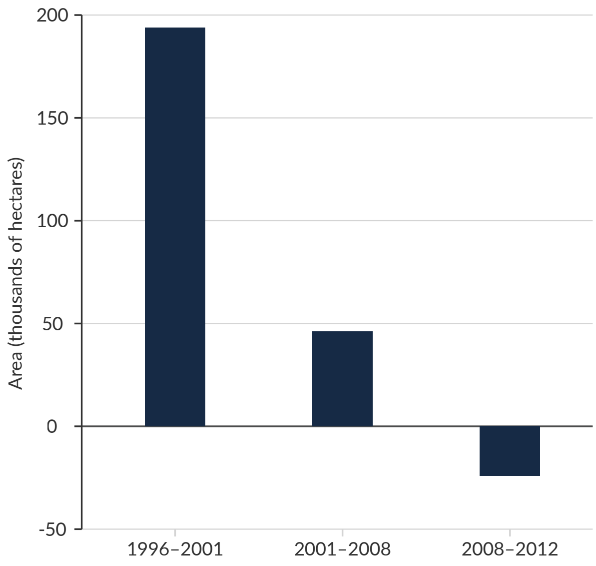
Wetland loss has also continued (Belliss et al, 2017). Between 2001 and 2016, 214 wetlands covering nearly 1,250 hectares were lost, with a further 746 wetlands declining in size. The regions with the greatest number of wetlands lost or declining were Canterbury, West Coast, Southland, and Auckland. Most of our large remaining wetlands are in public ownership, but the vast majority of smaller wetlands are surrounded by farmland in private ownership (Myers et al, 2013).

THE MIX OF EXOTIC LAND COVER HAS CHANGED

Shifts between types of exotic land cover also occurred between 1996 and 2012. The main changes were from exotic grassland and shrubland to exotic forest (some exotic forest conversion to grassland and shrubland) and a 10 percent expansion in urban land cover.

These shifts have occurred at different rates between the national surveys in 1996, 2001, 2008, and 2012. For example, cropland expanded between 1996 and 2001, but more so between 2001 and 2008. Between 1996 and 2001, the area covered by exotic forest increased by more than 10 percent (expanded by 194,000 hectares). In recent years deforestation and conversion to other land uses have exceeded new tree planting, so between 2008 and 2012 the area of exotic forest decreased by about 1 percent (declined 24,000 hectares) (see figure 6).

Figure 6: Exotic forest area net change, 1996–2012



Data source: Manaaki Whenua – Landcare Research

What has contributed to this issue?

LAND USE HAS CHANGED TO SUPPORT THE WAY WE LIVE

To support the way we live and grow our economy, we have increased the cover of exotic forestry. Once planted, these forests have some similar characteristics to the native forests they replace. But it is during harvesting that this change in land use can have consequences, particularly on the state of highly erodible land.

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 soil exposure and disturbance can increase erosion and the amount of sediment entering our waterways. Hilly land that is prone to erosion is particularly vulnerable for up to six years after harvest, until newly planted trees have grown enough to provide a canopy over the replanted area (Marden & Rowan, 1993).

Agriculture is one of the largest industries in the tradable economy. To support grazing, land has been converted, wetland areas have been drained, and grass and legumes planted.

Exotic grasslands are markedly different to native forests in the ecosystem services they provide, as well their susceptibility to erosion. Streams in farmed areas typically receive higher run-off (loss of water from the land that may transport eroded soil), particularly where riparian vegetation has been removed. This is because pasture intercepts less rain than forest vegetation and grazing livestock can compact the soil. Livestock can also cause damage to stream banks, channels, and riparian areas (McDowell & Wilcock, 2008).

What are the consequences of this issue?

EROSION AND SOIL LOSS INCREASED

The New Zealand empirical erosion model (NZEEM) has been developed to estimate New Zealand's annual soil erosion, taking account of land cover, the location of highly erodible land, and average annual rainfall (Dymond et al, 2010). In the absence of measured data, NZEEM provides estimates of soil erosion. The modelled rate of soil erosion is 720 tonnes per square kilometre per year, with similar rates in the North and South islands. (See indicator: Estimated long-term soil erosion.)

The modelled soil erosion is especially high in two parts of Aotearoa New Zealand, but for different reasons (see figure 7). In Gisborne, the lack of woody vegetation (shrubs and trees), combined with the area's geology (steep slopes and loose soils), result in high soil erosion rates. On the west coast of the South Island, despite the high proportion of native forest cover, the region's naturally high rainfall and mountainous terrain account for high rates of soil loss.

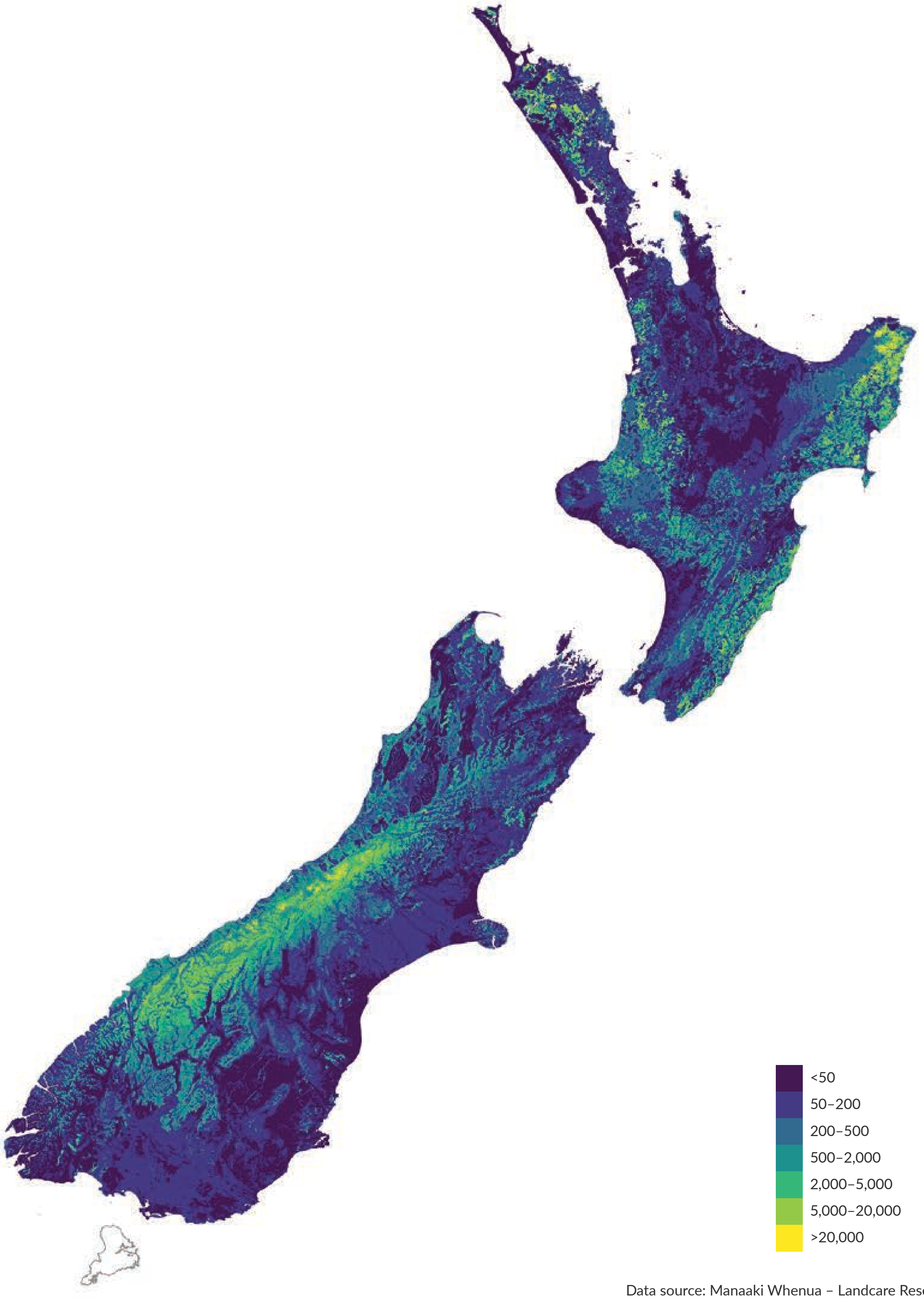
Expanding areas of exotic grassland since humans arrived in New Zealand have accelerated our natural high rates of erosion and soil loss. NZEEM estimates that of the 192 million tonnes of soil lost annually into waterways, 44 percent of the sediment comes from land covered in pasture *(Our land 2018).*

EROSION AND SOIL LOSS ARE COSTLY AND CREATE SEDIMENT

Soil productivity may be affected when the topsoil is lost. Topsoil lost in landslides can result in degraded soil and lost pasture productivity that may not be regained in our lifetimes (Lambert et al, 1984; Rosser & Ross, 2011). Reduced soil productivity can lead to a greater demand for nutrients (typically through fertiliser), which brings an added financial and environmental burden. The economic losses associated with soil erosion and landslides are estimated to be at least $250–300 million a year (Page, 2015).

Increased erosion and soil loss can also increase the concentration of sediment in our rivers, lakes, and coastal environments. (See Issue 4: Our waterways are polluted in farming areas.) Excess sediment can inhibit growth of aquatic and marine plants, and algae, damage the structures that marine animals use to respire (like fish gills) (Lowe et al, 2015), smother seabed habitats (Clapcott et al, 2011), degrade aesthetic values and recreational use, and increase the risk of flooding in towns and cities (Davies & McSaveney, 2011).

Figure 7: Modelled long-term soil erosion, 2012 (tonnes/km²)



Data source: Manaaki Whenua – Landcare Research

Note: Data was not available for Stewart Island.

Marlborough Sounds: Pāua, water, kelp, and forestry

Pāua are found on our rocky shores.

Photo credit: Claire Murphy

Pāua are deserving of their place in New Zealand culture as a Kiwi icon. They are valued as a taonga (treasure) and a source of mahinga kai by Māori and other fishers. Lining the rough exterior of their shell is the iridescent blue and purple material beloved of jewellers and Māori carvers.

Commercial fishers harvest the larger black-foot pāua *(Haliotis iris)*. Pāua is exported to China, Malaysia, Singapore, and Hong Kong, with a growing interest in live exports. Also, since abalone is a delicacy in China, tourists often enjoy our pāua in Chinese restaurants when they visit New Zealand.

As large sea snails, pāua live on rocks near the shore and use a radula (tongue) to scrape algae off the rocks and cut pieces of kelp (especially the giant kelp *Macrocystis pyrifera*) down to an edible size. Kelp beds create calmer areas for larvae and young pāua, and provide habitat for other species like kina, rock lobster, and blue cod. Pāua thrive in clean, clear water – the most productive pāua fisheries are on exposed coasts beside land covered in native forest.

In the Marlborough Sounds, large areas of native vegetation have been replaced with plantation forests – more than 17,000 hectares in 2017 (Ulrich, 2017). When these trees mature and are harvested, the bare soil is exposed to wind and rain for several years until new trees have grown. This increases erosion (particularly on steep sloping sites) and the risk of sediment being carried down streams into the sea.

Once in the water, sediment has a number of negative effects – settling on kelp and reducing its health, smothering young pāua, hindering the growth of adult pāua, and making it difficult for larvae to settle. Sedimentation can also make pāua easier to dislodge from rocks and therefore more vulnerable to predators. The impacts of sedimentation also have an economic cost and are thought to be a factor in an estimated loss of quota value of about $20 million for the pāua fishing industry nationwide for 2001–14 (Larned et al, 2018a).

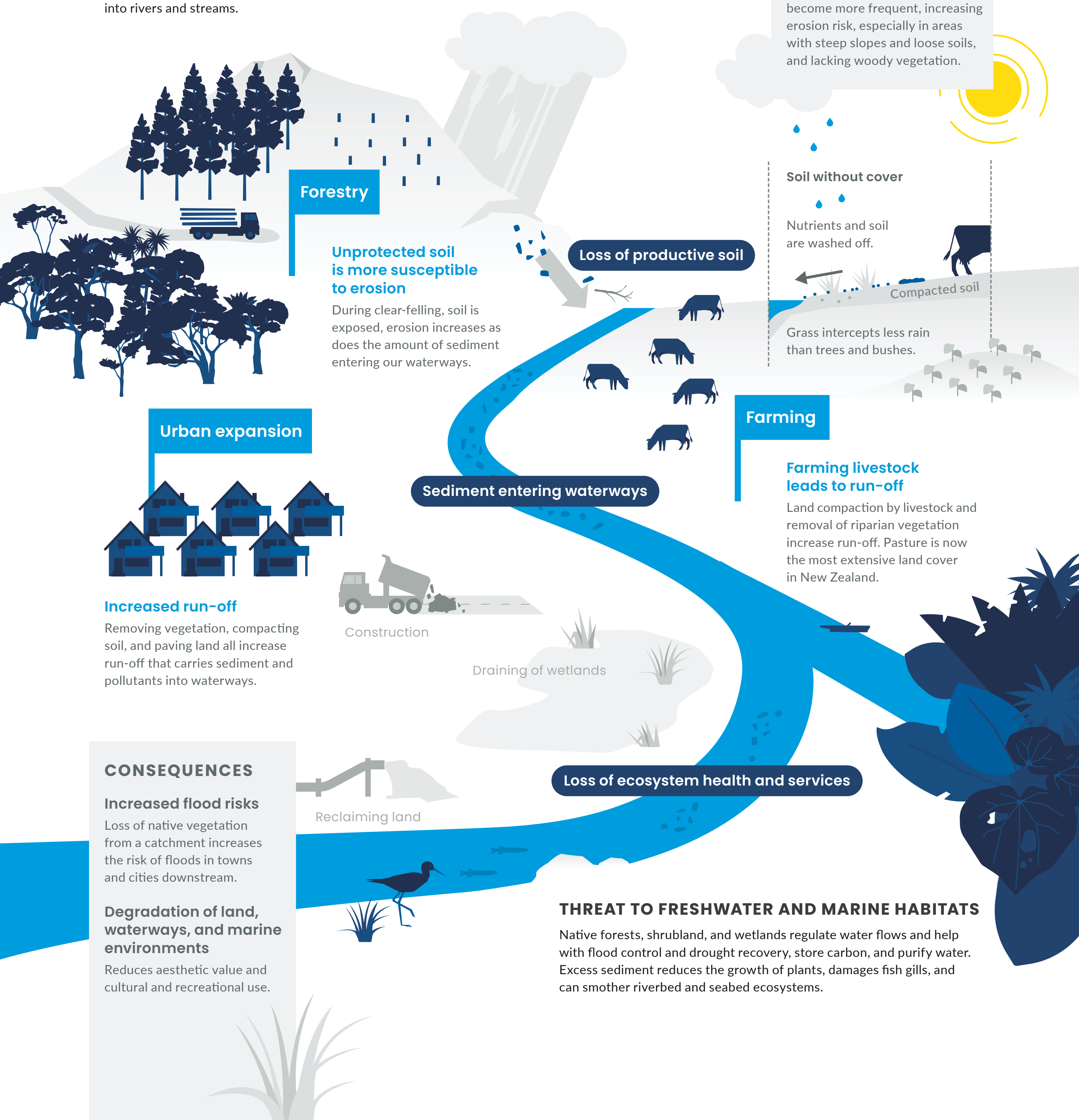
Pāua and kelp are also affected by fishing and climate change (warmer temperatures and acidification). In response to these compounding pressures, Moana New Zealand (New Zealand's largest Māori-owned fishing company) piloted an ecosystem service review to identify threats to the pāua ecosystem (Aotearoa Fisheries Limited, 2014). This was aligned with Moana's strong belief in their role as kaitiaki (guardians) of the sea for future generations, and a world first for a commercial fishery.

The review identified sedimentation from human activities as a significant risk for pāua fisheries. It also raised the importance of understanding the compounding pressures on the ecosystem; managing customary, recreational, and commercial pāua fishing; collaborating on complex resource management challenges; and calculating the monetary loss of ecosystem services.

Awareness of the impacts of logging on marine ecosystems has since grown, and recommendations for better forestry practices were proposed in a Scion report to Marlborough District Council's Environment Committee in December 2015 (Ulrich, 2017). These recommendations included not logging to the water line, using different harvest methods, and retiring the steepest and most erosion-prone land. The draft Marlborough Environmental Plan proposes prohibiting harvesting within 200 metres of the coast.

The changing way we use our land

Replacing native vegetation with exotic forest, grasslands, or urban areas can increase erosion and degrade land, freshwater, and marine environments.



THE PROCESS OF EROSION

Water, wind, or ice can move sediment into rivers and streams.

CLIMATE CHANGE

Extreme rainfall is likely to become more frequent, increasing erosion risk, especially in areas with steep slopes and loose soils, and lacking woody vegetation.

Soil without cover

Nutrients and soil are washed off.

Grass intercepts less rain than trees and bushes.

Forestry

Unprotected soil is more susceptible to erosion

During clear-felling, soil is exposed, erosion increases as does the amount of sediment entering our waterways.

Farming

Farming livestock leads to run-off

Land compaction by livestock and removal of riparian vegetation increase run-off. Pasture is now the most extensive land cover in New Zealand.

Urban expansion

Increased run-off

Removing vegetation, compacting soil, and paving land all increase run-off that carries sediment and pollutants into waterways.

CONSEQUENCES

Increased flood risks

Loss of native vegetation from a catchment increases the risk of floods in towns and cities downstream.

Degradation of land, waterways, and marine environments

Reduces aesthetic value and cultural and recreational use.

THREAT TO FRESHWATER AND MARINE HABITATS

Native forests, shrubland, and wetlands regulate water flows and help with flood control and drought recovery, store carbon, and purify water. Excess sediment reduces the growth of plants, damages fish gills, and can smother riverbed and seabed ecosystems.

LOSS OF NATURAL BENEFITS FROM THE LAND

Native forests, shrubland, and wetlands provide us with a wide range of ecosystem services. These benefits include regulating the flow of water in rivers and streams, storing carbon, purifying water, and providing habitats for native species (Patterson & Cole, 2013). Both historic and recent changes in land cover have serious impacts on our biodiversity and ecosystems as native habitats are lost and degraded. (See Issue 1: Our native plants, animals, and ecosystems are under threat.)

Wetlands are one example. Our remaining freshwater wetlands were estimated to provide benefits with an estimated value of more than $5 million per year in 2012 (Patterson & Cole, 2013). Those with the highest estimated value included flood control, drought recovery, aesthetic and scientific value, and water purification (Clarkson et al, 2013). A compounding issue is that draining one wetland often affects the integrity of any remaining neighbouring wetlands.

CULTURAL HEALTH AND IDENTITY ARE AFFECTED

Transformation of the land continues to have a significant effect on Māori culture. Māori communities see land and all it produces as a source of cultural identity and mana (Smith et al, 2017) and integral to the spiritual well-being of people (Harmsworth & Awatere, 2013).

A te ao Māori view expressed through ki uta ki tai (from the mountains to the sea) highlights that effects are felt (and accumulate) from the mountains to estuaries, coasts, and marine environments. When ecosystems and biodiversity have been degraded, there is a corresponding effect on the extent, quality, and access to customary resources.

Māori see a need for improved provisions for tangata whenua to restore connections between iwi and hapū and their environments, and enable Māori participation in decision-making at all levels (Ruru et al, 2017).

Where are the gaps in our knowledge about this issue?

POOR UNDERSTANDING OF HOW OUR ACTIVITIES AFFECT EROSION

While there are national models that estimate erosion risks and rates, there are very few sites where erosion is actually measured. Without data collected at a sufficiently fine scale and over time (such as long-term trials and field sites), there is limited understanding of what is happening, where, and to what extent. The extent of human-induced erosion as opposed to that resulting from natural processes, like strong earthquakes or intense rainfall events, is also not well understood.

Without measured data on erosion rates, there is also limited quantitative understanding of how effectively mitigation strategies, like riparian planting and soil conservation planting, are working.

More research is also needed to account for other factors that affect erosion rates to anticipate changes that may occur in the future. For example, the more frequent and intense rainfall projected for parts of the country from climate change is expected to increase erosion, predominantly in our steep hill country.

POOR UNDERSTANDING OF ALL CONSEQUENCES OF REMOVING NATIVE VEGETATION

We know that ecosystems provide benefits that contribute to our well-being. While we have some high-level understanding of which ecosystem services are provided by native vegetation (eg erosion control, carbon sequestration, recreation) we cannot easily quantify them. This is due to the variety of ecosystems and dependencies. For forest cover, it is even harder to separate the level of services provided from indigenous versus exotic species.

There are also some ecosystem services that we know little about. For example, the benefits provided by native species are likely to underpin many recreational and (eco) tourism opportunities, but these benefits have not been measured or quantified.

The effects of this issue on te ao Māori are recognised but have not been assessed or reported with enough detail. We also have limited information about the impacts of sedimentation on the special and significant interests Māori have in coastal ecosystems, particulary at important customary and commercial fishery sites.

ISSUE 3

Urban growth is reducing versatile land and native biodiversity

Growth of urban centres has led to land fragmentation and threatens the limited supply of versatile land near Auckland and other regional centres.

Why does this issue matter?

SPATIAL EXTENT

It affects all our urban areas and surrounding environments.

DEPARTURE FROM NATURAL CONDITIONS

The modifications to land cover and loss of biodiversity are significantly different to natural conditions.

IRREVERSIBILITY

Changes to the landscape and loss of natural vegetation may be irreversible.

IMPACTS ON WHAT WE VALUE

It can affect our well-being, future food production, and native biodiversity on the urban edges.

KNOWLEDGE GAPS

Lack of up-to-date information on the size of urban areas, where they are growing, and how fast, limits our ability to manage the impacts of growth.

What is the current state of this issue?

Most New Zealanders live in cities – according to 2018 population estimates, 86 percent of us live in urban areas (Stats NZ, 2018a). This proportion has remained relatively constant since 1991.

Our urban areas make up a small proportion of our total land area. In 2012, 0.85 percent (approximately 228,000 hectares) of the country was classified as having urban land cover. (See indicator: Land cover.)

Land that has been developed for urban use is very different from its natural condition. Not only is native forest removed, but wetlands are often drained – natural land cover is usually reduced to less than 2 percent in urban centres (Clarkson et al, 2007).

Most urban centres have developed on our best land. They are often located on fertile floodplains near the coast, which were historically chosen for their strategic location in good harbours, giving access for overseas trade, productive land, and local markets.

Versatile land

Our most productive land can be called versatile land, high-class land, and land with elite or high-class soils. These terms can all mean different things.

The New Zealand Land Resource Inventory (Manaaki Whenua – Landcare Research, 2010) classifies land into eight classes of land-use capability based on a range of factors that include soil type, terrain, and climate (Lynn et al, 2009).

Class 1 land is generally considered to be the most versatile with no limitations on use. Class 2 land is very good land with slight physical limitations to arable use, and class 3 land has moderate limitations for arable use. In this report 'versatile' is used to mean classes 1 and 2 land.

What has changed?

OUR URBAN AREAS ARE SPREADING

The area of urban land increased by 10 percent between 1996 and 2012 to approximately 228,000 hectares. The largest expansion was in Auckland (up 4,211 hectares), followed by Waikato (up 3,900 hectares) and Canterbury (up 3,829 hectares). (See indicator: Land cover.)

Between 1990 and 2008, 29 percent of new urban areas were on 'versatile' land (see Versatile land below). This type of land has many potential agricultural uses and is highly productive (*Our land 2018*). The largest areas of versatile land converted from agricultural to urban use were in Canterbury (4,800 hectares) and Auckland (2,600 hectares) (Andrew & Dymond, 2013).

Between 1990 and 2008, 0.5 percent of New Zealand's total versatile land area was converted to urban land (Andrew & Dymond, 2013). Although this figure does not seem large, land with a favourable climate that has easy access to markets for perishable produce, is our most valuable versatile land. This is the land that is being converted to urban use.

OUR LAND IS BECOMING MORE FRAGMENTED

The fringes of urban areas are increasingly being broken into smaller land parcels, or fragmented and sold as lifestyle blocks.

The number of lifestyle blocks has increased sharply in recent decades. A 2013 study showed that 175,000 lifestyle blocks occupied 873,000 hectares of land in 2011. Of these, more than 40 percent had been established since 1998 – an average of 5,800 new blocks a year (Andrew & Dymond, 2013). Seventeen percent (148,000 hectares) of these lifestyle blocks were located on versatile land, which represents a loss of 10 percent of all versatile land in New Zealand.

Land fragmentation has been identified as an issue in Northland, Auckland, Waikato, Bay of Plenty, Gisborne, and Tasman regions (Rutledge et al, 2015).

What has contributed to this issue?

OUR POPULATION IS GROWING

Urban expansion is mostly driven by population growth. Between 2008 and 2018 our population increased by 14.7 percent (Stats NZ, 2018a). Growth is expected to continue – projections estimate New Zealand's population may reach 5 million in the next five years (Stats NZ, 2016). Population growth is projected to be higher in Tauranga, Auckland, and Hamilton, and lower in Wellington and Dunedin (NZPC, 2017).

The population of our urban centres has been growing faster than our rural areas. Between 1996 and 2006, the total population growth rate in our main urban centres was higher than the overall population growth rate (Stats NZ, n.d.-b).

INCREASING INTEREST IN LIFESTYLE BLOCKS

Our growing population, coupled with the Kiwi dream of a 'quarter-acre section' (rather than an inner-city apartment), has created pressure on the boundaries of our urban areas. Some city dwellers have also decided that the urban environment does not meet their needs and have embraced country living on a lifestyle block.

A 2013 study found that 35 percent of Auckland's versatile land was used as lifestyle blocks (Andrew & Dymond, 2013). Although the fragmentation of land is legally reversible, it is not often practical to do so because the value of a property increases when land is converted from agricultural use to a lifestyle block (Andrew & Dymond, 2013; Curran-Cournane et al, 2018).

Land fragmentation does not necessarily lead to a complete loss of productivity – some food production often occurs on small pieces of land. In this context, however, the issue is concerned with the fragmentation of land to lifestyle blocks where the use of the land is considered 'non-economic' and "revenues from production are likely to be insufficient to cover the costs of the property" (Andrew & Dymond, 2013).

What are the consequences of this issue?

OUR VERSATILE LAND AND HIGH-CLASS SOILS ARE GRADUALLY BEING LOST

Historically, vegetables have been grown on productive soils close to major urban centres. There are provisions in the Resource Management Act 1991 to protect the life-supporting capacity of soil (noted in Part 2 of the Act). However, urban growth has resulted in the loss of some of our most versatile land, making it unavailable for growing food. Versatile land represents just over 5 percent of our total land area (Rutledge et al, 2010) and, so, is a scarce resource.

The loss of versatile land is happening at the same time as our food production system is under pressure to increase production without increasing its effect on the environment (Curran-Cournane et al, 2016). Food production is recognised as the largest cause of global environmental change and significant modifications to food production are needed to meet increasing demand (as populations grow) while also being sustainable (Willett et al, 2019).

A further consequence of losing versatile land out of production is that it can force growers onto more marginal land that is naturally less productive and requires more inputs (like fertiliser) or changes in methods for the same production (Andrew & Dymond, 2013). Shifting production further from urban centres or onto lower-quality soils also has economic and environmental consequences by increasing transport costs.

URBAN DEVELOPMENT REDUCES NATIVE BIODIVERSITY

Urban growth causes a dramatic change in land cover and is often responsible for reduction in habitat. In New Zealand, native land cover accounts for less than 2 percent of land in urban centres and only 10 percent on the urban-rural boundary (Clarkson et al, 2007). This loss of native vegetation often results in the loss of native species and an increase in non-native species (Grimm et al, 2008; McKinney, 2006).

Many of the plants and animals people bring with them to cities can also increase the pressure on native biodiversity. For example, cats can hunt native animals (Flux, 2007; Baker et al, 2005) and while gardens and urban planting can be a place for native flora, they are also a source of non-native plants that can become problematic weeds if they spread to native areas (Sullivan et al, 2005). Some pest mammals, like rats and mice, are particularly well adapted to life in urban environments. This can increase predation and other issues for native plants and animals that live in and around urban areas.

Urban areas are also a source of pollutants that can have a negative impact on the condition of some ecosystems. (See Issue 5: Our environment is polluted in urban areas.)

OUR WELL-BEING IS AFFECTED

The reduction of vegetation and biodiversity in our urban areas (and their fringes) can have negative impacts on our well-being. Having access to green spaces is known to improve the physical and mental well-being of people living in cities (Fuller et al, 2007; Taylor & Hochuli, 2015).

Converting horticultural and agricultural land at the urban-rural boundary to urban use reduces job opportunities and ready access to fresh fruit and vegetables. Because of the irreversibility of this conversion, it also has the potential to limit the options for future generations (Curran-Cournane et al, 2016).

Another consequence of the proliferation of lifestyle blocks is 'reverse sensitivity' where new rural land owners discover that rural life includes dealing with noise, animal odour, and crop spraying on neighbouring properties. Restrictions placed on agricultural and horticultural operations as a result can affect their productivity (Andrew & Dymond, 2013).

Where are the gaps in our knowledge about this issue?

WE LACK KNOWLEDGE OF THE CURRENT EXTENT OF URBAN AREAS AND WHERE THEY ARE GROWING

Monitoring actual changes as opposed to planned urban extent is challenging and is usually based on satellite imagery or aerial photography. The information we currently have on the area of urban land in New Zealand is based on the Land Cover Database – its most recent update (version 4.1) only provides data up until 2012 (Manaaki Whenua – Landcare Research, 2015). This limits our understanding of the extent of urban areas, how much they are expanding, and where they are expanding. It also limits our understanding of the impacts urban expansion is having on our access to the most productive soils.

IMPACTS OF LAND FRAGMENTATION AND THE PRODUCTIVITY OF LIFESTYLE BLOCKS ARE NOT KNOWN

The impacts of land fragmentation are difficult to quantify. While we have some information that details the development of lifestyle blocks, we do not have information on the productivity of lifestyle blocks or the impacts on food production on the environment.

THEME 3

Pollution from our activities

Photo credit: Ministry for the Environment

Our environment is polluted when substances or kinds of energy (noise, light, heat) enter it and cause harm.

Some pollutants directly affect our health. Bacteria like *Campylobacter* in drinking water can cause illness, and very fine particles in the air can cause lung and heart problems. Other pollutants pose threats to the health of plants, animals, and ecosystems, like plastic waste in the ocean or excess nutrients in our waterways. Pollution also affects our connections to nature. Artificial light from towns and cities reduces our view of the night sky, and murky streams spoil our enjoyment of these environments.

Most pollution comes from human activities, such as industry, agriculture, power generation, home heating, and transport, but some comes from natural events like volcanic eruptions. Often pollution has a mix of sources. Waterways, for example, can contain disease-causing bacteria from bird faeces, nutrients from farm run-off, and heavy metals from vehicle wear (copper from brake pads and zinc from tyres).

Pinpointing the cause of pollution can be difficult. Some pollution comes from one place (eg a factory or sewage treatment plant) while other pollution has many sources (eg vehicle emissions). Pollutants can move in the air, in water, and through soil, often over large distances and long periods of time. They can also change their form, sometimes becoming more-hazardous pollutants.

This theme focuses on two kinds of pollution that are considered of most importance to New Zealand, based on the criteria listed earlier in A focus on what matters:

1. **Pollution of waterways from farming:** Excess nutrients and disease-causing microorganisms affect our rivers, lakes, groundwater, and coastal areas. This type of pollution affects almost all farmed areas in Aotearoa New Zealand and involves major changes to the natural state of our waterways.
2. **Pollution in urban areas:** The air, land, and water in some of our towns and cities is being polluted by our waste, home heating, vehicles, and industries. This pollution has a major effect on our environment, harming our ecosystems and our relationship with nature, and posing risks to human health.

Other issues highlighted in this report also contribute to or are related to pollution:

- **Issue 1:** Our native plants, animals, and ecosystems are under threat – describes how pollution of our waterways affects biodiversity, including the effect of sediment in estuaries.
- **Issue 2:** Changes to the vegetation on our land are degrading the soil and water – describes how this contributes to pollution of our waterways.
- **Issue 9:** Climate change is already affecting Aotearoa New Zealand – describes how climate change is predicted to put more pressure on the quality of our fresh water.

ISSUE 4

Our waterways are polluted in farming areas

Waterways in farming areas are polluted by excess nutrients, pathogens, and sediment. This threatens our freshwater ecosystems and cultural values, and may make our water unsafe for drinking and recreation.

Why does this issue matter?

SPATIAL EXTENT

It affects almost all rivers and many aquifers in farming areas. Some lakes and estuaries may also be affected.

DEPARTURE FROM NATURAL CONDITIONS

In areas of pastoral farming the median concentrations of nutrients, pathogens, and sediment in rivers are between 2 and 15 times higher than natural conditions.

IRREVERSIBILITY

It is difficult to reverse because farming is important for the economy, some catchments respond slowly to interventions, the issue is widespread, and departure from natural conditions is large.

IMPACTS ON WHAT WE VALUE

71 percent of river length in areas of pastoral farming has modelled levels of nitrogen that may cause some growth effect on aquatic species, and 82 percent of river length in farmed areas has modelled pathogen levels that pose risks to human health from swimming. Both degrade cultural well-being.

KNOWLEDGE GAPS

There is poor understanding and insufficient data for exactly where, when, and what farming and farm management practices have contributed to or mitigated the observed state and trends.

What is the current state of this issue?

Understanding water quality and why it varies from location to location and over time is challenging. Part of the difficulty arises because rivers, lakes, and groundwaters are parts of an interconnected freshwater system that flows into estuaries and coastal environments. A reduction in water quality in one part of the system can affect water quality elsewhere and make it difficult to determine the sources of pollution. Polluted groundwater, for instance, can flow into a river that flows into an estuary. Also, pollution moves slowly through some catchments, so the water quality in some locations today may be the result of land use that occurred many years ago (see Lag times can be long).

Catchments can contain a mix of land-cover types and land uses, like native vegetation, exotic forest, urban areas, and farming (ie agriculture), which can affect water quality in different ways. As used in this report, farming refers to pastoral farming (including dairy, beef, sheep, and other livestock), horticulture, and arable cropping. Different types of farming can also have a variety of effects on water quality – depending on the characteristics of the farmed land and the way the farming is managed. For example, some farm management practices, like keeping stock out of streams or riparian planting, can mitigate or limit the impacts on water quality (Larned et al, 2018a), but information about the types of management practices on specific farms is not generally available.

Despite these challenges to understanding water quality, there is clear evidence that waterways in our farming areas have markedly higher pollution by nutrients (nitrogen and phosphorus), microbial pathogens, and sediment than waterways in native catchments. Although all these pollutants occur naturally in freshwater systems, excess concentrations can cause harm. (See Issue 5: Our environment is polluted in urban areas for a comparison between water quality in farming and urban environments.)

Pollutants in our waterways

Nutrients

Nitrogen and phosphorus are essential nutrients for plants, and small amounts are a natural component of healthy freshwater ecosystems. Different forms of nitrogen and phosphorus have different properties:

- Nitrate-nitrogen dissolves and moves easily in water. It can be carried by streams into rivers and lakes or leach through the soil into underground aquifers. Ammoniacal nitrogen does not leach through soils as easily.
- Phosphorus sticks to tiny soil particles that can build up as sediment on river and lake beds. Most phosphorus stays chemically bound to this sediment. Reactive phosphorus forms if conditions allow the bound phosphorus to dissolve. It can then be taken up by plants and algae, allowing them to grow rapidly.

When nitrogen and phosphorus accumulate in rivers, lakes, and enclosed coastal waters above certain concentrations (referred to as nutrient enrichment), they can stimulate excessive growth of algae, water weeds, and cyanobacteria. At very high concentrations, nitrate-nitrogen and ammonia (a form of ammoniacal nitrogen) can be toxic to aquatic life. Very high concentrations of nitrate-nitrogen also make water unsafe to drink. Little is known about the effects of nutrient enrichment on groundwater ecosystems.

Pathogens

Several pathogens cause disease if they are consumed by people, like *Campylobacter* bacteria, the protozoa *Giardia* and *Cryptosporidium*, and some types of viruses. These pathogens can cause rapid and major outbreaks of illness and limit how we use our fresh water for drinking and recreation. The possible presence of pathogens is assessed by monitoring the levels of the indicator bacteria *E. coli* in fresh water, or *Enterococci* and faecal coliforms in sea water. Finding these indicator organisms in water is a reliable sign that it contains animal or human faeces, which signals that pathogens may be present. Some pathogens, such as toxoplasmosis, can also persist for months in coastal seas.

Sediment

Sediment includes all the solid particles carried by and in water. Fine particles like silt, mud, and organic material can reduce clarity (underwater visibility) and increase turbidity (cloudiness) in rivers, lakes, and coastal waters. Poor clarity and high turbidity affect the habitat and food supply of aquatic life, like fish and birds, and the growth of aquatic plants. Excess fine sediment that settles onto the bottom of rivers, lakes, and estuaries can smother aquatic ecosystems. Excess sediment can also have an impact on the aesthetic values and recreational use of rivers, lakes, and coastal areas.

This report assesses the current state of water quality against two sets of guidelines and thresholds (see Water quality guidelines and thresholds below). A comparison with the water quality under estimated natural conditions is based on the default guideline values in the latest *Australian and New Zealand guidelines for fresh and marine water quality* (ANZG, 2018). A comparison with water quality that may cause effects on ecosystem health or human health for recreation is based on the National Objectives Framework in the *National Policy Statement for Freshwater Management 2014 (Amended 2017)* (MfE, 2017b).

Agriculture's contribution to our economy

- $11.3 billion
- 4.2 percent of gross domestic product (GDP)
- 122,600 (4.7 percent) of people were employed in agriculture as their main income source.

Note: All gross domestic product (GDP) figures are from the *National accounts (Industry production and investment): year ended March 2017.* These figures exclude manufacturing or processing of primary products. They are in current prices, ie not adjusted for the effect of changing prices over time. The people employed information is from linked employer-employee data (LEED). The measure is main earning source, by industry using New Zealand standard industry output categories.

Water quality guidelines and thresholds

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

Australian and New Zealand guidelines for fresh and marine 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 it 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 Objectives Framework

The *National Policy Statement for Freshwater Management* (Freshwater NPS) (MfE, 2017b) requires councils to set objectives for freshwater management in their regional plans. The National Objectives Framework (NOF), a part of the Freshwater NPS, helps local authorities and communities set these freshwater management objectives.

The NOF defines minimum acceptable states for water quality based on ecosystem health and human health.

The NOF defines bands (ranges) for relevant variables to support these values in rivers and lakes. The NOF 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.

The bands are designed to help communities make decisions on how to manage water quality. For example, the NOF includes bands for the concentrations of *Escherichia coli (E. coli)* in relation to the risk of infection by *Campylobacter* during swimming in rivers and lakes, and bands for concentrations of nitrate-nitrogen and ammonia in relation to toxicity effects on aquatic species.

Councils are also required to maintain or improve water quality – they cannot allow water quality to drop from band A to band B for example.

Note that the NOF bands are not directly comparable to the DGVs in the *Australian and New Zealand guidelines for fresh and marine water quality.*

RIVERS IN FARMING AREAS ARE POLLUTED

Many studies at national, regional, and catchment scales show that concentrations of nitrogen, phosphorus, fine sediment, and *E. coli* in rivers all increase as the area of farmland upstream increases (Larned et al, 2018a). This section focuses on pastoral farming, for which most data is available and which occurs over much more land area than horticulture or growing arable crops (Larned et al, 2018a).

Computer models have been developed to estimate the water quality in New Zealand rivers (figure 8 for example, shows nitrate-nitrogen concentrations). This report uses four categories – pastoral, urban, exotic forest, and native – to classify monitoring sites and stretches (or reaches) of rivers according to the type of land cover in the catchment upstream. (Note: Land-cover class is determined by the spatially dominant land-cover type in the upstream catchment, unless pasture exceeds 25 percent of catchment area, in which case the pastoral class is assigned, or unless urban cover exceeds 15 percent of catchment area, in which case the urban class is assigned. Any catchment includes a mixture of land cover, but each river reach is assigned to one of four land-cover categories for the purpose of this report.)

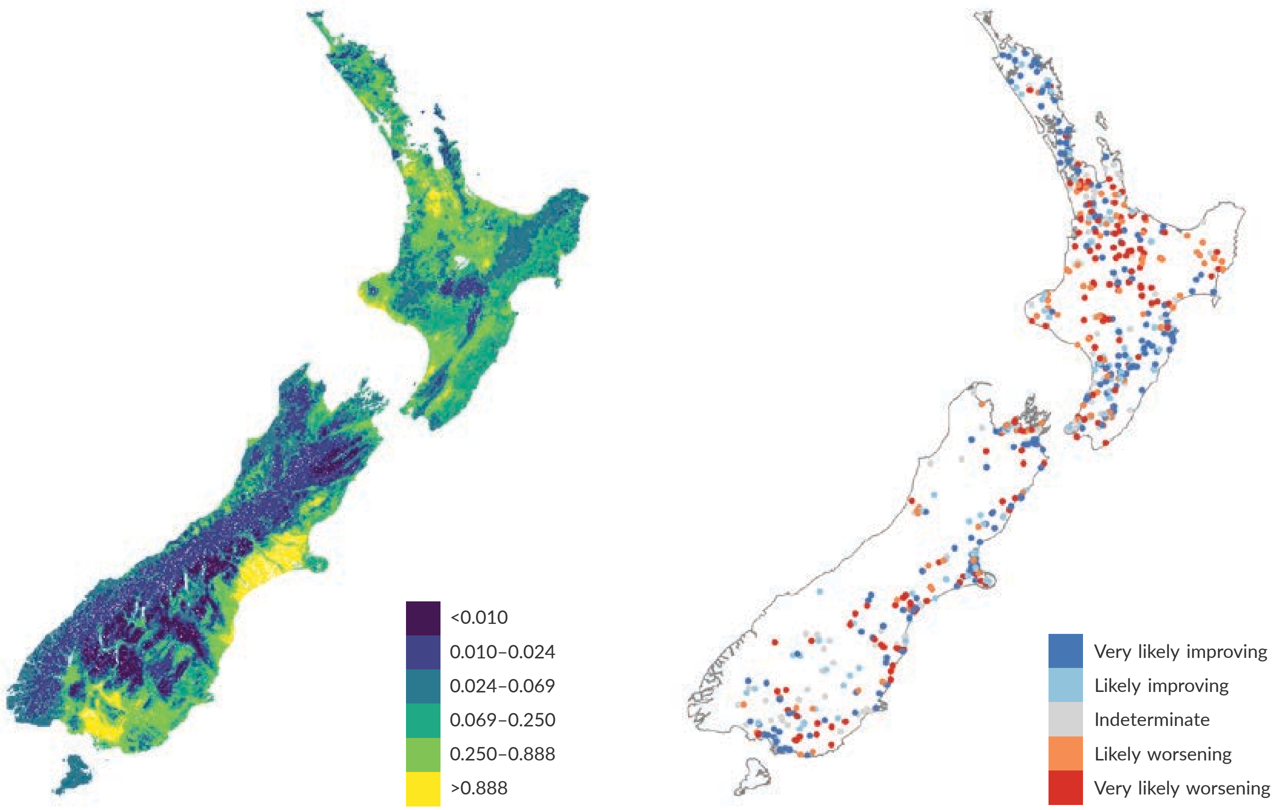
River pollution can be assessed (degree and spatial extent) by comparing the modelled water quality in the native land and pastoral classes. The river water quality expected for native land cover, ie in natural conditions, is shown by the DGVs in the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZG, 2018). Comparing against expected natural conditions, although not a perfect measure, gives a benchmark to assess the scale of change against. The same approach is used in Issue 5: Our environment is polluted in urban areas, where river water quality is compared for the urban and native land-cover classes.

The models show that, for most water quality variables, 50–90 percent of the total river length in the pastoral land-cover class exceeds the relevant DGV for 2013–17 (see table 1). In comparison, the models show that DGVs are exceeded in less than 30 percent of the river length in the native land-cover class. (A total of 188,024 kilometres of New Zealand's river length is in the pastoral land-cover class, whereas a total of 198,126 kilometres is in the native land-cover class.)

Figure 8: River water quality nitrate-nitrogen concentrations for all land-cover classes

Modelled median concentrations in g/m³, 2013–17

Measured trends, 2008–17



Data source: NIWA

From 2013 to 2017, compared with rivers in the native land-cover class, the pastoral land-cover class had modelled median nitrate-nitrogen levels that were 9.7 times higher, dissolved reactive phosphorus levels 3.4 times higher, turbidity 2.2 times higher, and *E. coli* levels 14.6 times higher (see table 1).

Lake, coastal, and estuarine water quality monitoring sites are not categorised by the amount of farmland in their catchments, so the impacts of farming cannot be specifically assessed. (See indicators: Lake water quality and Coastal and estuarine water quality.)

GROUNDWATER QUALITY IS MIXED

The quality of groundwater varies across New Zealand. Nationally over the period 2010–14, 34 percent of 342 sites had median nitrate-nitrogen concentration greater than 3 grams per cubic metre. These values are above the expected concentrations for natural conditions, based on national-scale studies in New Zealand (Daughney & Reeves, 2005; Morgenstern & Daughney, 2012). Expected levels in natural conditions have not yet been defined for other groundwater quality parameters (like phosphorus or *E. coli*).

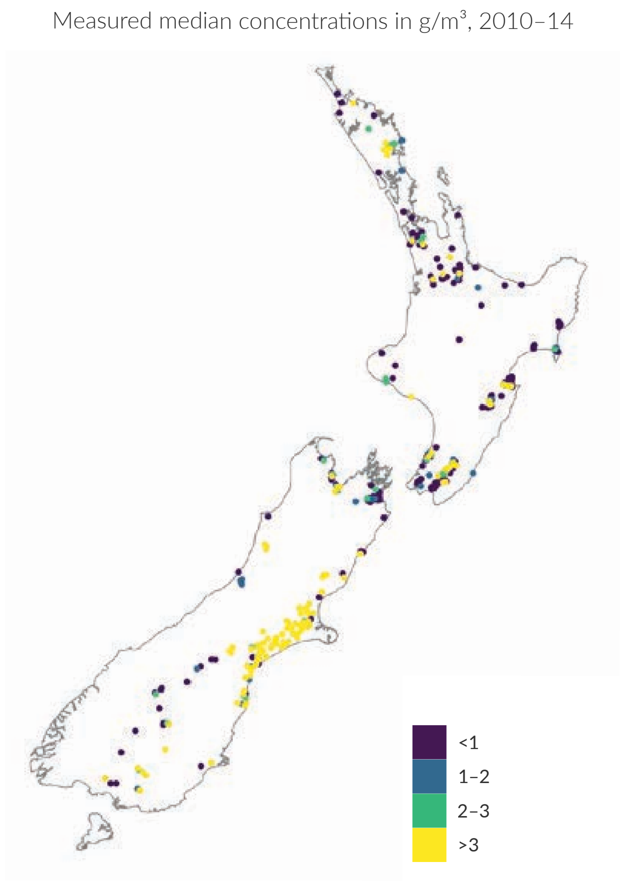
Groundwater quality monitoring sites are not categorised according to land use, so the specific effects of farming cannot be identified. However, some patterns coincide with pastoral land cover – especially nitrate-nitrogen in Canterbury (see figure 9 compared with figure 4). (See indicator: Groundwater quality.)

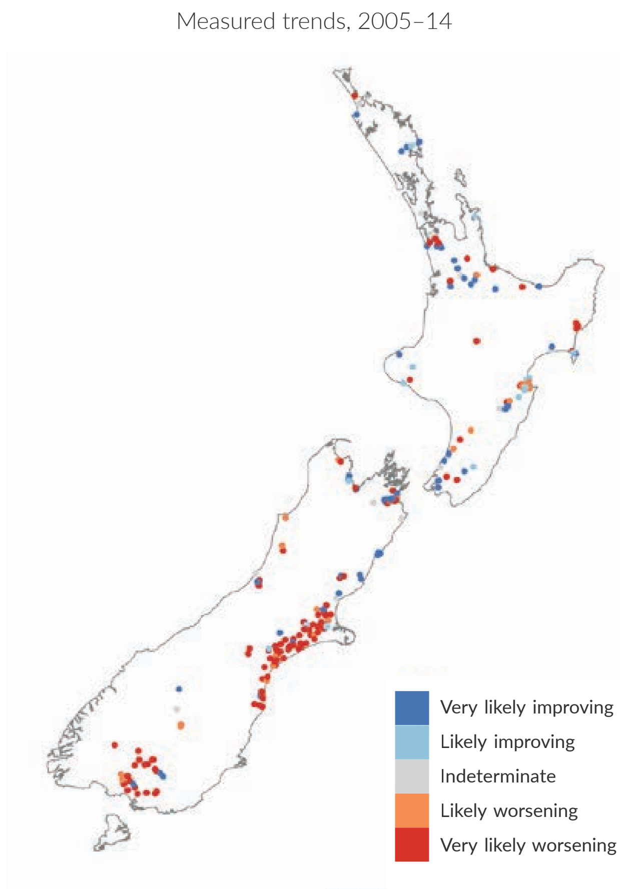
Table 1: River water quality (modelled) in pastoral land catchments compared with native catchments

		Modelled median value of water quality variable, 2013–17		River length (km) that does not meet ANZG DGV	
Water quality variable	**Units**	**Pastoral land cover**	**Native land cover**	**Pastoral land cover**	**Native land cover**
Total nitrogen	mg/m³	738.6	115.9	162,475 (86%)	57,027 (29%)
Nitrate-nitrogen	mg/m³	246.6	25.6	155,000 (82%)	26,610 (13%)
Ammoniacal nitrogen	mg/m³	8.3	4.0	94,237 (50%)	29,464 (15%)
Total phosphorus	mg/m³	32.5	8.3	169,142 (90%)	50,977 (26%)
Dissolved reactive phosphorus	mg/m³	14.6	4.4	144,191 (77%)	45,270 (23%)
E. coli	cfu/100 ml	195.0	13.3	47,314 (25%)	1,117 (0.6%)
Turbidity	NTU	2.9	1.3	117,343 (62%)	22,962 (12%)
Clarity	m	1.7	3.3	13,499 (7%)	1,467 (1%)

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.

Figure 9: Groundwater quality nitrate-nitrogen concentrations for all land-cover classes





Data source: Regional councils; GNS Science

Intensified farming

Recent intensification of farming has increased the risks of water pollution.

CHANGES TO OUR USE OF LAND IN THE PAST THREE DECADES

Less sheep, more cows

Cattle numbers have increased, especially dairy cattle. Cows produce more urine with a higher nitrogen concentration than sheep.

More animals per hectare

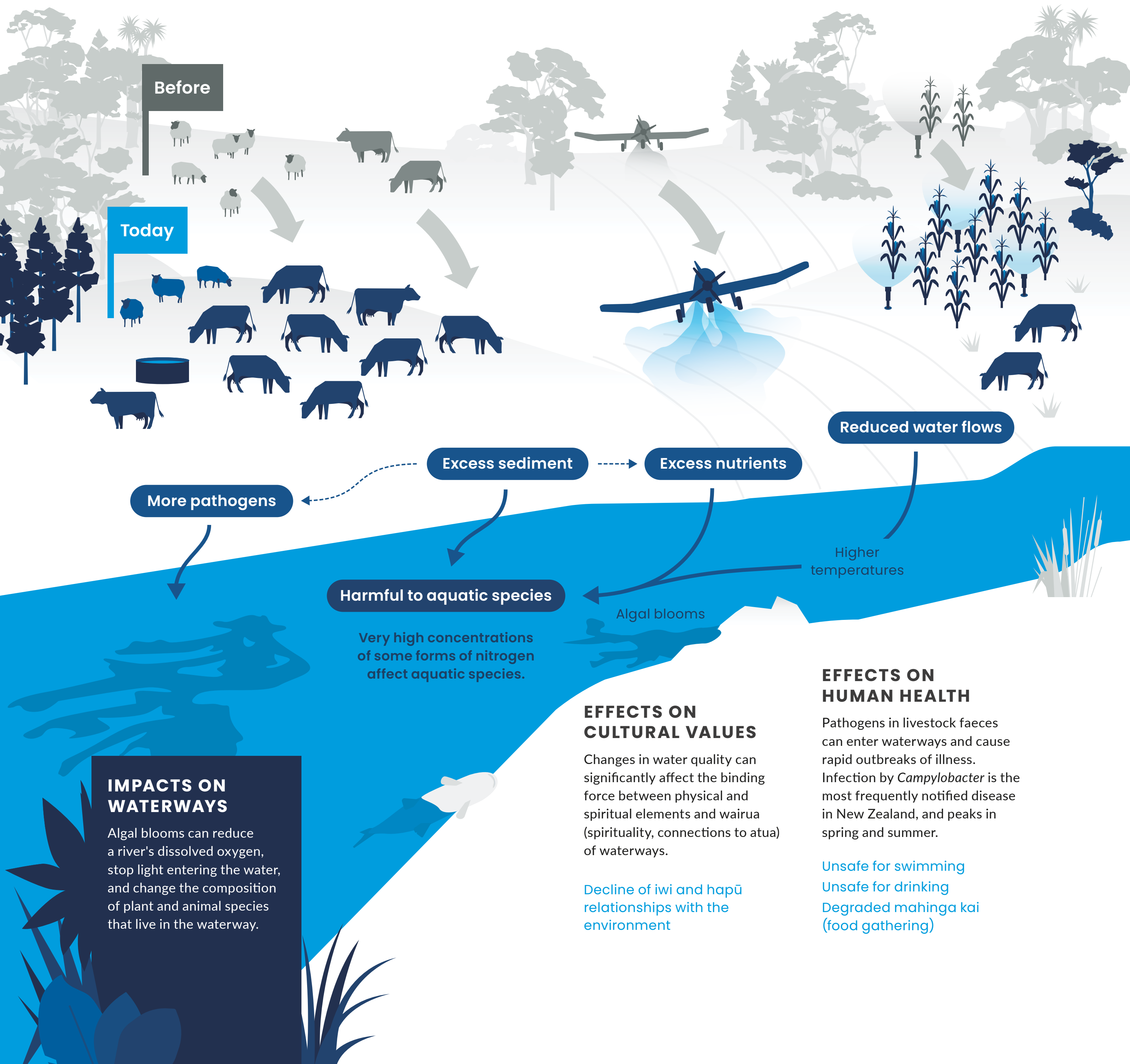
High stocking rates and vehicles driven on the land cause soil compaction, increasing the likelihood of polluting run-off into streams.

More fertiliser

The amount of nitrogen applied in fertiliser has increased. Fertilisers like nitrogen and phosphorus can pollute waterways.

More irrigated land

The amount of irrigated land has increased. Taking more water for irrigation reduces river flows and affects species and habitats.



What has changed?

Changes in water quality are measured using trend tests. A worsening trend means that the amount of nitrogen, phosphorus, *E. coli*, or sediment is increasing over time so the water quality is likely to be worsening. An improving trend means that the concentration of these pollutants is decreasing.

More research is needed to understand how, where, and why trends in water quality occur, and why they speed up or slow down. The effects of natural climatic variations compared with the effects of human activities are also poorly understood (see Where are the gaps in our knowledge about this issue?).

RECENT CHANGES IN RIVER QUALITY ARE MIXED

In the 10 years from 2008 to 2017, some river water quality monitoring sites showed improving trends and some showed worsening trends. The pastoral and native land-cover classes had similar proportions of sites with improving and worsening trends (see figure 10). The absolute rate of change in both classes of land cover was less than 4 percent per year for most variables at most sites. (See indicators: River water quality: clarity and turbidity, River water quality: *Escherichia coli*, River water quality: macroinvertebrate community index, River water quality: nitrogen, and River water quality: phosphorus.)

Understanding the causes of these trends is difficult due to the complex interconnections between water bodies, variable lag times, and the mixture of land cover, land use, and land management that occurs in any given catchment (see What is the current state of this issue?).

Changes in water quality trend assessments since *Our fresh water 2017*

The water quality in our rivers, groundwater, and lakes as reported above is generally similar to that in *Our fresh water 2017*, which reported on water quality using datasets ending between 2013 and 2015.

Trend assessments of water quality in this report, however, are based on improved methods (see Larned et al, 2018b; McBride, 2018; and Snelder & Fraser, 2018 for technical details).

The improved methods permit rates of change to be estimated more accurately at a larger number of sites. For example, this report uses data from at least 50 percent more river monitoring sites than were available for *Our fresh water 2017*.

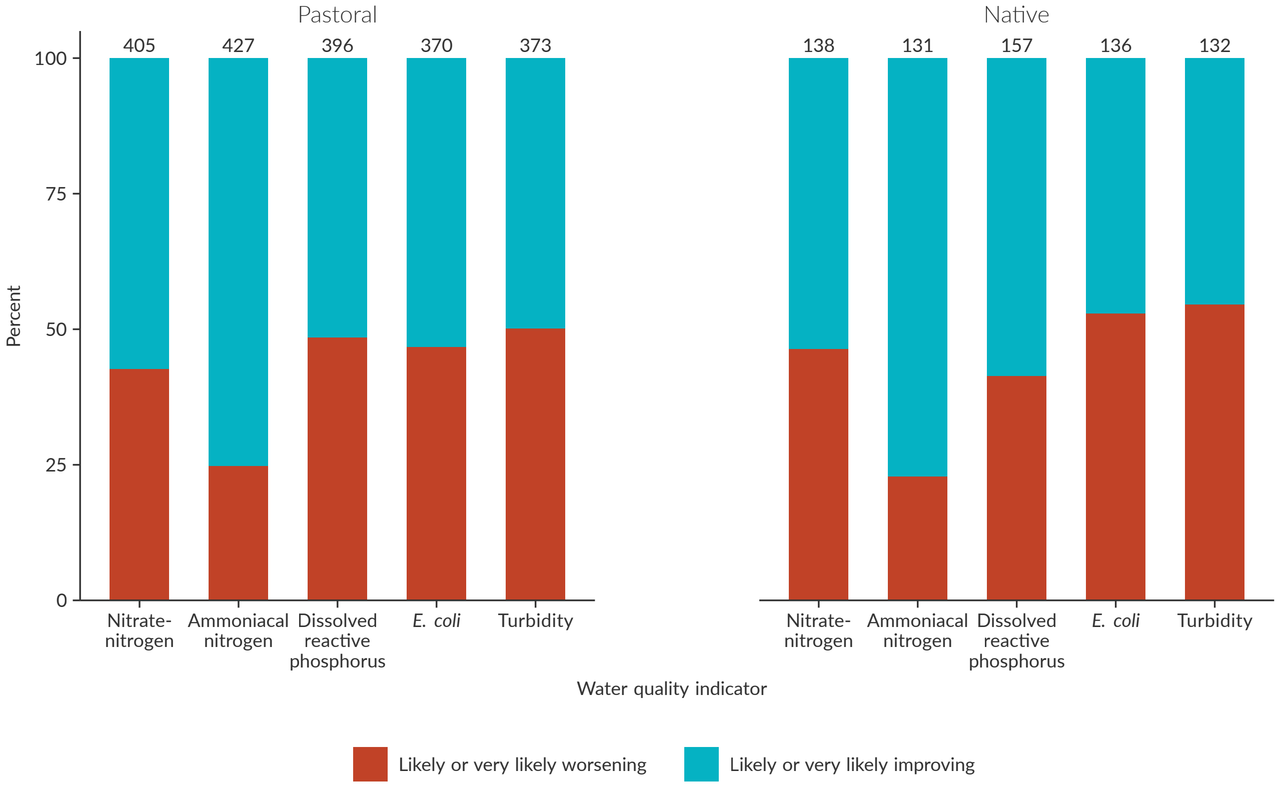
The improved methods also allow trends to be classified according to their certainty:

- very likely, 90–100 percent certainty of an improving or worsening trend
- likely, 67–89 percent certainty of a trend
- indeterminate, less than 67 percent and not enough statistical certainty to determine the trend direction.

By contrast, trends in *Our fresh water 2017* used a 95 percent threshold to identify improving and worsening trends (as opposed to the 67 percent threshold used in this report). This means that *Our fresh water 2017* reported a much higher proportion of sites as having indeterminate trends than this report.

The changes in trend assessment method and differences in available data mean that the trend results reported here are not directly comparable to those reported in *Our fresh water 2017*. These new methods for trend evaluation are, however, consistent with the approaches used by regional councils (Land, Air, Water Aotearoa website).

Figure 10: River water quality at sites with pastoral and native land cover, 2008–17



Data source: NIWA

Note: Sites with indeterminate trends are excluded. The number at the top of each bar shows the number of sites where a trend could be assessed. Land-cover class is determined by the land-cover type in the upstream catchment (see Rivers in farming areas are polluted).

Across all land-cover classes, the distribution of sites with improving versus worsening trends was not spatially uniform (see figure 11):

- Many sites with worsening nitrate-nitrogen trends were in the central North Island, including parts of Waikato, Gisborne, Taranaki, and Manawatu-Wanganui, and in the south-eastern South Island, including parts of Canterbury, Otago, and Southland. Many sites with improving nitrate-nitrogen trends were in Northland, parts of Manawatu-Wanganui, and Hawke's Bay.
- Sites with worsening dissolved reactive phosphorus trends were over much of the North Island, while improving trends were reported for much of the South Island.
- Many sites with worsening *E. coli* trends were in parts of Manawatu-Wanganui, Hawke's Bay, Taranaki, Wellington, Marlborough, Canterbury, and Southland. Many sites with improving *E. coli* trends were in Gisborne, Waikato, and Northland.
- Many sites with worsening turbidity trends were in parts of Waikato, Gisborne, Manawatu-Wanganui, Canterbury, and the West Coast. Many sites with improving turbidity trends were in Northland.

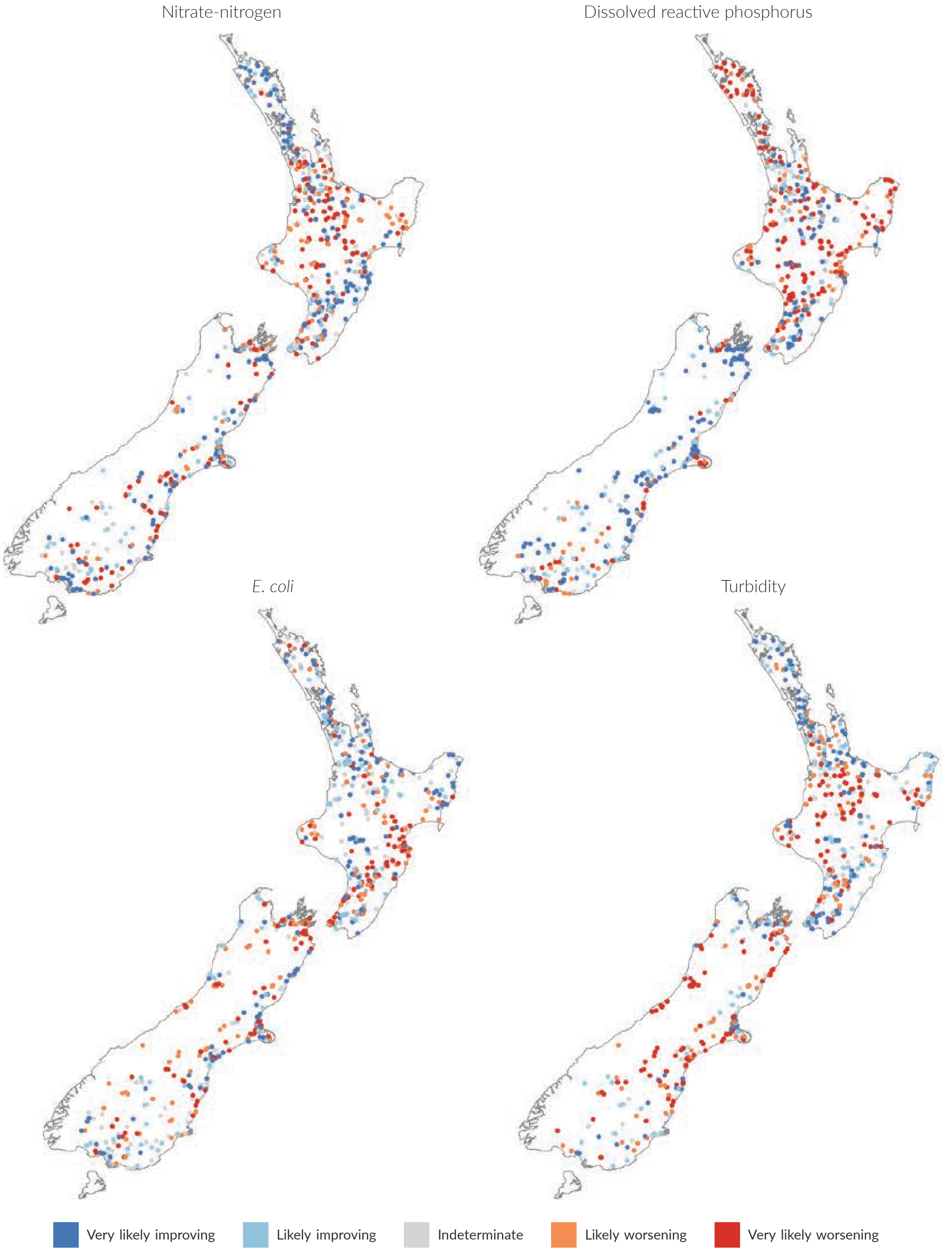
Lake, coastal, and estuarine water quality monitoring sites are not categorised by the amount of farmland in their catchments, so the impacts of farming cannot be specifically assessed.

CHANGES IN OUR GROUNDWATER QUALITY ARE MIXED

Excluding sites with indeterminate trends, about two-thirds of groundwater sites had worsening trends in nitrate-nitrogen, ammoniacal nitrogen, and *E. coli* for 2005–14 (more recent national data had not been compiled at the time of writing this report). About half of the sites had worsening trends in dissolved reactive phosphorus in the same time period.

As with the assessment of the current state of groundwater quality, how farming has affected trends in groundwater quality cannot be assessed because monitoring sites are not categorised by land cover. However, some patterns coincide with pastoral land cover – especially for trends in nitrate-nitrogen in Canterbury (see figure 9 compared with figure 4).

Figure 11: River water quality measured trends for all land-cover classes, 2008–17



Data source: NIWA

Ōtukaikino Creek: Restoration by a whole community

New native planting beside Ōtukaikino Creek.
Photo credit: Arthur Adcock

Just south of the Waimakariri River in Christchurch is Ōtukaikino Creek. Fed by springs and groundwater, the small river is joined by water from a small wetland as it runs towards the east coast. This area was once used for burial preparations and is significant for Ngāi Tahu whānui.

The land was changed significantly by farming and urban development – native forest around the river was removed, the wetland became smaller, and the city grew. These changes combined to degrade the river's water quality, with high levels of nutrients (nitrogen and phosphorus) and *E. coli* reported (LAWA, n.d.-a, n.d.-b). (See Issue 4: Our waterways are polluted in farming areas.)

Keeping farm animals away from rivers has many recognised benefits for the environment. It stops the animals causing direct damage to riverbanks by eroding the banks and adding sediment to the waterway, and trampling the places where birds live and make their nests. Fencing rivers also protects the riverside plants where native fish (like whitebait) lay their eggs (Richardson & Taylor, 2002). Dung and urine from the animals contain nutrients and pathogens (including *E. coli*) that reduce the water quality if they enter a waterway.

Following conversations between members of the community, landowners, and Arthur Adcock (a park ranger), a fencing and planting programme was begun in 2003. This was an essential part of its restoration. Farmers voluntarily fenced off 20–100-metre buffer zones between their stock and the river along almost its whole length, and an estimated 195,000 locally sourced native plants (including carex, flax, kahikatea, tōtara, and mātai) were planted in this area. Besides the cost of fencing, farmers also lost productive land and had to find new water sources for their animals.

Today, Ōtukaikino Creek has very good water quality. There have been substantial decreases in phosphorus levels in the past 10 years and concentrations of ammoniacal nitrogen, total nitrogen, and total oxidised nitrogen have also reduced. It is now a popular place for recreation, especially with a new walking track beside the river.

The wetland is now part of the 13-hectare Ōtukaikino Wildlife Management Reserve, which is being developed by the Department of Conservation with sponsorship from Lamb and Hayward. Long- and short-finned eel (tuna), flounder, whitebait, and native snails (pūpū) live there, as do pūkeko, shoveler (kuruwhengu), grey teal (tētē), and marsh crake (koitareke).

The collective actions of many people and organisations have contributed to the success of the restoration. Isaac Conservation and Wildlife Trust and Clearwater (a golf club and resort) helped create the large buffer zones that are thought to have made the restoration so successful. Department of Corrections community service workers weeded out species like willow and gorse and replanted with natives. Christchurch City Council, Fish and Game, Environment Canterbury, QEII National Trust, Department of Conservation, Trees for Canterbury, Z Energy (Aviation), local schools, Scout groups, and private landowners also made significant contributions.

Ōtukaikino Creek won the supreme award for most improved river at the New Zealand River Awards in 2018.

What has contributed to this issue?

In less than 1,000 years New Zealand has changed from an unpopulated group of islands covered with dense forest, to an intensely farmed country dependent on export agriculture. Setting up our farms involved clearing native forests and scrub, and draining wetlands. These large-scale changes dramatically affected how our soils and water function. (See Issue 2: Changes to the vegetation on our land are degrading the soil and water.)

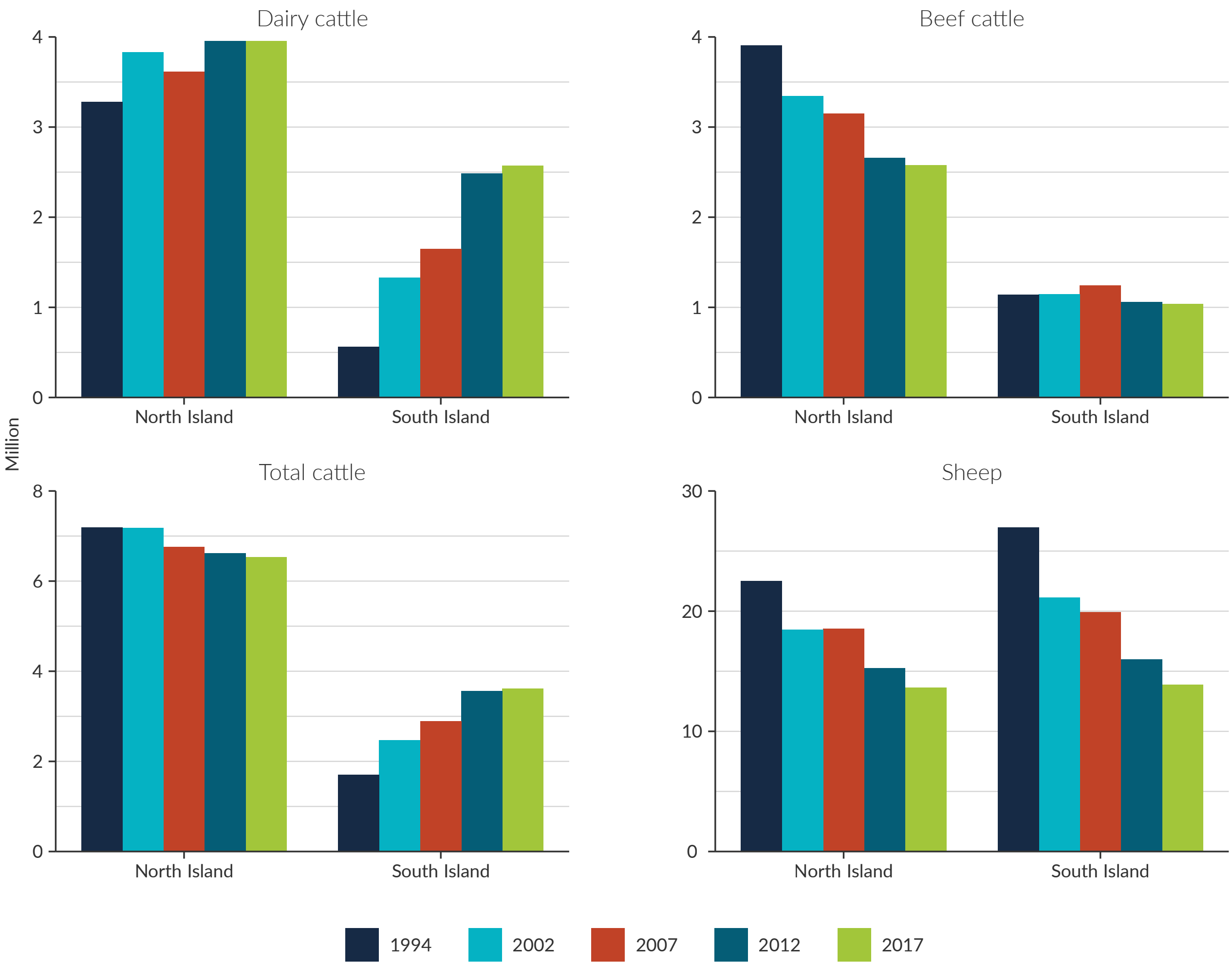
Establishing commercial agriculture also involved adapting imported farming systems to New Zealand conditions, including the use of fertiliser, trace elements, and irrigation to lift soil productivity. (See Issue 6: Taking water changes flows which affects our freshwater ecosystems.)

Several studies of river water quality indicate that an increasing proportion of agricultural land in an upstream catchment leads to increased concentrations of nitrogen, phosphorus, and *E. coli*, and sediment in waterways (Larned et al, 2018a).

While farming is not the only source for these pollutants, it is a major contributor:

- A 2012 study estimated that, at a national scale, the largest source of dissolved nitrogen is from diffuse sources, mainly urine spots in pastures (Parfitt et al, 2012).
- Important sources of phosphorus in farming systems include fertiliser, effluent, supplements, and excreted animal dung (Selbie et al, 2013).
- A 2012 study monitored water quality at 53 sites in 10 regions and found faecal matter from ruminants (eg cows, sheep, deer, goats) at 79 percent of the sites, showing that livestock dung was a major contributor to faecal contamination of waterways in farming areas (Cornelison et al, 2012).
- Models estimate that 44 percent of the soil that enters our rivers each year comes from pasture. (See Issue 2: Changes to the vegetation on our land are degrading the soil and water.)

Figure 12: Livestock numbers in the North and South islands, 1994–2017



Data source: Stats NZ

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 12), notably in Canterbury, Otago, and Southland. (See indicator: **Livestock numbers**.)

The land area used for dairy farming has also increased. In 2016, the area of land used for dairy production was 2.6 million hectares (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. Cattle excrete more nitrogen per animal than sheep (cows produce more urine and the urine has a higher nitrogen concentration), so nitrogen from cattle is more likely to leach through soil than nitrogen from sheep (MfE, 2018).

When the concentration of nitrogen in animal dung and urine exceeds the amount that soil and plants can absorb, nitrogen is lost either through the soil into waterways, or into the air as a gas.

Models of the total amount of nitrate-nitrogen leached from livestock show this has increased from 189,000 tonnes per year nationwide 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 around the country. According to the model, the highest nitrate-nitrogen leaching from livestock in 2017 occurred in Waikato, Manawatu-Wanganui, Taranaki, and Canterbury (see figure 13).

The modelling also shows that dairy cattle make a proportionally higher contribution to nitrogen leached from agricultural soils, compared with other types of livestock.

In 1990, 39 percent of modelled national nitrate-nitrogen leaching came from dairy cattle, 26 percent from beef cattle, and 34 percent from sheep. By 2017, nationally, 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 dairying occurring on less than 7 percent of New Zealand's land at that time (Elliot et al, 2005).

FARMING HAS INTENSIFIED

The number of cattle per hectare has increased between 1994 and 2017 in some areas of the country, notably Canterbury and Southland. (See indicator: **Livestock numbers**.)

More animals per paddock can contribute to nitrogen loss (Julian et al, 2017). When animals are closer together, there are more frequent and overlapping patches of urine, and a greater likelihood that soil and plant absorption will be overloaded (Ledgard, 2013).

High animal stocking rates and vehicles driven on the land can also cause soil compaction, 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. The nitrogen on the surface of the soil can contribute to greenhouse gas emissions as nitrous oxide (N_2O) more easily (van der Weerden et al, 2017) or be washed directly into waterways.

Use of nitrogen fertiliser has also 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 annually peaked at 219,000 tonnes in 2005, but has reduced to about 150,000 tonnes per year in the last decade (155,000 tonnes in 2015). The risk of leaching depends on when the fertiliser is applied, eg in relation to rainfall, but data related to the timing of application is not available. (See indicator: **Nitrogen and phosphorus in fertilisers**.)

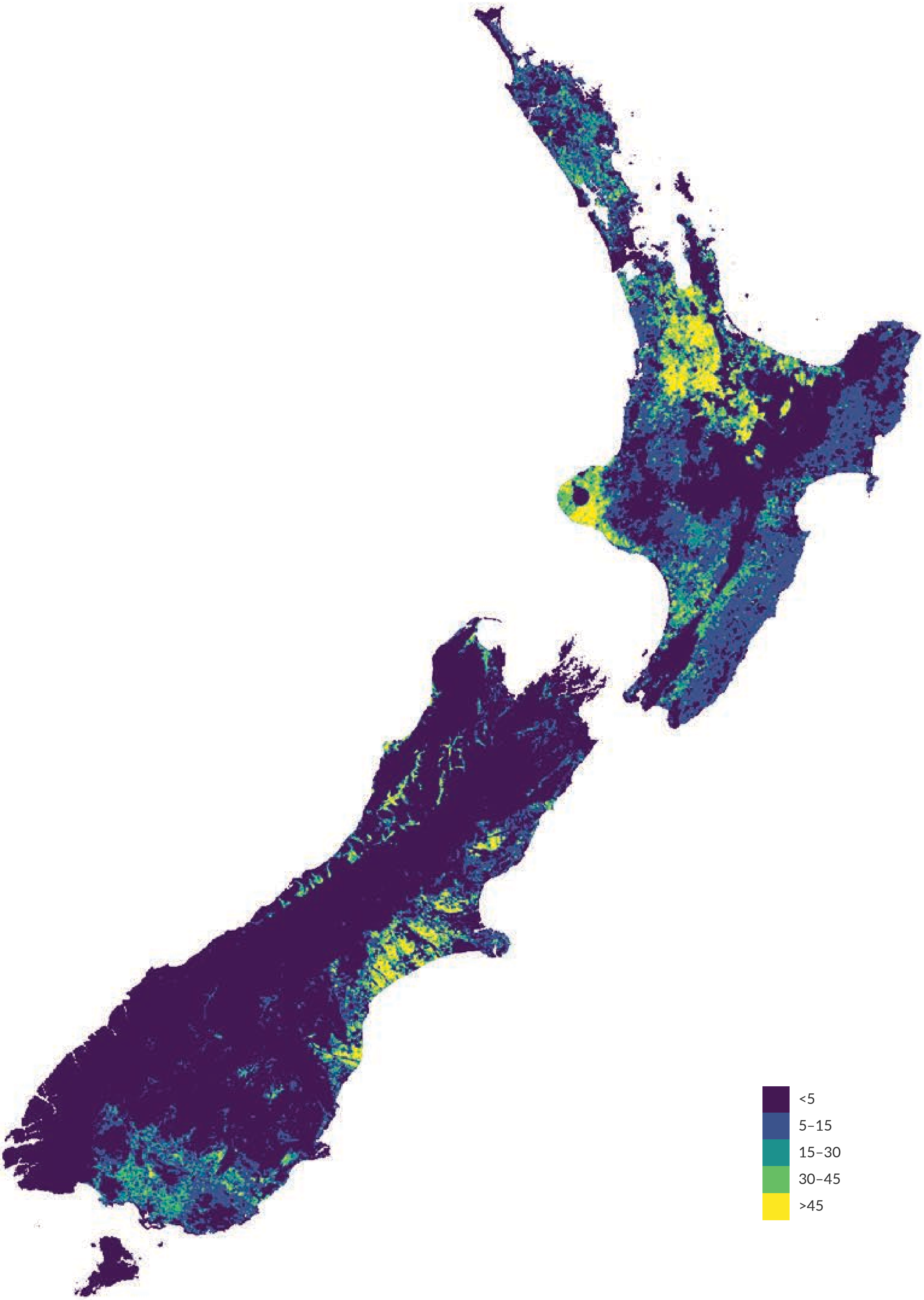
Lag times can be long

Some parts of the environment respond slowly to pressures. For example, it can take decades or more for groundwater (and the contaminants it contains) to move from the surface, through aquifers and back into surface water systems such as rivers, springs, lakes, or estuaries, and cause harm (Morgenstern & Daughney, 2012).

This creates a delay – known as lag time – between land-use impacts and their effects in a particular part of the environment. For example, in the catchment of Lake Rotorua, the average groundwater lag time is about 50 years and is more than 100 years in one catchment (Morgenstern et al, 2015).

As a result of long lag times, the water quality seen in some locations today may be the result of land use that occurred many years ago. It also means that, in some locations, today's farming activities will not be seen to affect water quality for several years or even decades.

Figure 13: Modelled nitrate-nitrogen leached from livestock, 2017 (kgN/ha)



Data source: Manaaki Whenua – Landcare Research

What are the consequences of this issue?

POLLUTION CAN MAKE WATERWAYS TOXIC TO AQUATIC LIFE

Pollutants like nutrients and sediment begin to affect whole ecosystems as their concentrations increase. In extremely polluted waterways, very high concentrations of nitrate-nitrogen or ammonia are toxic to aquatic species.

One assessment of toxicity risk can be made by comparison of current water quality to the National Objectives Framework (NOF) bands for ecosystem health. NOF band A (the best water quality) describes conditions in which little or no toxicity risk is expected, even to the most sensitive aquatic species. In the native land-cover class, 98 percent of total river length is in NOF band A, based on the modelled concentrations of nitrate-nitrogen and ammonia. Only 29 percent of total river length in pasture-dominated catchments met this same condition.

NOF band D describes water quality that does not meet the national bottom line for a minimum acceptable state (ie where toxicity affects the growth and mortality of multiple sensitive species). None of New Zealand's river lengths, in any land-cover class, had modelled concentrations of nitrate-nitrogen or ammonia in NOF band D. Likewise, the national bottom line for toxicity was not exceeded at any lake water quality monitoring sites.

Toxicity effects on groundwater ecosystems cannot be assessed because the effects of excess nutrients are not well known (Fenwick et al, 2018).

ALGAL BLOOMS COULD BECOME MORE FREQUENT

Algae, including cyanobacteria, occur naturally in rivers, lakes, and the sea (generally as periphyton – the natural growth on rocks and riverbeds – in shallow rivers, and as phytoplankton in deep rivers, lakes, and the sea). Algal blooms occur when the environmental conditions change and allow algae to reproduce rapidly. High concentrations of nitrogen and phosphorus, and warmer temperatures promote the growth and proliferation of these algae into a bloom.

National-scale information is not yet available to assess changes in periphyton biomass in rivers. Regional councils collect data on periphyton biomass (a requirement under the NOF) but this information does not yet provide a detailed national perspective. National-scale models have been developed to estimate periphyton biomass based on predictors such as nutrient concentrations, river flows, and the type of sediment on the riverbed, but these models have high uncertainty (Larned et al, 2015).

In lakes, the median TLI was rated poor or very poor at 57 percent of 58 monitored lake sites for 2013–17, indicating that frequent algal blooms were possible at these sites. The national bottom lines for total phosphorus, total nitrogen, and chlorophyll-a were not met at 17 percent, 30 percent, and 35 percent of the 63 monitored sites respectively during this period, indicating a high risk of degradation in lake ecological communities.

There is insufficient data to report on algal blooms or other indicators of eutrophication in coastal ecosystems.

An increasing frequency of algal blooms may have a range of consequences. Algal blooms can decrease the dissolved oxygen, prevent light from penetrating water, and change the composition of freshwater plant and animal species that live in a waterway. Some cyanobacteria produce toxins that can be harmful to ecosystems and contaminate water for drinking and swimming. Dogs are particularly susceptible because they are drawn to the odour of some cyanobacteria in rivers. More than 70 dog deaths have been reported across New Zealand since 2006 (*Our fresh water 2017*). Algal blooms may also degrade the recreational and cultural uses of waterways.

POLLUTION CAN INCREASE RISKS TO HUMAN HEALTH

The presence of *E. coli* bacteria above a certain limit is used to assess the health risk from the pathogen *Campylobacter* in rivers and lakes. Infection by *Campylobacter* can cause gastrointestinal illness and is the most frequently notified disease in New Zealand, peaking in spring and summer (Ministry of Health, 2018).

Computer models (Whitehead, 2018) can be used to estimate the average *Campylobacter* infection risk from swimming in any New Zealand river. For 2013–17, 82 percent of the river length in the pastoral land-cover class was not suitable for activities such as swimming, based on a predicted average *Campylobacter* infection risk of greater than 3 percent (NOF bands D and E respectively – the two highest risk categories). Only 5 percent of the river length in the native land-cover class exceeded the same threshold.

Regional councils monitor popular swimming sites, including rivers, lakes, and coastal areas, to assess the health risk. For the most up-to-date information on your local swimming spot, see the Land, Air, Water Aotearoa website.

UNTREATED GROUNDWATER MAY NOT BE SAFE TO DRINK

Monitoring untreated water in aquifers for 2010–14 found that 59 percent of 147 sites failed to meet the drinking water standard for *E. coli* on at least one occasion. (This indicates a potential risk of illness if the water is ingested without being treated.) The drinking water standard of 11.3 grams per cubic metre of nitrate-nitrogen was exceeded on at least one occasion at 13 percent of 364 sites tested. (At this concentration, nitrate-nitrogen has a potential risk of causing methaemoglobinaemia, blue baby syndrome, in bottle-fed infants.)

This monitoring contributes to a picture of the overall quality of our groundwater. Information is not available about which of these monitoring wells are actually used for drinking water, which wells are situated in farming areas, and whether treatment is in place to remove pathogens and nitrate-nitrogen from well water.

A large proportion of New Zealand's drinking water comes from rivers and underground aquifers and is tested and treated to make it safe to drink.

The concentration of pesticides in surface waters is not routinely measured, but groundwater monitoring shows that pesticides in the water in aquifers currently pose a low risk to health *(Our fresh water 2017)*.

POOR WATER QUALITY REDUCES CULTURAL HEALTH

Changes in water quality can significantly affect the mauri (binding force between physical and spiritual elements) (Morgan, 2006) and wairua (spirituality, connections to atua) of waterways. Degraded waterways can affect the perception of mana (prestige) associated with an iwi or hapū *(Our fresh water 2017)*. 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 (food gathering area) from waterways 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 inter-generational transfer of mātauranga) (Harmsworth & Awatere, 2013; Lyver et al, 2017a; Royal, 2007; Timoti et al, 2017).

Some iwi and hapū monitor fresh water using cultural indicators (like the time it takes to collect enough pipi for a family meal) to record changes in the health of these areas. *Our fresh water 2017* reported on a cultural health index (CHI) for water quality (see indicator: **Cultural health index for freshwater bodies**) 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).

Of 41 sites at which 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. Sites were not classified according to land cover so the impacts of farming cannot be specifically assessed.

Where are the gaps in our knowledge about this issue?

HOW FARM MANAGEMENT PRACTICES AFFECT WATER QUALITY

Data clearly shows that at a national scale, water quality in pastoral farming areas is degraded. Horticulture and arable cropping can also affect water quality (Larned et al, 2018a), though these cover much less area than pastoral farming. At a local scale, however, there is insufficient information and knowledge about exactly where, when, and what specific activities and management practices (eg tillage, effluent management) have contributed to (or mitigated) water pollution in farming areas (Larned et al, 2018a; McDowell et al, 2019).

This is partly because there is no national-scale database or map of farm management practices. Furthermore, in locations with long lag times (see Lag times can be long), the current water quality may be the result of past management practices, rather than what we are doing now. More information is therefore needed about the flow of pollutants as they move through catchments – including the locations, sizes, and properties of New Zealand's aquifers, and where and how groundwater and surface waters interact.

There is also poor understanding of the causes of water quality trends. 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 distinguish input of nutrients from farming from other sources like wastewater treatment systems.

Because of these large knowledge gaps, it is hard to assess the impacts on water quality from specific land management practices like stocking density, fertiliser use, and the disposal of agricultural effluent, or measure improvements in water quality arising from specific actions like riparian planting.

HOW CHANGES IN WATER QUALITY AFFECT THE THINGS WE VALUE

There is a lack of knowledge about how changes in water quality affect the health of an ecosystem. A framework to describe ecosystem health holistically has been developed (Clapcott et al, 2018), but work is still underway to choose the parameters to evaluate it. (See Issue 1: Our native plants, animals, and ecosystems are under threat.) National datasets for some variables relevant to ecosystem health is still lacking (like deposited sediment, continuous dissolved oxygen, and algal biomass). There is also insufficient information about biodiversity and native fish populations, including taonga species (*Our fresh water 2017*). Very little is known about groundwater ecosystems. Also, the interacting and cumulative effects of water pollution and other pressures on ecosystem health are not well understood (Larned et al, 2018a).

There is a critical gap in our knowledge about the impacts of water pollution on te ao Māori, particularly how mātauranga Māori, tikanga Māori, kaitiakitanga, customary use, and mahinga kai are affected. Although some relevant datasets are available (like information about traditional freshwater crayfish (kōura) gathering), we lack information about how changes in land use affect Māori values for fresh water (Larned et al, 2018a).

Information about the impacts of water pollution on human health is also poor. Regional authorities carry out water quality monitoring at approximately 150 of New Zealand's lakes and *E. coli* is monitored at very few of these (Larned et al, 2019). New research programmes are just beginning to collect data on emerging contaminants in our waterways. These include pesticides, pharmaceuticals, nanoparticles, and other chemicals that are now found more commonly in waterways overseas (Petrie et al, 2015).

ISSUE 5

Our environment is polluted in urban areas

Some of our cities and towns have polluted air, land, and water. This comes from home heating, vehicle use, industry, and disposal of waste, wastewater, and stormwater. Pollution affects ecosystems, health, and use of nature.

Why does this issue matter?

SPATIAL EXTENT

It can apply to all cities and towns.

DEPARTURE FROM NATURAL CONDITIONS

The type and severity of pollution varies from place to place and over time.

IRREVERSIBILITY

It is challenging to reverse because changing our cities and lifestyles would require significant investment and changes in behaviour.

IMPACTS ON WHAT WE VALUE

There is high risk to human health and cultural well-being, practices, and knowledge because 86 percent of New Zealanders live in an urban centre. Fresh water, marine, air, and atmosphere can all be affected.

KNOWLEDGE GAPS

Data for all pollutants in urban areas is lacking. Their cumulative impacts on human health, ecosystems, and cultural well-being are not known.

What is the current state of this issue?

Many different pollutants are produced in urban centres, from home heating, vehicle use, industry, waste disposal, wastewater, and stormwater. The pollutants vary in type and amount from place to place and over time. Although some pollutants occur naturally, in urban areas pollution comes mostly from human activities and can accumulate to harmful levels in air, land, freshwater, and marine environments.

In the most recent national land-cover assessment (2012), urban areas covered 0.8 percent of our land. (See indicator: Land cover.) Our urban centres have been growing – urban land area increased by 10 percent between 1996 and 2012. (See Issue 3: Urban growth is reducing versatile land and native biodiversity.)

About 86 percent of New Zealanders lived in an urban centre in 2013 – 73 percent in a city or a major urban area (more than 30,000 people), 6 percent in a large regional centre (10,000–29,999 people), and 8 percent in smaller towns (1,000–9,999 people) (Stats NZ, n.d.-a).

There is also some evidence of increasing population density. From 1996–2013 the density of Auckland's urban area rose from 21 people per hectare to 25 people per hectare (Auckland Council, 2014).

AIR QUALITY IS GENERALLY GOOD

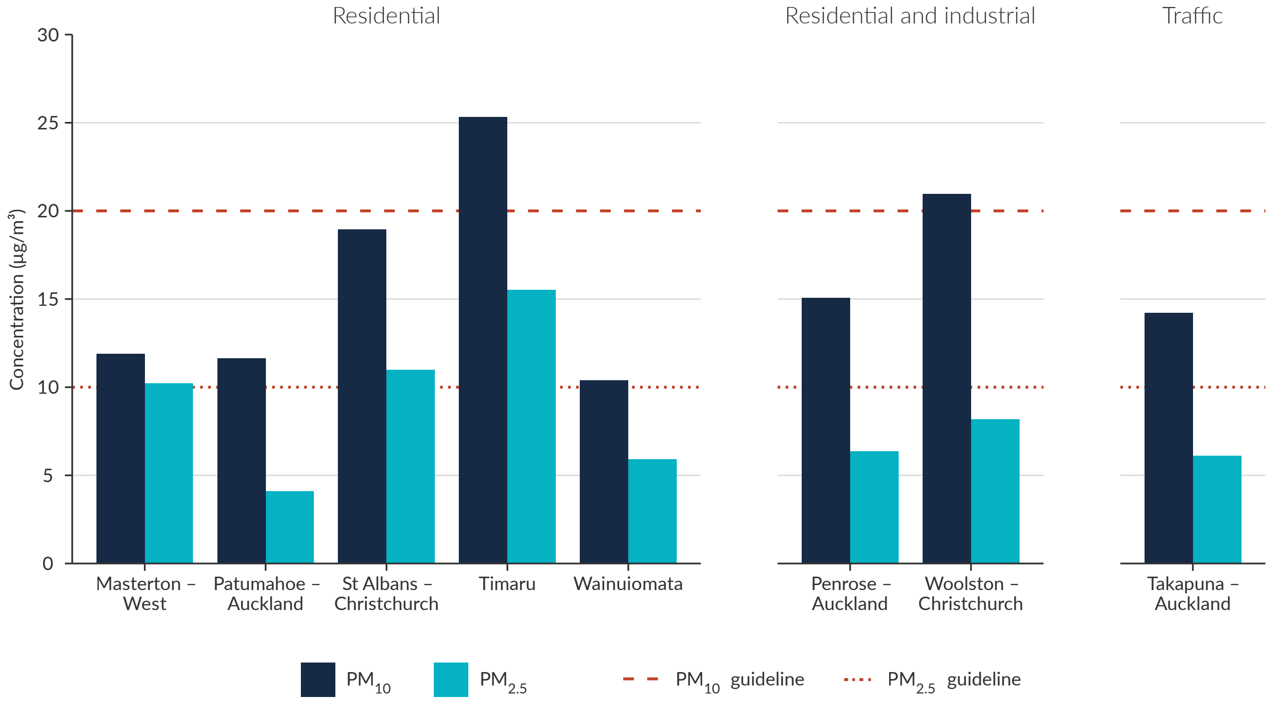
Our air quality is good in most places and at most times of the year, particularly when compared with heavily industrialised countries *(Our air 2018)*. The most common air pollutants in urban areas are gases like nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO), and very fine particles or particulate matter (PM). Particulate matter is often classified by its size. PM_{10} has a diameter of 10 micrometres (µm) or less. $PM_{2.5}$ has a diameter of less than 2.5 µm and is therefore a subset of PM_{10}. Generally, the smaller the particles, the greater the risk to human health.

PM levels can exceed standards and guidelines, especially in cooler months due to emissions from home heating, and when calm weather and the landscape allow pollutants to build up in the air (see figure 14).

Less data is available for gaseous air pollutants. The available measurements show that SO_2 levels can exceed environmental standards at some locations, whereas exceedances of NO_2 standards are less common. The concentrations of O_3 and CO are low and are unlikely to exceed the standards *(Our air 2018)*. (See indicators: Nitrogen dioxide concentrations, Sulphur dioxide concentrations, Ground-level ozone concentrations, and Carbon monoxide concentrations.)

Light pollution, noise pollution, and odours can also be polluting *(Our air 2018)*. Light pollution is very low in most parts of New Zealand but all our large urban areas have levels of artificial light that can affect visibility of the night sky. (See indicator: Artificial night sky brightness.) Data for noise pollution and odours is not available for New Zealand.

Figure 14: Particulate matter (PM) average annual concentrations at selected sites, 2014–16



Data source: Regional councils and unitary authorities

Note: Guideline values from World Health Organization. Only sites with with both PM_{10} and $PM_{2.5}$ data are shown.

MOST RIVERS IN URBAN AREAS ARE POLLUTED

Computer models are used to estimate the median concentrations of nutrients, *Escherichia coli (E. coli)*, clarity, and turbidity in New Zealand waterways for 2013–17 (Whitehead, 2018). (See **Issue 4: Our waterways are polluted in farming areas** and indicators: **River water quality: clarity and turbidity**, **River water quality: *Escherichia coli***, **River water quality: nitrogen**, and **River water quality: phosphorus**.)

The models show that, for most water quality variables, over 80 percent of the total river length in the urban land-cover class exceeds the relevant default guideline value (DGV) (see table 2). In comparison, the models show that DGVs are exceeded by slightly lower percentages of river length in the pastoral land-cover class and less than 30 percent of the river length in the native land-cover class (compare with table 1). (In total, 3,344 kilometres of New Zealand's river length is in the urban land-cover class, compared with 188,024 kilometres in the pastoral land-cover class, and 198,126 kilometres in the native land-cover class.)

These models also show that river water quality in urban areas was much worse than expected for natural conditions for 2013–17 (see table 2). For these stretches (or reaches) of urban rivers, modelled median nitrate-nitrogen levels were 19.5 times higher, dissolved reactive phosphorus levels 4.7 times higher, turbidity 3.3 times higher, and *E. coli* 30 times higher than in river reaches dominated by native land cover. The river water quality in urban areas was even poorer than in pastoral areas for the same time period, based on the modelled median concentrations of these pollutants (compare with table 1).

Heavy metals also commonly pollute urban streams – the concentration of copper and zinc increases with the proportion of urban land in the catchment. Monitoring data for 2013–15 show that dissolved zinc and copper concentrations in urban streams in Auckland, Wellington, and Christchurch are higher than in non-urban areas. (See indicator: **Urban stream water quality**.)

Wastewater and stormwater can also contain pollutants such as pesticides, pharmaceuticals, personal care products, and other substances that are not adequately removed by treatment plants (Petrie et al, 2015). Many types of litter (including plastic) can end up on land, be washed into waterways, and may eventually reach the ocean. Data for these emerging pollutants in New Zealand waterways is not available.

Groundwater and lake water quality monitoring sites are not categorised according to land use, so the specific effects of urban land cover on these water bodies cannot be identified.

Table 2: River water quality (modelled) in urban land catchments compared with native catchments

Water quality variable	Units	Modelled median value of water quality variable, 2013–17		River length (km) that does not meet ANZG DGV	
		Urban land cover	Native land cover	Urban land cover	Native land cover
Total nitrogen	mg/m^3	992.2	115.9	3,153 (94%)	57,027 (29%)
Nitrate-nitrogen	mg/m^3	497.8	25.6	3,214 (96%)	26,610 (13%)
Ammoniacal nitrogen	mg/m^3	29.9	4.0	3,020 (90%)	29,464 (15%)
Total phosphorus	mg/m^3	43.3	8.3	3,267 (98%)	50,977 (26%)
Dissolved reactive phosphorus	mg/m^3	20.5	4.4	3,104 (93%)	45,270 (23%)
E. coli	cfu/100 ml	399.9	13.3	1,512 (45%)	1,117 (0.6%)
Turbidity	NTU	4.4	1.3	2,276 (68%)	22,962 (12%)
Clarity	m	1.5	3.3	163 (5%)	1,467 (1%)

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, even 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.

DATA FOR COASTAL AND ESTUARY POLLUTION FROM URBAN AREAS IS LACKING

Coastal water quality is strongly affected by the polluting nutrients, pathogens, and sediment that are carried downstream by rivers (Dudley et al, 2017). (See Issue 4: Our waterways are polluted in farming areas.) Monitoring data for 2013–17 showed that high nitrogen concentrations and high levels of faecal bacteria occurred at the coastal sites with high river inflows, particularly in tidal estuaries with short residence times. Deep estuaries had the best water quality because they tended to receive less contamination from rivers. (See indicator: Coastal and estuarine water quality.)

The land cover upstream from coastal monitoring sites has not been categorised, so the proportion of nutrients, pathogens, and sediment delivered from urban areas, as opposed to other land uses such as farming, is not known.

Heavy metals are known to reach estuaries primarily via urban streams (with the exception of cadmium, which can also come from farming areas). Data at most monitoring sites in 13 regions for 2015–2018, however, showed that the concentration of heavy metals in estuarine and coastal sediment was below the levels expected to affect benthic species. (See indicator: Heavy metal load in coastal and estuarine sediment.)

DATA FOR LAND AND SOIL POLLUTION IN URBAN AREAS IS LACKING

Industrial, commercial, and domestic activities can all contaminate soil in urban areas. Historic activities can continue to contaminate soil for decades.

Although the types of contamination that occur in New Zealand are known, there is not enough data to report on their extent or magnitude here (*Our land 2018*).

What has changed?

AIR QUALITY HAS IMPROVED IN SOME PLACES

PM_{10} concentrations decreased in 17 of 39 monitored areas (airsheds) in winter between 2007 and 2016. This data is from 47 monitoring sites that are mostly in residential areas. (See indicators: PM_{10} concentrations and $PM_{2.5}$ concentrations.) NO_2 concentrations improved at 23 sites and worsened at 3 sites for 2010–16, as recorded at 92 urban monitoring sites across the country. Few monitoring sites have sufficient data to assess trends in SO_2, O_3, or CO. No data is available to assess trends in light pollution, noise pollution, or odours.

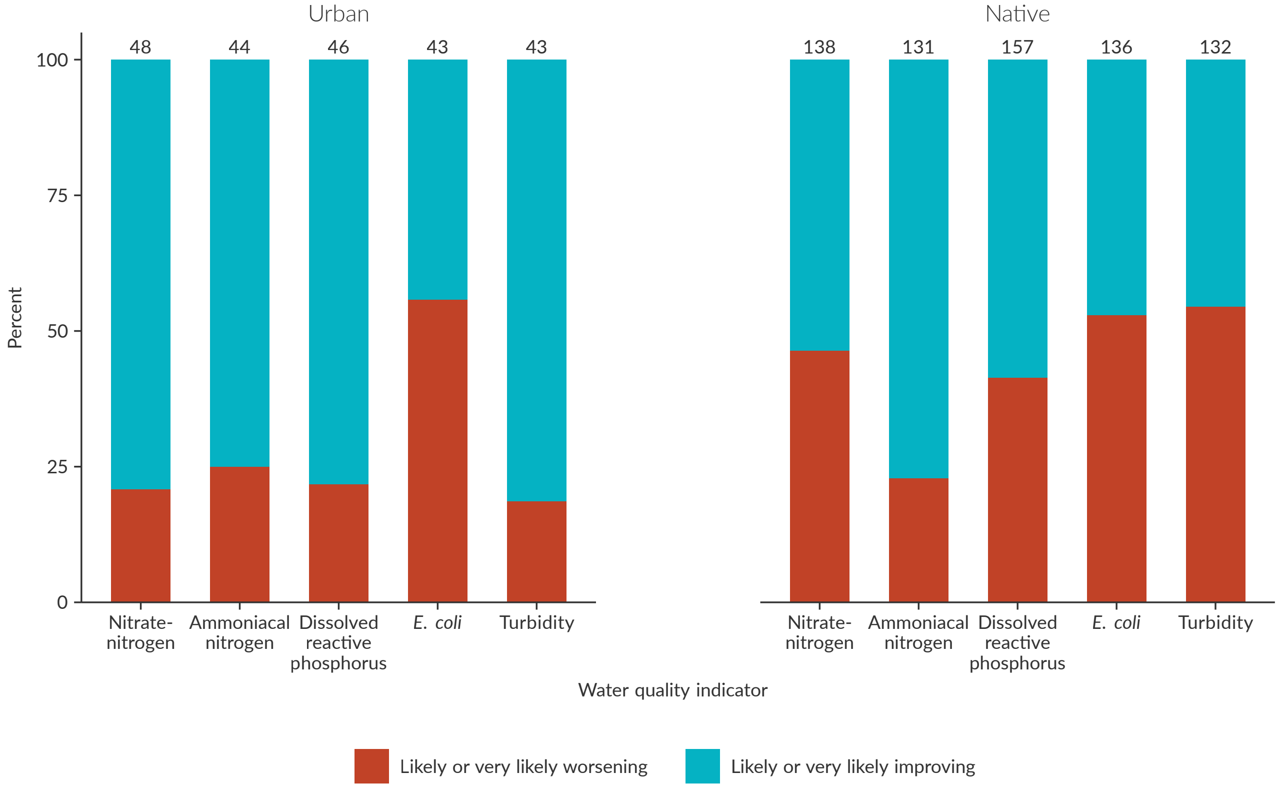
URBAN RIVER WATER QUALITY IS IMPROVING

Excluding sites with indeterminate trends, about 75 percent of urban river water monitoring sites for 2008–17 had improving trends for nitrate-nitrogen, ammoniacal nitrogen, dissolved reactive phosphorus, and turbidity. Approximately half of the sites had improving trends for *E. coli* (see figure 15).

More urban river sites had improving trends for nitrate-nitrogen, dissolved reactive phosphorus, and turbidity than sites with pastoral or native land cover during this time. Monitored sites with urban, pastoral, and native land cover had similar proportions of improving and worsening trends for ammoniacal nitrogen and *E. coli*.

The absolute rate of change at sites in the urban land-cover class was less than 4 percent per year for most variables at most sites for 2008–17. (See Issue 3: Urban growth is reducing versatile land and native biodiversity.)

Figure 15: River water quality trends at sites with urban and native land cover, 2008–17



Data source: NIWA

Note: Sites with indeterminate trends are excluded. The number at the top of each bar shows the number of sites where a trend could be identified. Land-cover class is determined by the land-cover type in the upstream catchment (see Rivers in farming areas are polluted).

TRENDS IN LAND, SOIL, AND COASTAL WATER IN URBAN AREAS CANNOT BE ASSESSED

In coastal environments, for most water quality variables, more sites show improving trends than worsening trends for 2008–17. Levels of *Enterococci* (used instead of *E. coli* as an indicator in coastal waters) were decreasing at 41 percent of monitored sites. Only total nitrogen, ammoniacal nitrogen, and dissolved oxygen showed a greater proportion of sites with worsening trends in this period. However, the monitoring sites were not categorised according to the land cover upstream so the effects of urban areas, as opposed to other land uses such as farming, cannot be assessed. There is not enough data to assess trends in the concentrations of heavy metals in coastal and estuarine sediments.

Regional councils keep records of sites where land contamination has been confirmed, but there is currently no integrated dataset available for the national scale. A number of previously unreported contaminants have been found recently in some areas *(Our land 2018)*. These include per- and poly-fluoroalkyl substances (PFAS). These chemicals have many uses including waterproofing and printing, and were used historically in foams for fighting flammable liquid fires at airfields and fuel storage facilities.

What has contributed to this issue?

HOME HEATING IN WINTER CAUSES AIR POLLUTION

The most common human-made source of PM in our urban atmospheres is emissions from burning fuels like wood and petrol. Home heating emissions (burning wood and coal) produced 25 percent of PM_{10} and 33 percent of $PM_{2.5}$ in 2015, mainly in urban areas. (See indicator: Air pollutant emissions.) Burning treated timber to heat homes is also the primary source of arsenic in urban air (Cavanagh et al, 2012).

EMISSIONS FROM TRANSPORT AFFECT AIR QUALITY

Vehicle emissions contribute to poor air quality in some places. Cars typically emit air pollutants including PM, carbon dioxide (CO_2), CO, volatile organic compounds (VOCs, as unburned hydrocarbons), and oxides of nitrogen (NOx). Wear and abrasion of road surfaces, tyres, and brake pads also release small particles that can be a significant source of heavy metals like zinc, cadmium, barium, antimony, and copper (Schauer et al, 2006).

Spills and leaks of petroleum fuels at storage facilities, including service stations, can contaminate land, soil, and water *(Our land 2018)*.

Ships are another important source of air pollutants in coastal urban areas (mainly SO_2 but also NO_2 and PM) because many ports are located close to city centres.

INDUSTRY AND MANUFACTURING GENERATE A RANGE OF POLLUTANTS

Burning fuel to power industrial processes or generate electricity (in wood- or coal-fired boilers for example) can produce air pollution. Pollutants can also be emitted from the processes themselves, like the gases released during smelting. Pollutants emitted by industry are as varied as the industries that produce them and can include NOx, SO_2, CO_2, VOCs, PM, and heavy metals *(Our air 2018)*. Industrial pollutants can end up in urban soil, waterways, and on land.

Although there is no database of confirmed contaminated land in New Zealand, the *Resource Management Act survey of local authorities 2012/2013* (MfE, 2014) reported 19,568 sites nationwide where activities and industries are considered likely to cause land contamination from the use, storage, or disposal of hazardous substances. Not all of these sites are in urban areas.

WASTEWATER AND STORMWATER POLLUTE URBAN WATERWAYS

In urban environments, pollutants enter waterways through the stormwater and wastewater networks. (Stormwater is rainwater plus any pollutants it picks up on the land surface, while wastewater is the water used in houses, businesses, and industrial processes.) Pollutants can enter urban streams through illegal connections to wastewater and stormwater networks, and leaky pipes, and pumps. Pollutants from urban streams can be carried into rivers, aquifers, estuaries, and coastal areas.

Nutrients and faecal pathogens are common pollutants in wastewater. Nutrients can also enter the stormwater system from spills or fertiliser used on lawns and golf courses *(Our fresh water 2017)*. Stormwater can contain elevated concentrations of heavy metals (Lewis et al, 2015), coming from vehicles (copper from brake pads and zinc from tyres), metal roofing, and industrial yards (Kennedy & Sutherland, 2008). Wastewater and stormwater can also contain many other pollutants including personal care products, medicines, and plastics that were washed into waterways.

The extent to which stormwater and wastewater pollute fresh water is determined by how much land is covered by solid surfaces like roofing, asphalt, and concrete. These impervious surfaces reduce the amount of rain that soaks into soils and aquifers, and increase the amount entering the stormwater system.

The design, maintenance, and operation of infrastructure also affect water pollution in urban areas. Many stormwater and wastewater networks have consented overflows for storms, so during these times, wastewater can flow into stormwater systems *(Our fresh water 2017)*. Better wastewater treatment may be associated with the improvement in water quality reported in urban streams (Davies-Colley, 2013). However, nationally, one-quarter of wastewater assets are more than 50 years old, with 10–20 percent of the network requiring significant renewal or replacement (LGNZ, 2014).

Urban pollution

Urban areas are sources of pollutants that affect ecosystems and our health. The type and amount can vary from place to place and over time.

SOURCES OF URBAN POLLUTION

Home heating

Burning wood and coal for home heating during cooler months is the main source of particulate matter in the air in our cities and towns. Burning treated timber is the primary source of arsenic in urban air.

Air particulate matter

Transport

Vehicle emissions contribute to poor air quality. Abrasion of road surfaces, tyres, and brake pads release small particles, including heavy metals into the environment. Petroleum spills and leaks contaminate land, soil, and water.

Air particulate matter
Gaseous pollutants
Heavy metals

Industry and manufacturing

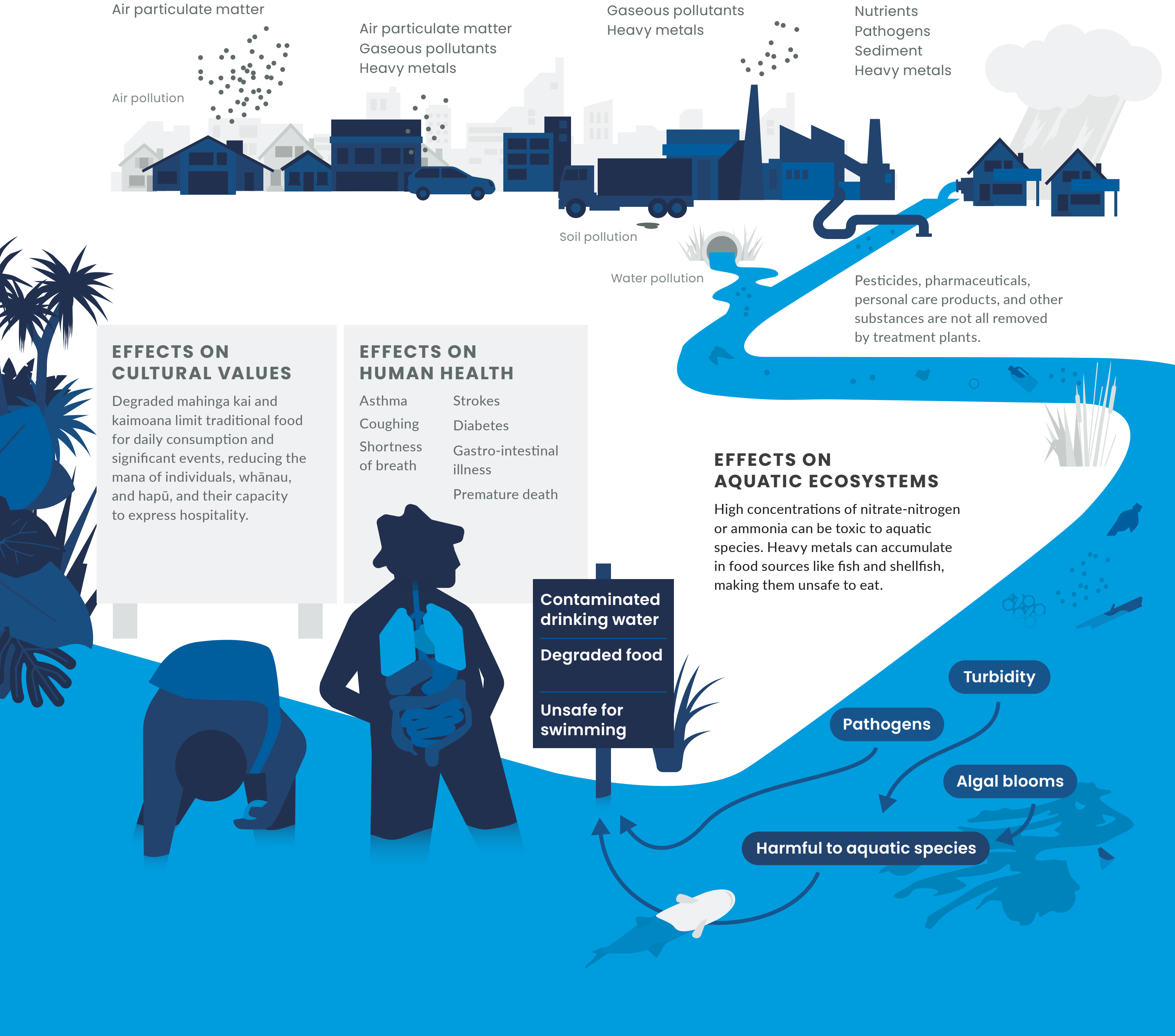
Pollutants from industry vary depending on the type of industry. Burning fuels for processes or electricity pollutes the air while storage or disposal of waste can contaminate soil and waterways.

Air particulate matter
Gaseous pollutants
Heavy metals

Wastewater and stormwater

Wastewater and stormwater enter urban streams through leaky pipes, illegal connections, and consented overflows during storms. Rainwater carries pollutants through the stormwater system into the waterways.

Nutrients
Pathogens
Sediment
Heavy metals



Pesticides, pharmaceuticals, personal care products, and other substances are not all removed by treatment plants.

EFFECTS ON CULTURAL VALUES

Degraded mahinga kai and kaimoana limit traditional food for daily consumption and significant events, reducing the mana of individuals, whānau, and hapū, and their capacity to express hospitality.

EFFECTS ON HUMAN HEALTH

Asthma
Coughing
Shortness of breath
Strokes
Diabetes
Gastro-intestinal illness
Premature death

EFFECTS ON AQUATIC ECOSYSTEMS

High concentrations of nitrate-nitrogen or ammonia can be toxic to aquatic species. Heavy metals can accumulate in food sources like fish and shellfish, making them unsafe to eat.

What are the consequences of this issue?

POLLUTION CAN MAKE WATERWAYS TOXIC TO AQUATIC LIFE

Algal blooms and the growth of cyanobacteria (see Issue 4: Our waterways are polluted in farming areas) are more likely in waterways with higher concentrations of nutrients. The concentrations of nitrogen and phosphorus are much higher in rivers in urban areas than those with native vegetation, so the likelihood of blooms is higher in these environments (if other necessary conditions for algal growth are met).

Very high concentrations of nitrate-nitrogen or ammonia can be toxic to aquatic species. Whereas 98 percent of river length in the native land-cover class had modelled median concentrations of nitrate-nitrogen and ammonia that were expected to pose little or no toxicity risk to aquatic species, only 6 percent of river length in the urban land-cover class met this same condition (as did 29 percent of river length in the pastoral land-cover class).

High concentrations of heavy metals can also be toxic to aquatic species. For 2013–15, the concentrations of dissolved copper and dissolved zinc exceeded toxicity guidelines for 12 of 17, and 27 of 50 urban sites, respectively (Gadd, 2016). The current levels of heavy metals in estuary sediments are mostly unlikely to cause harm to seabed species.

POLLUTION CAN INCREASE RISKS TO HUMAN HEALTH

Air pollution can cause coughing, shortness of breath, heart attack, stroke, diabetes, and premature death *(Our air 2018)*. Studies that are specific to New Zealand are limited, but models estimate that there were 27 premature deaths per 100,000 people from exposure to PM_{10} in 2016. Per capita, the number of premature deaths was estimated to be 8 percent lower in 2016 than in 2006, mostly because more people were living in areas with lower PM_{10}, like Auckland, rather than a reduction in overall PM_{10} *(Our air 2018)*. (See indicator: Health impacts of PM_{10}.)

Pollution of urban waterways and coasts by faecal pathogens can make water unsafe for swimming. Regional councils monitor popular swimming sites, including rivers, lakes, and coastal areas to assess the level of health risk for recreational activities (see Land, Air, Water Aotearoa website).

Nationwide estimates of the average *Campylobacter* infection risk from river water are made by modelling the median *E. coli* concentration (Whitehead, 2018). For 2013–17, 94 percent of the total river length in the urban land-cover class was not suitable for activities such as swimming, based on a predicted average *Campylobacter* infection risk of greater than 3 percent (National Objectives Framework (NOF) bands D and E, which are the two highest risk categories). For the pastoral land-cover class, the same *Campylobacter* infection risk was estimated at 82 percent of river length but only 5 percent in catchments in the native land-cover class.

Heavy metals can accumulate in food sources like fish and shellfish, making them unsafe to eat. Data from monitored sites indicate that this is a low risk.

POOR WATER QUALITY REDUCES CULTURAL HEALTH

Pollution in urban areas impacts the mauri of ecosystems and affects values like the condition of mahinga kai and kaimoana (traditional foods), recreation (swimming, waka ama), and oranga (health and well-being) of Māori (Harmsworth & Awatere, 2013; Madarasz-Smith, 2013). It also significantly diminishes the existence and capacity of waterways and ecosystems to sustain and provide for the spiritual, cultural, and physical needs of hapū and whānau.

The effects can be critical, for example, the inability of hapū and whānau to access and maintain mahinga kai and kaimoana, in turn, impacts the mana of those groups by limiting their ability to sustain themselves and express manaakitanga (hospitality, generosity). In addition, the loss of access to native species (through biodiversity degradation) over time constrains the ability to express kaitiakitanga and to maintain the knowledge and practice that accompanies that responsibility.

The responsibility of kaitiakitanga extends to air and light quality (Kuschel et al, 2012; Scheele et al, 2016), so pollution could negatively affect cultural practices including reading tohu (signs or indicators, eg during Matariki), navigation, and using maramataka (Māori lunar calendar).

Where are the gaps in our knowledge about this issue?

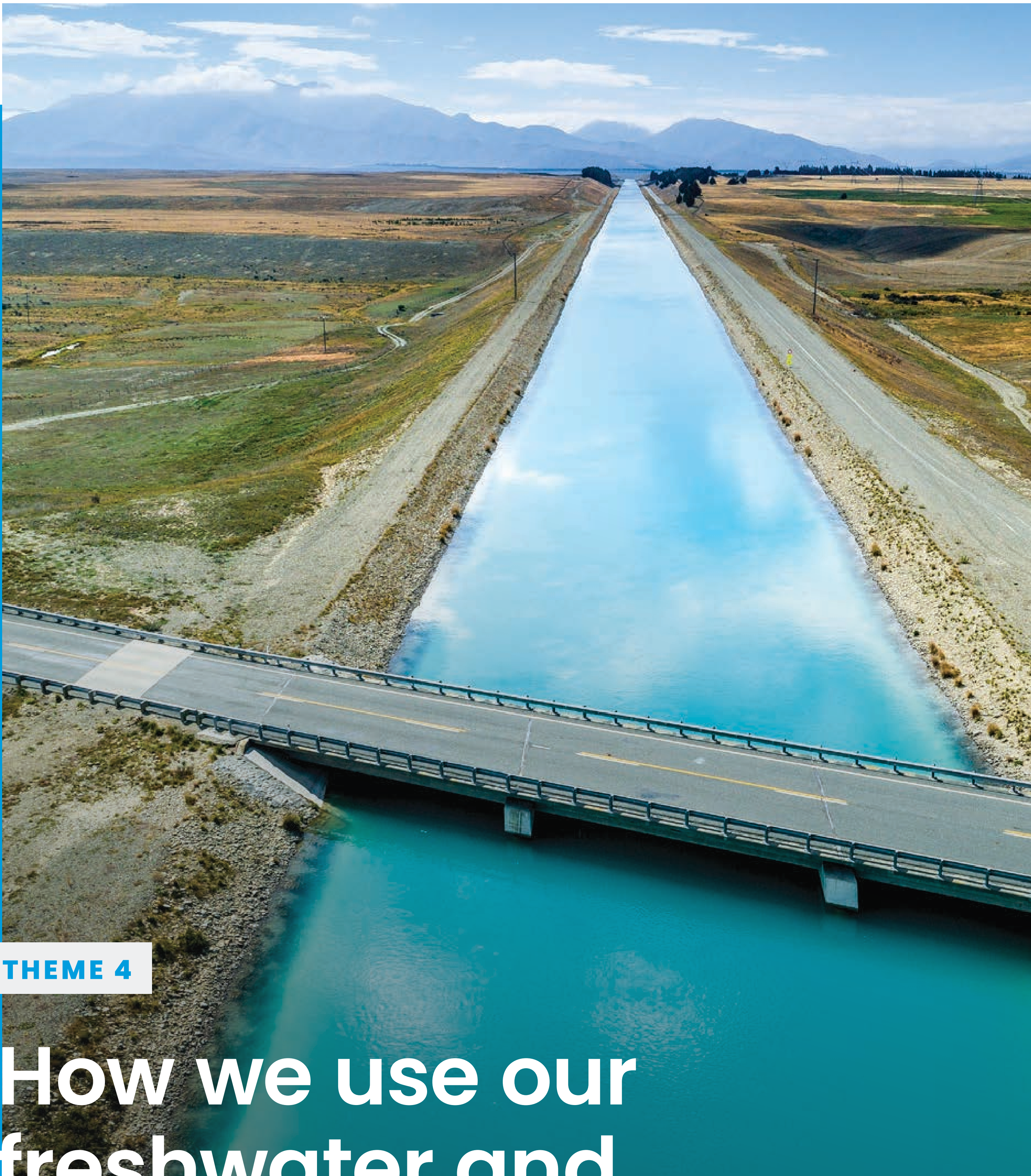
Many of the knowledge gaps identified in Issue 4: Our waterways are polluted in farming areas also apply to urban pollution.

THE FULL RANGE OF POLLUTANTS IS NOT KNOWN

There is clear evidence that levels of pollutants like nutrients, pathogens, sediment, and heavy metals in waterways, and air particulate matter are higher in urban than non-urban areas, but the sources of urban pollution can be very localised and vary significantly over short time periods. Monitoring networks do not yet cover all our cities and towns and are notably lacking for land and soil. Time-series datasets that are long enough and have high enough resolution are not available for some pollutants. There is also no data to evaluate new issues like indoor air quality or emerging contaminants in fresh water and land.

THE CUMULATIVE EFFECTS OF POLLUTANTS ARE POORLY UNDERSTOOD

There is limited understanding of how urban pollution affects the things we value. Data to measure the impacts of pollution on ecosystems and cultural values is lacking. A particular challenge arises when or where many different types of pollutants are present simultaneously because of their combined and interacting effects. Such cumulative effects may also be compounded by other pressures acting on the environment, like habitat modification, introduced pests, and modified water flows.



THEME 4

How we use our freshwater and marine resources

Photo credit: Nature's Pic Images

Natural resources are essential for our modern way of life and we use them in an astounding number of ways. Some resources regenerate naturally but others, like fossil fuels, are not easily replaced. If we take too much from the environment, the use of a resource becomes unsustainable. This can affect natural systems and deny future generations the same opportunities and benefits from nature that we enjoy today.

This theme examines two activities where our use of a natural resource is affecting how the environment functions, and changing our relationship with it:

1. **Taking water from rivers, lakes, and aquifers:** Using water for agriculture, hydroelectric generation, and domestic purposes can have significant effects on our waterways. Here, we look at how taking water is affecting our waterways and our relationships with them.
2. **Fishing:** We fish for commercial gain, for food, recreation, and as part of our culture in te ao Māori. Fishing and gathering seafood are widespread in coastal areas and in our exclusive economic zone, and can have long-lasting effects.

Other natural resources we use or have previously harvested include trees and wildlife from native forests, whitebait (the juveniles of five species of native fish), and fish that live in both ocean and freshwater environments like tuna (eels). These flora and fauna are all taonga for Māori and contribute significantly to people's livelihoods and well-being. The extraction of oil, gas, and other minerals from land and marine areas, and extracting gravel from riverbeds, are not mentioned in this report.

For other issues connected to our use of natural resources see:

- **Issue 2:** Changes to the vegetation on our land are degrading the soil and water – for physical changes.
- **Issue 5:** Our environment is polluted in urban areas – for the effects of water pollution on the survival of fish and shellfish.
- **Issue 9:** Climate change is already affecting Aotearoa New Zealand – for climate change effects on marine and freshwater species.

ISSUE 6

Taking water changes flows which affects our freshwater ecosystems

Using freshwater for hydroelectric generation, irrigation, domestic, and other purposes changes the water flows in rivers and aquifers. This affects freshwater ecosystems and the ways we relate to and use our waterways.

Why does this issue matter?

SPATIAL EXTENT

Taking water for irrigation happens nationwide but mainly in Canterbury and Otago at a large scale; hydro dams are nationwide.

DEPARTURE FROM NATURAL CONDITIONS

The total consented water extraction from some catchments can exceed the mean annual river flow expected under natural conditions.

IRREVERSIBILITY

Difficult, because farming is important for the economy and requires irrigation. Dams reduce our need to use fossil fuels for electricity generation and hence reduce carbon dioxide emissions.

IMPACTS ON WHAT WE VALUE

Taking or diverting water at unsustainable levels affects ecosystems and can affect cultural values, identity, and the maintenance and transmission of traditional knowledge.

KNOWLEDGE GAPS

There is a lack of information on how much water we take relative to how much is available, and how changes in flow caused by over-extraction will lead to wider impacts on the things we value.

What is the current state of this issue?

New Zealand has plenty of fresh water. Lakes contain approximately 320 billion cubic metres and aquifers 711 billion cubic metres, and about 440 billion cubic metres flow in rivers and streams each year *(Our fresh water 2017)*. About 70 percent of our groundwater – 519 billion cubic metres in 2014 – is located in Canterbury. (See indicator: Groundwater physical stocks.)

We are heavy users of fresh water. In 2014, New Zealand had the second highest volume of water take per person of OECD countries – 2,162 cubic metres compared with the OECD average of 815 cubic metres (OECD, 2018). This can lead to situations where there is not enough to meet all our demands.

CONSENTED WATER TAKES ARE MAINLY FOR HYDRO-ELECTRICITY AND IRRIGATION

Consents (permits) to take water are managed by regional authorities that allocate water for hydroelectric generation, irrigation, drinking water, industrial, and other uses (see figure 16).

The quality and completeness of data on actual water use (as opposed to consented volumes) is inconsistent across the regions, so it is not possible to evaluate the actual metered water takes at a national scale in this report (see Where are the gaps in our knowledge about this issue?).

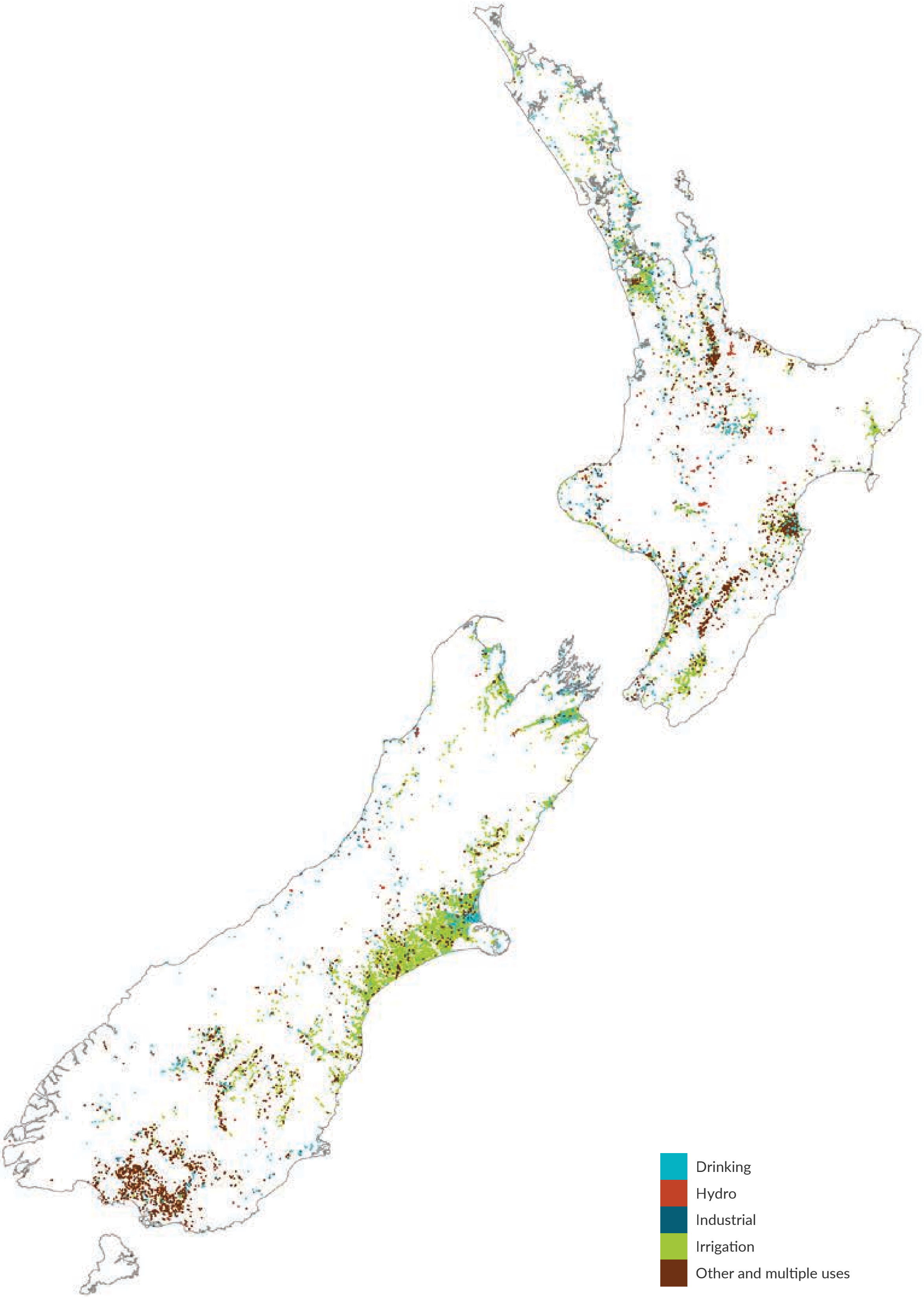
Hydroelectric generation is an important consented use of fresh water. Electricity is generated at about 100 sites nationwide but is dominated by large power stations like Manapouri (MBIE, 2018). Some of our major river systems like the Clutha, Waikato, and Waitaki have multiple dams.

Aside from hydroelectricity uses, there were 10,900 consents to take groundwater and 5,100 consents to take surface water in the 2013/14 water reporting year. Surface water allocation was 74 percent of the total water allocated nationally, with the remainder from groundwater. (See indicator: Consented freshwater takes.)

Nationally, aside from hydroelectricity, most of the allocated water use was for irrigation (51 percent). Household consumption made up 14 percent, and industrial use made up 13 percent (see figure 17). Household consumption includes the water we use for drinking and sanitation. There is no national data for consents to take water for bottling and sale but, as at 2017, water bottling consents made up less than 0.1% of all active consents to take water in Canterbury (Environment Canterbury, 2018).

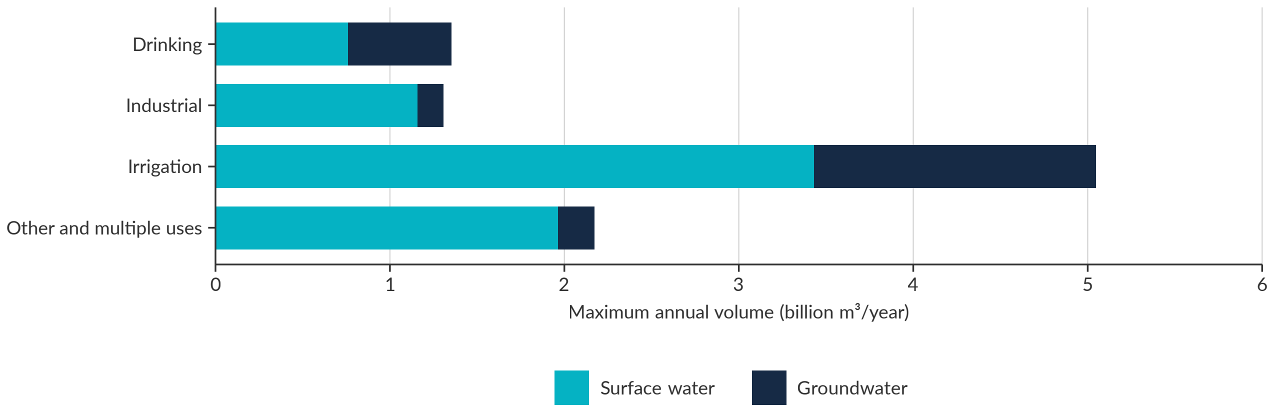
Regional councils set limits or restrictions on consents to take water to manage allocation. Individual consents to take water have specified conditions, such as how much water can be taken, from where, at what rate, and at what times. Regional councils also limit the total consented allocation within catchments or water management zones. In 2010 for example, 10 of the 29 allocation zones in Canterbury were fully allocated and 6 were above 80 percent of the allocation limit (Kaye-Blake et al, 2014).

Figure 16: Consented freshwater takes by primary use, 2013–14



Data source: NIWA

Figure 17: Maximum annual volume of consented freshwater takes by primary use, 2013–14



Data source: NIWA

Note: Freshwater takes for hydroelectricity is excluded, because it is generally non-consumptive, ie the water is generally returned to the river downsteam.

What has changed?

CHANGES IN CONSENTED AND ACTUAL WATER USE ARE NOT KNOWN

Recent data on changes in consented water takes over time is not presently available.

Data on actual water use is not available nationally, so changes in the volume of water extracted cannot be assessed.

IRRIGATED LAND AREA HAS INCREASED

Large-scale irrigation began in the 1930s, supported by government schemes that included building storage dams. Central government investment continued until the 1970s but from the 1980s the demand for more irrigation was mostly driven by farmers (Heiler, 2008).

The area of irrigated agricultural land almost doubled between 2002 and 2017 from 384,000 hectares to 747,000 hectares – a 94 percent increase. 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 New Zealand's irrigated agricultural land was in Canterbury. (See indicator: Irrigated land.)

NO LARGE HYDROELECTRICITY INFRASTRUCTURE HAS BEEN BUILT RECENTLY

Hydroelectricity generation now provides 55–60 percent of our electricity (MBIE, 2018). This renewable energy lessens our reliance on fossil fuels and contributes to reductions in our greenhouse gas emissions.

The first hydroelectricity schemes were built in the early 1880s. New schemes continued in the 20th century, including after World World II in response to a shortage of energy. The 1950s, '60s and '70s saw dams built on the Waikato, Waitaki, and Rangitāiki rivers. In 1990, a dam was built at Clyde on the Clutha River. No new large hydroelectric dams have been built since the 1990s (Martin, 2010).

What has contributed to this issue?

DEMAND FOR WATER FOR FARMING HAS INCREASED

A shift from sheep and beef farming to dairy farming and an increase in the number of animals per hectare (see Issue 4: Our waterways are polluted in farming areas) have increased the demand for water. These changes in livestock type have been especially marked in the South Island, most notably Canterbury and Southland.

In 2017, dairy farming accounted for 59 percent of the irrigated agricultural land area in New Zealand. (See indicator: Irrigated land.) Other types of livestock farming accounted for 17 percent of irrigated agricultural land, with 24 percent used for grain, vegetables, fruit, and other horticulture.

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. Nationally, the annual precipitation was less than this average in nine of the years between 2000 and 2014 (with regional variations), likely as a result of natural periodic climate patterns (Stats NZ, 2018b, see System of Environmental-Economic Accounting (SEEA) water physical stock account).

In dry years, more irrigation may be needed to sustain farming operations. Taking more water during years with low rainfall could lead to issues relating to low river flows or less groundwater availability. However, the data available suggests that New Zealand's total freshwater balance remained relatively constant between 1994 and 2014 (see SEEA water physical stock account). For example, the estimated volume of groundwater varied by less than 2 percent across all regions during this time period. (See indicator: Groundwater physical stocks.)

The balance of water extraction and input from rain and snowmelt may change as our climate changes. Projections indicate that precipitation will change and may alter river flows in some locations. In places where there is a decline in precipitation, taking water may increase the negative effects of water extraction. One study suggested that by late in this century, seasonal and annual mean flows would decline in several North Island rivers and increase in some South Island rivers (Collins et al, 2018).

What are the consequences of this issue?

TAKING WATER AFFECTS RIVER FLOWS

The consequences of this issue are mainly related to the changes in river flows caused by taking water – average flows are reduced, and the size and frequency of high and low flows can be altered. Greater impacts on flow occur when larger volumes of water are taken from multiple locations, particularly in dry periods. Altered river flows can also change the flows in connected water bodies. Groundwater and surface water are part of the same hydrological system, so taking water from aquifers can reduce river flows and vice versa (Rosen & White, 2001). Wetlands are also connected to lakes, rivers, and aquifers, so taking water from rivers can reduce the water level in these ecosystems too (Rosen & White, 2001).

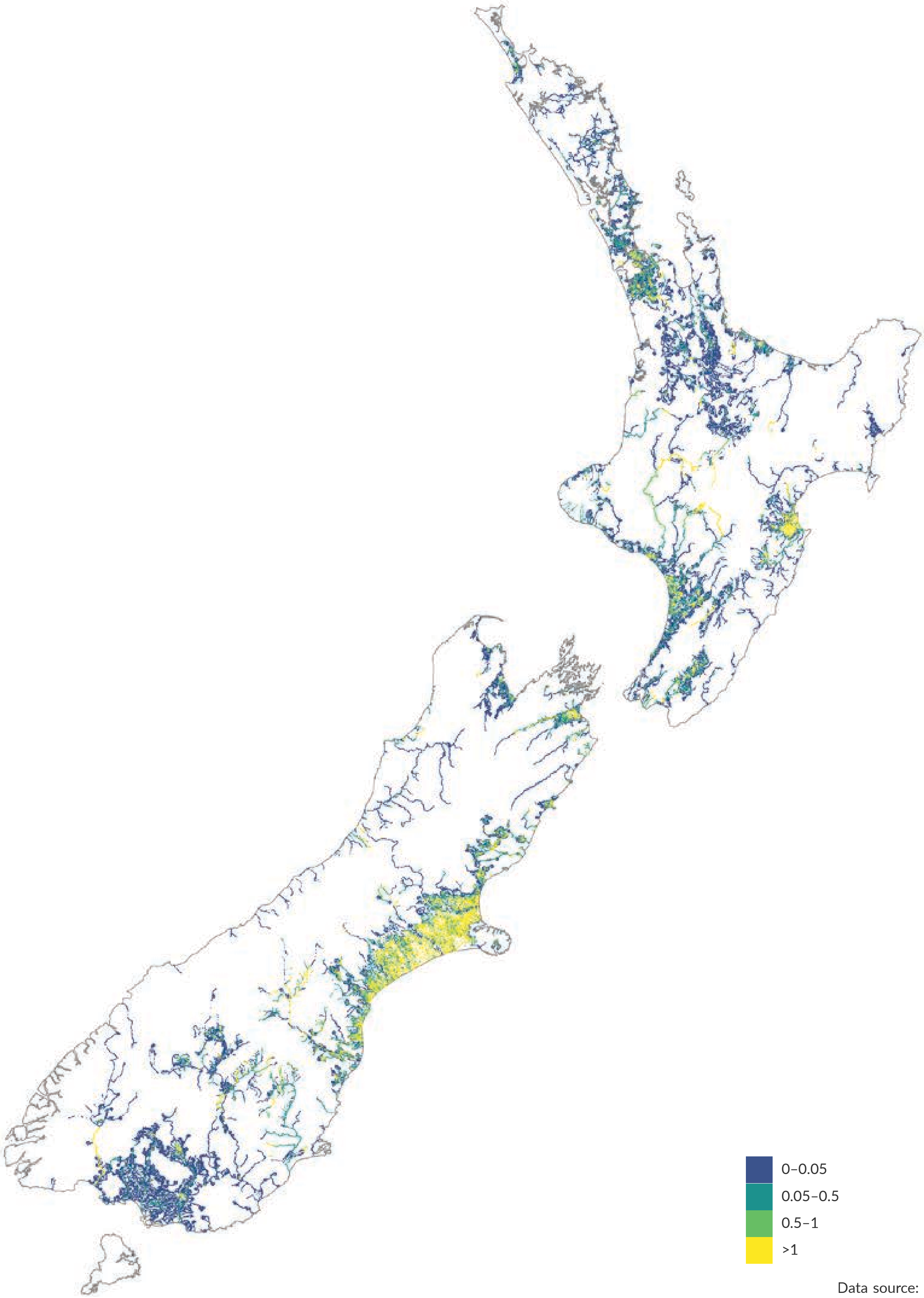
Computer modelling for 2013/14 predicted a potential reduction in the flow of water in our streams in some parts of the country as a result of consented water extraction. In some parts of Canterbury and Hawke's Bay, the modelled total volume of upstream consented takes exceeded the natural median river flow (see figure 18).

At a national scale, taking water for irrigation has the greatest potential to cause widespread reductions in river flows compared with other water uses (Booker et al, 2016).

Dams also alter river flows and can affect the ecology of river systems (Nilsson & Berggren, 2000). The impacts of larger dams may extend hundreds of kilometres downstream (Schmidt & Wilcock, 2008). Dams on the Waitaki River, for example, have reduced the variability of river flows and reduced the frequency of floods, which has caused more vegetation to grow in the river channel, altered the movement of sediment, and reduced the quality of habitat for sensitive aquatic species (Tal et al, 2003).

Figure 18: Modelled potential river flow reduction as a proportion of the natural median flow due to all upstream consented water takes, 2013–14

Upstream total consented takes divided by median flow



Data source: NIWA

Note: Data used is the consented volume not the actual quantity extracted, as this is not available. Flow is shown as a proportion of the modelled median flow under natural conditions, not an actual flow. The map is a worst-case scenario of river flow depletion because it does not take restrictions on water takes into account, and all groundwater takes were assumed to deplete river flow. The map does not show river reaches where there is a net increase in flow (eg due to water returned after hydroelectric generation). The effects of 53 percent of Otago consents are not included because they had missing values.

LOWS FLOWS NEGATIVELY AFFECT SPECIES AND HABITATS

Low river flows reduce the quantity of habitat for freshwater fish, invertebrates, and other species, which provide food for other species and for people (*Our fresh water 2017*; Booker et al, 2014; Dewson et al, 2007; Nilsson & Berggren, 2000; Storey, 2015).

Cultural effects include a reduced harvest of tuna and other freshwater species. There is also a risk that traditional knowledge relating to tuna and the rituals surrounding that harvest could be lost.

More than half of our native fish species move between the sea and freshwater habitats during their lifecycle. These include the taonga whitebait species inanga, shortjaw kōkopu, giant kōkopu, kōaro, and kanakana/piharau (lamprey), and both species of tuna (longfin eel and shortfin eel) (McDowall, 2010). Changes to river flows and structures in waterways (like overhanging culverts and hydro dams) can disrupt or block these journeys and are a significant and ongoing threat to our native fish (*Our fresh water 2017*; Franklin et al, 2018; Goodman, 2018). (See indicator: Selected barriers to freshwater fish in Hawke's Bay.)

Reduced flows can increase the temperature and the concentration of nutrients and pathogens in a waterway (Nilsson & Malm-Renöfält, 2008). These factors combined with fewer floods can increase the likelihood of algal blooms. (See Issue 4: Our waterways are polluted in farming areas.)

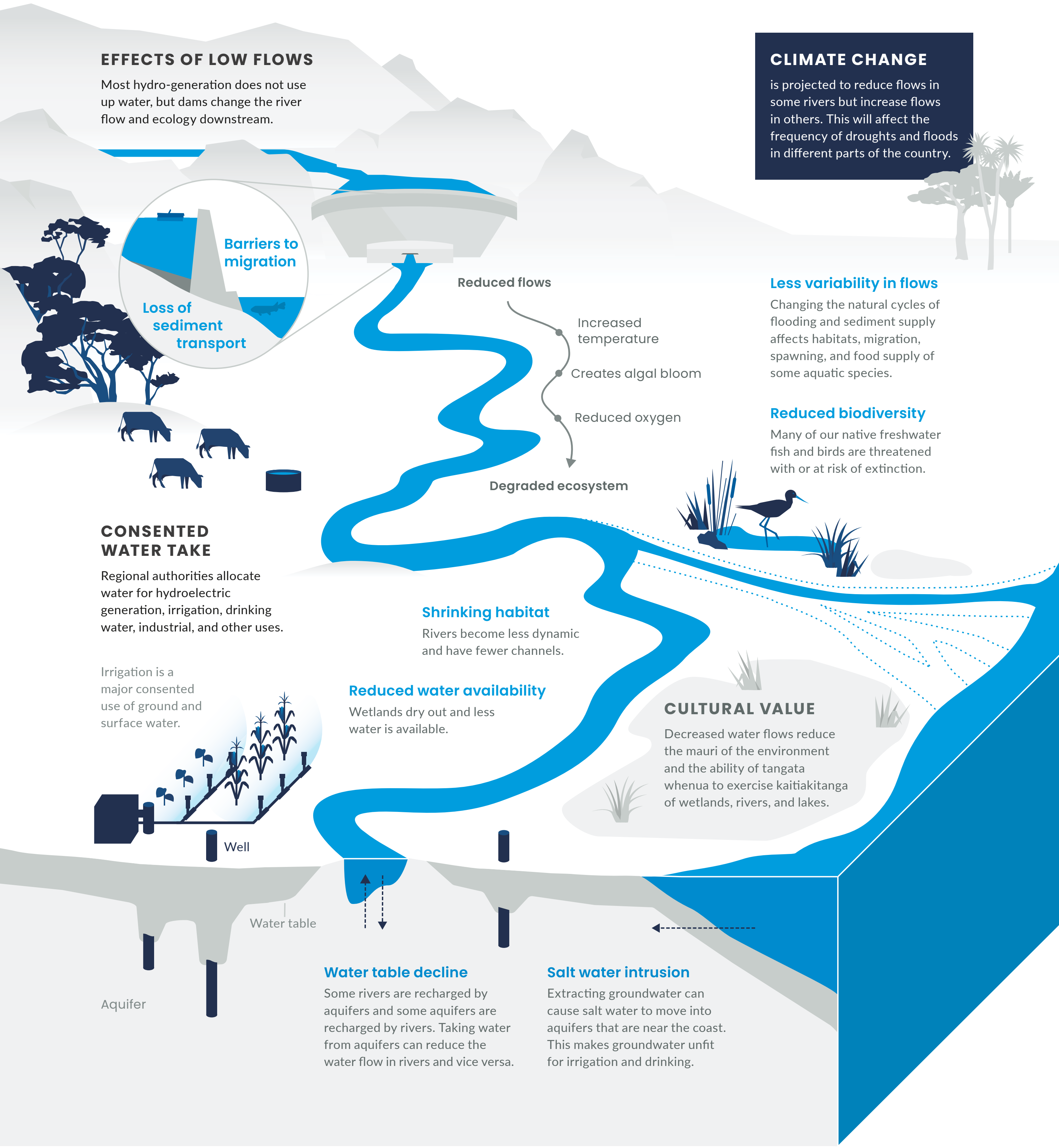
Low river flows can also affect estuaries and their biodiversity. Effects include changes in the salinity that allow more marine species to colonise and altering the rate of sedimentation and the shape and extent of the estuary (Gillanders & Kingsford, 2002).

Decreased flows can limit our ability to use rivers, lakes, and estuaries for swimming and other recreation. Decreased flows may also affect cultural values like mahinga kai status and the navigability of waterways. (See indicator: Cultural health index for freshwater bodies.)

In braided rivers, both damming and taking water have negative consequences by changing the natural cycles of flooding and sediment supply (Gray & Harding, 2007). Braided rivers are important habitats for threatened birds like wrybill *(Anarhynchus frontalis)* and kakī *(Himantopus novaezelandiae)* (O'Donnell et al, 2016; Robertson et al, 2017). Lower water flows can reduce the number of channels and make the rivers less dynamic (Gray et al, 2018) which reduces the amount of habitat these birds depend on. Of our braided rivers, 64 percent are in Canterbury (O'Donnell et al, 2016), the region where the demand for irrigation is highest.

Effects of taking water

Taking water for irrigation, drinking, and hydroelectricity generation reduces the flow of water and its variability.



Where are the gaps in our knowledge about this issue?

INFORMATION ON ACTUAL WATER USE IS LIMITED

The actual quantity of water taken from all our rivers, lakes, and groundwater is not known.

Regional councils collect data on actual water use. 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, while others consistently took more water than their consented volume, and other users did not supply records of their water use (Booker et al, 2017).

The total amount of water that is potentially available for use is not well understood. Detailed maps of the locations, volumes, and properties of New Zealand's aquifers are not available, so the volume, quality, and availability of water stored in aquifers is not known. The effects of projected climate change on the flow of water in rivers and aquifers is also poorly understood.

These limitations around our actual water use compared with its availability make it difficult to know if our freshwater resources are over-exploited and how long they will continue to meet our needs. This is a significant management issue given our economic reliance on agriculture, especially dairy farming.

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

We know that changing water flows can have significant effects on habitats, but information about the extent and scale of these impacts on our ecosystems is lacking. Other water issues like pollution also have an effect, but the cumulative impact of these changes on our social and economic values is difficult to determine.

Understanding the impact of this issue on kaitiakitanga and mātauranga Māori is currently dominated by western science-based techniques (Tipa, 2010). This inhibits data collection and analysis that could be more consistent and appropriate from a Māori cultural perspective. Cultural health indicators and mauri measures from mātauranga Māori for example could provide a better understanding of cultural impacts for decision-making.

Substantial sources of information about the cultural impacts of water takes have been recorded as evidence for water take or diversion consents, regional plans, Waitangi Tribunal claims, and Treaty of Waitangi settlements. All these could help provide a more comprehensive understanding of the impacts of this issue.

ISSUE 7

The way we fish is affecting the health of our ocean environment

Harvesting marine species affects the health of the marine environment and its social, cultural, and economic value to us. Fishing could change the relationship that future generations have with the sea and how they use its resources.

Why does this issue matter?

SPATIAL EXTENT

Commercial fishing takes place in all our coastal waters, the Chatham Rise, and the Challenger and Campbell plateaus. Seabed trawling is limited to waters less than 1,600 metres deep (Baird & Wood, 2018). Recreational fishing is widespread but most common from Northland to Bay of Plenty (Fisheries New Zealand, 2019).

DEPARTURE FROM NATURAL CONDITIONS

Marine biodiversity is reduced and parts of the seabed are profoundly modified.

IRREVERSIBILITY

Long-lived species may recover slowly from fishing pressure, as may the structure of the seabed after trawling.

IMPACTS ON WHAT WE VALUE

It poses significant threats to protected species and ecosystems, affects social and economic values, and impacts iwi relationship with rohe moana (a coastal and marine area over which an iwi or a hapū exercises its mana and its kaitiakitanga) and cultural practices.

KNOWLEDGE GAPS

We lack full information of the ecological impact of fishing, which limits our ability to manage the impact of fisheries.

What is the current state of this issue?

SOME STOCKS ARE OVERFISHED

Fish stocks are managed under Aotearoa New Zealand's quota management system (QMS) – 642 individual fish stocks that include 98 species (or species groups) (MPI, 2018d). A stock is defined as a species of fish, shellfish, or seaweed in a particular area. About half the stocks have sufficient information available to be assessed annually.

The QMS gives quota holders a right to harvest a fish stock up to a maximum level – the total allowable catch. This limit is set with the aim of ensuring harvests in the future and allows for commercial, customary, and recreational fishing.

In 2017, 84 percent of routinely assessed stocks were considered to be fished within safe limits and 97 percent of all commercial fish landings came from such stocks (MPI, 2018d). Eight of our fisheries (hoki, hake, southern blue whiting, ling, albacore tuna, skipjack tuna, some stocks of orange roughy, and Ross Sea Antarctic toothfish) have Marine Stewardship Council certification for environmental sustainability (MSC, 2019).

In the same year, 16 percent of routinely assessed stocks were overfished (meaning that these stocks are depleted) (MPI, 2018d). Snapper stocks in the eastern Northland, Hauraki Gulf, and Bay of Plenty (Snapper 1 area) for example, are considered likely to be overfished (MPI, 2018b). Ten stocks had collapsed, meaning that closure should be considered to rebuild the stock as quickly as possible (MPI, 2018d). For example, two sub-stocks of scallops (Tasman Bay and Golden Bay) were closed to fishing in 2016 (MPI, 2018b).

About half our fish stocks (mainly minor fished species) lack sufficient information to assess their status.

BYCATCH THREATENS SOME OF OUR PROTECTED SPECIES

Protected species like seabirds, marine mammals, and sharks get caught unintentionally while fishing. This bycatch has a serious effect on our protected species because they generally have long life spans, mature at a late age, and have low fertility (Carrier et al, 2010; Chilvers et al, 2010; MPI, 2013; Schreiber & Burger, 2001).

The main identified cause of death for Hector's and Māui dolphins is bycatch from commercial and recreational fishing. Between 1921 and 2015, entanglement in fishing gear accounted for 71 percent of the 301 Hector's and Māui dolphin deaths for which a cause of death was determined. (See indicator: Bycatch of protected species: Hector's and Māui dolphins.) In 2017/18, six Hector's dolphins were caught in commercial set nets (DOC, 2019).

An estimated 5,075 seabirds were caught or killed by fishing operations in New Zealand waters in 2014. (See indicator: Bycatch of protected species: seabirds.) Seabirds are the world's most threatened birds (Croxall et al, 2012). Nearly a quarter of all seabird species breed in New Zealand and 10 percent only breed here (Taylor, 2000). In 2017, of the 71 New Zealand seabirds assessed, black petrel were considered at very high risk from commercial fishing (the most at risk species), seven species were considered to be at high risk, five at medium risk, four at low risk, and the rest at negligible risk (Richard & Abraham, 2017).

Other protected species caught or killed as bycatch in the 2014/15 fishing year included an estimated 536 fur seals, 104 common dolphins, 12 New Zealand sea lions, and 13 sea turtles (Abraham & Berkenbusch, 2017). Between 2009/10 and 2013/14, commercial fisheries also accidentally caught 165 tonnes (about 33 individuals) of protected basking shark and 24 tonnes (about 150–250 individuals) of protected spinetail devilray (MPI, 2017).

Bycatch also affects non-protected species. Some of these species can be landed by fishermen, but those without commercial value are discarded. In 2012, bycatch of unwanted fish and invertebrates in deepwater fisheries was estimated at 32,000 tonnes. (See indicator: Bycatch of fish and invertebrates.) The scampi fishery is the most wasteful, with 3.8 kilograms discarded for every kilogram of scampi caught (MPI, 2017). The discard rates in other fisheries range from 0.01 to 0.34 kilograms discarded per kilogram of target catch (MPI, 2017).

MUCH OF THE SHALLOWER SEABED IS TRAWLED OR DREDGED

Seabed (bottom) trawling and dredging involve large nets (bottom trawling) or heavy metal baskets (dredging) being towed near or along the seafloor. They are the most destructive fishing methods, causing damage to seabed habitats and reducing the density and diversity of the species that live there (MPI, 2017).

Trawling is carried out in both shallow and deep water and is used to catch a range of species, like hoki and squid. Dredging is carried out on the seabed in shallow waters and often targets shellfish species like scallops and oysters.

Between 1990 and 2016, trawling occurred over approximately 28 percent of the seabed where the water depth was less than 200 metres and 40 percent of the seabed where water depth was 200–400 metres (Baird & Wood, 2018) (see figure 19). The trawled area decreased in deeper waters but still affected 4 percent of the seabed at 1200–1600 metres depth (Baird & Wood, 2018).

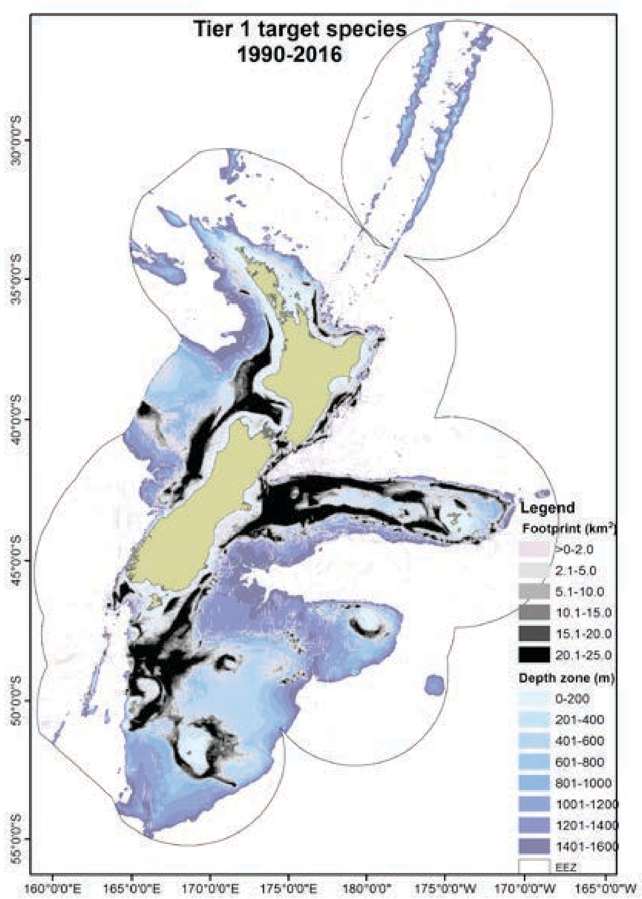
Seamounts (undersea mountains) are some of the most productive areas in the sea. These too are trawled, which has a significant impact on their biodiversity (Clark et al, 2010; Clark & O'Driscoll, 2003; Clark & Rowden, 2009). (Some seamounts are protected from seabed trawling.)

Fishing and aquaculture's contribution to our economy

- $452 million
- 0.2 percent of GDP
- 5,920 (0.2 percent) of people were employed in fishing and aquaculture as their main income source.

Note: All gross domestic product (GDP) figures are from the *National accounts (Industry production and investment): year ended March 2017*. These figures exclude manufacturing or processing of primary products. They are in current prices, ie not adjusted for the effect of changing prices over time. The people employed information is from linked employer-employee data (LEED). The measure is main earning source, by industry using New Zealand standard industry output categories.

Figure 19: Trawled area for main deepwater fisheries, 1990–2016



Source: Map created by NIWA (Baird & Wood, 2018)

Note: The main deepwater fisheries are hake, hoki, jack mackerel, ling, oreo, orange roughy, southern blue whiting, scampi, and arrow squid. The map shows where the seabed is trawled and how the shallower depths are most affected.

What has changed?

Commercial fishing and the pressures associated with it have reduced in the last decade but are still significant. Because of an incomplete understanding of the cumulative effects of fishing on the marine environment, it is unclear if the current levels of fishing are sustainable (see Where are the gaps in our knowledge?).

Interviews with kaitiaki around New Zealand revealed a common concern that the abundance and diversity of kaimoana have declined along much of the coastline and inshore fisheries in the past 30–50 years (Dick et al, 2012; Mccarthy et al, 2014).

FISHING PRESSURE HAS EASED

New Zealand's total marine catch peaked at nearly 650,000 tonnes in 1997 and 1998, but has since declined to less than 450,000 tonnes per year since 2009 (FAO, 2018a). This is consistent with the stabilisation of the annual fishing catch globally (FAO, 2018b).

Between 2009 and 2017, more than 80 percent of New Zealand's assessed fish stocks were considered to be managed sustainably, and almost all of the annual catch was from these stocks (MPI, 2018d). (See indicator: State of fish stocks.) The proportion of stocks that were overfished reduced from 19 percent in 2009 to 16 percent in 2017. Fish and invertebrate (animals without a backbone, for example squid or shellfish) bycatch also reduced during this time period, peaking in 2002 at 114,000 tonnes. (See indicator: Bycatch of fish and invertebrates.) Some species, however, are increasingly being caught (Anderson, 2013).

BYCATCH OF PROTECTED SPECIES HAS REDUCED BUT IS STILL A THREAT

Eight Hector's and Māui dolphins were caught in fishing gear in 2011–15, which is a reduction from the 14 caught in 2006–10 and the 37 caught in 2001–05. (See indicator: Bycatch of protected species: Hector's and Māui dolphins.) Māui dolphins have a nationally critical conservation status – only an estimated 63 animals were left in 2015/16 (Baker et al, 2016) – so any accidental captures are a significant issue.

The number of seabirds caught by fishing declined from an estimated 9,185 in 2003, to 5,033 in 2008 – a figure that has been about the same since. (See indicator: Bycatch of protected species: seabirds.) Measures adopted in 2006 and 2008 to reduce incidental capture may have contributed to this reduction in captures.

The seabirds that are still being caught or killed by fishing include some of our rarest native albatross, shearwater, and petrel species, which are at high or very high risk of death from bycatch (*Our marine environment 2016*). Salvin's albatross, for example, has a nationally critical conservation status and a very high risk of fishing-related death.

The incidental capture of sea lions has decreased since 1996 and the incidental capture of fur seals has decreased since 1999. (See indicator: Bycatch of protected species: sea lion and fur seal.) The breeding success of sea lions on the Auckland Islands has also improved since 2009, after a marked decline from 1997/98 to 2008/09 (MPI, 2017).

TRAWLING HAS REDUCED BUT REMAINS SIGNIFICANT

The area of seabed trawled has been between approximately 40,000 and 44,000 square kilometres for the last decade. In 2003, the trawled area peaked at 80,000 square kilometres. The number of seabed-contacting tows has nearly halved from nearly 60,000 in 1998 to 26,000 in 2016 (Baird & Wood, 2018).

Some areas of the seabed have been trawled every year for 27 years. About 76 square kilometres of seabed was trawled for the first time in 2016, which expanded the trawled area slightly (Baird & Wood, 2018).

What has contributed to this issue?

FISHING HAS BECOME MORE INDUSTRIALISED

Fishing vessels are now larger and more powerful, and use wider trawls and longer lines than when trawling first started more than 100 years ago. A small number of boats today can have the same impact as a larger fleet would have had in previous decades. Similar changes have occurred worldwide.

New Zealand's total marine catch (deepwater and inshore) was approximately 30,000 tonnes per year in the 1950s and increased to about 58,000 tonnes per year until the mid-1970s (FAO, 2018b). Rapid growth in the late 1970s saw the inshore finfish catch rise from 14,000 tonnes in 1975 to 129,000 tonnes in 1981. This quantity was unsustainable and the overfished stocks crashed in the 1980s (Walrond, 2006).

The introduction of the quota management system in 1986 reduced the pressure on inshore fish (Walrond, 2006). Overall catch increased steadily until the late 1990s, with a peak in 1997 and 1998 of nearly 650,000 tonnes. The catch has since gradually declined to less than 450,000 tonnes a year (FAO, 2018a).

SOME PAST ACTIVITIES STILL HAVE AN IMPACT

Past activities are still having an effect on marine mammals, seabirds, and other species. Legacy issues include hunting of fur seal and sea lion (Seersholm et al, 2018) that once inhabited the east coast and parts of the west coasts of the North and South islands (Baird, 2011). These species recover slowly from disturbance due to their long lifespans but low fertility.

Seabirds, in particular native albatross, have been affected by Japanese longlines in the Southern Ocean. An estimated 44,000 albatrosses were killed annually in the Southern Ocean between 1981 and 1986 (Brothers, 1991).

Parts of the seabed that have been trawled take time to recover. Deepwater coral can take decades to recover (Althaus et al, 2009) but there is still some uncertainty about other species, particularly those that live in naturally disturbed areas (MPI, 2017).

OTHER PRESSURES INTERACT WITH FISHING TO INCREASE IMPACT

New Zealand's marine environment faces increasing pressures from activities besides fishing (MacDiarmid et al, 2012). Our coastal environments receive excess sediment and nutrients from rivers. (See Issue 4: Our waterways are polluted in farming areas and Issue 5: Our environment is polluted in urban areas.) Plastic pollution is a global issue that affects every ocean and many species of seabird, turtle, and marine mammal. Seabirds have also been affected by introduced predators (see Issue 1: Our native plants, animals, and ecosystems are under threat) on the mainland and offshore islands, loss of nesting habitat, and disturbance (DOC, 2000). Climate change is projected to have major impacts on the marine environment from ocean acidification and warming. (See Issue 9: Climate change is already affecting Aotearoa New Zealand.)

These multiple and simultaneous pressures may have complex and poorly understood effects on marine species and habitats (Crain et al, 2008). Such cumulative effects are expected to be more prevalent in our coastal waters, which are the areas of the ocean that we use the most and have the strongest connection with *(Our marine environment 2016).*

Cumulative pressures on the marine environment

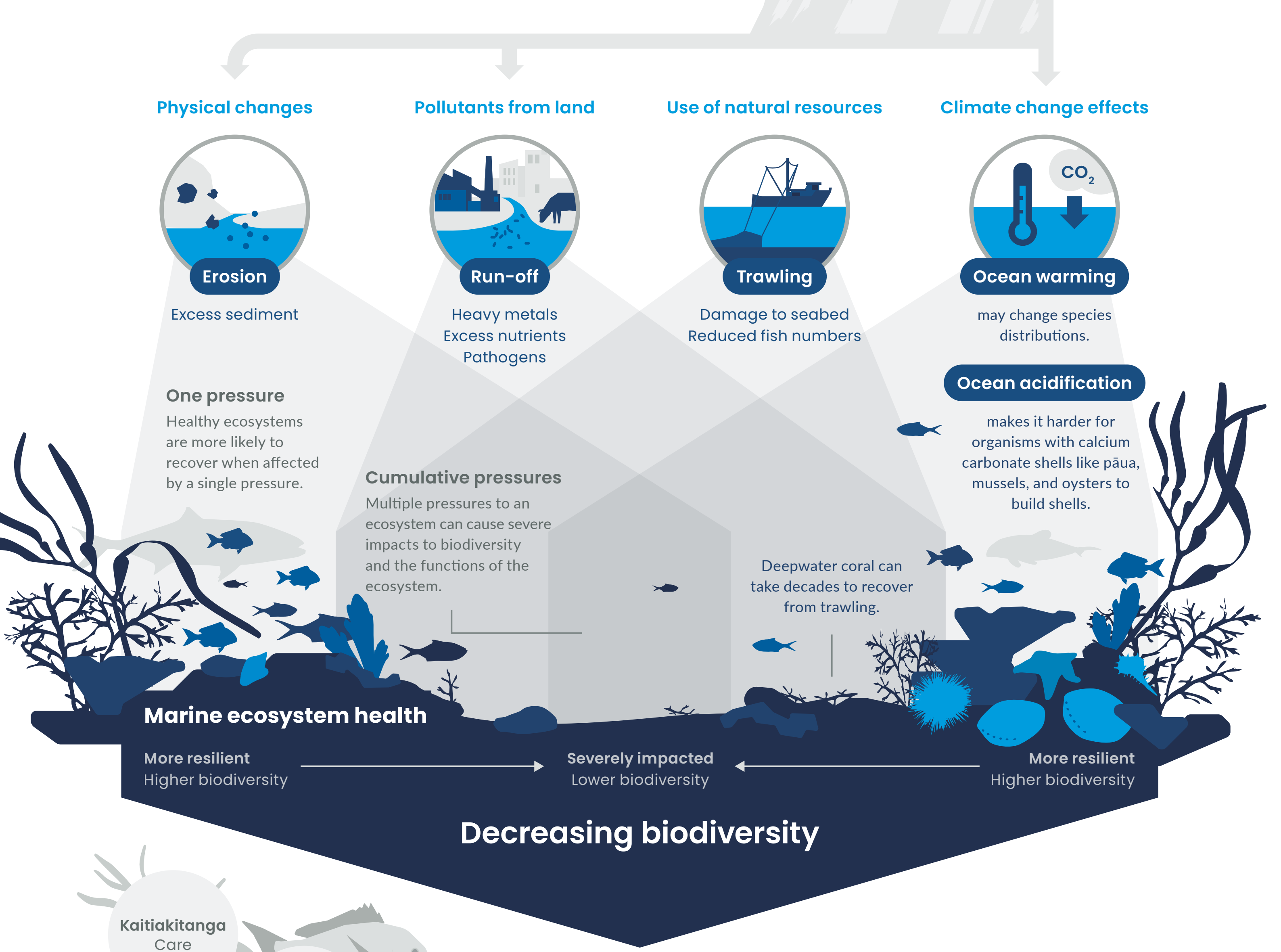
Life in the ocean is degraded when there are multiple pressures on the environment. Some of these pressures are illustrated below.

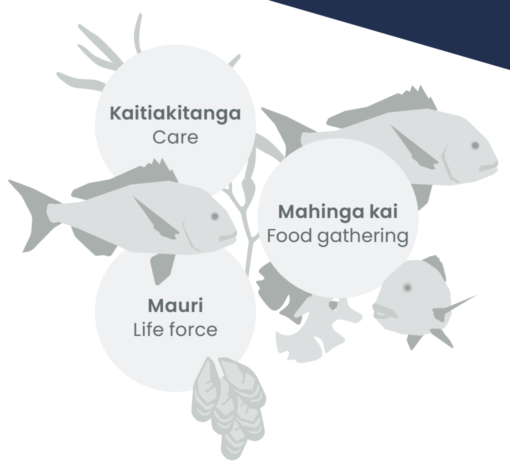
PRESSURES

Multiple pressures acting together have complex and poorly understood effects on marine species and habitats.

CLIMATE CHANGE

has direct impacts on ecosystems and worsens the effects of other pressures.





IMPACT ON VALUES

Losing biodiversity from the sea erodes mauri and takes away opportunities to express kaitiakitanga. Declining mahinga kai limit the ability of tangata whenua to put kaimoana on the table for the whānau and significant events and occasions.

Less marine biodiversity means there are less fish or shellfish to harvest commercially or as part of recreation.

What are the consequences of this issue?

FISHING AFFECTS THE WHOLE MARINE ECOSYSTEM

Taking fish from the ocean may make the remaining population less resilient, for example by reducing the genetic diversity or altering the population structure. This could affect breeding and thus the replenishment of the population, and increase the risk from other pressures.

Removing fish also changes food chains, affecting the species that depend on them for food (like seabirds and marine mammals) or are eaten by them, although evidence also exists of some species benefitting from discards from fishing. A lack of prey can affect how successfully predators can raise their young, sometimes leading to breeding failure if there is not enough food.

Seabed trawling changes the physical structure of the seabed, and reduces the density and diversity of seabed communities. These changes increase as seabed trawling intensifies. Long-lived species and those that form large structures (like mussels and corals) are most affected (MPI, 2017). Damage during fishing can also affect a wide range of ecosystem services provided by seabed habitats, like improving water quality, sequestering carbon, and providing habitat for other species (Geange et al, 2019; MacDiarmid et al, 2013).

OVERFISHING CAN LEAD TO LOSS OF LIVELIHOODS

The present and ongoing productivity of our fisheries is dependent on healthy marine ecosystems. Degradation of the marine environment could affect our ability to fish or harvest seafood for recreation, or to feed our families. For commercial fishers, depleted fish stocks could mean catching less or having to go out further to catch fish.

Changes like this could have a significant impact on the New Zealand economy. Recreational and commercial fishing sustains 16,000 jobs and generates about $4.2 billion in total economic activity (MPI, 2016). About 700,000 people fish in the sea every year, spending $946 million and generating $1.7 billion in economic activity (Holdsworth et al, 2016). This includes the contribution of other activities linked to fishing such as seafood processing. Also, more than 90 percent of our fisheries products are exported, which generates $1,375 million in export value (MPI, 2016).

Māori hold significant commercial marine interests and own more than 20 percent of fisheries quota and access to marine space for aquaculture (MPI, 2018a, 2018c). Māori customary interests are now well recognised and provided for in various legislation. These interests contribute significantly to the well-being of Māori communities today, as they have done for generations.

OVERFISHING DAMAGES CONNECTIONS BETWEEN TANGATA WHENUA AND THE SEA

The loss of biodiversity from local marine environments erodes mauri (the essential essence of all beings, the life force which is in everything) and constrains opportunities to express kaitiakitanga (guardianship obligations and responsibilities) that engage kawa (protocols), tikanga (rules), and ture (laws) for protecting, restoring, and using fish and shellfish. Declines in mahinga kai also limit the capacity of tangata whenua to put kaimoana on the table for daily consumption, and for significant events and occasions (Paul-Burke et al, 2018).

Many coastal iwi and hapū have whakapapa, traditions, and knowledge that relate to seabirds, marine mammals, sharks, and other species. This includes coastal plants like pīngao. For example, customary harvests of fish and shellfish – and for a number of iwi also seabirds (sooty shearwater *(Puffinus griseus)* and grey-faced petrel *(Pterodroma gouldi)*) – link strongly to the mauri of the environment and the mana of the people.

Some species also hold special significance as taonga or non-human forms of kaitiaki whose presence or absence is indicative of ecosystem health. Taonga species are also indicators of intergenerational knowledge transmission and identity, connecting Māori to their Polynesian ancestors and relations across the Pacific and beyond. A reduction or loss of these species as a result of fishing is therefore a significant issue for Māori.

Damage to the marine environment transgresses the basic concepts of a Māori worldview in ways that undermine cultural and individual identity. The degradation of coastal mahinga kai – fish, shellfish, and marine ecosystems – has a significant detrimental effect on the relationship of Māori with their rohe moana (traditional marine environments). Other cultural consequences include fewer connections between people in a community, risk of cultural knowledge not being passed down, and impaired well-being and tribal development (Dick et al, 2012).

Where are the gaps in our knowledge about this issue?

MARINE SPECIES AND ECOSYSTEMS ARE POORLY UNDERSTOOD

Our marine environment is highly complex and has many interacting components that are still poorly understood. Many of our marine species have not been discovered yet – experts estimate that there could be 17,000 or more species still to be identified (Gordon et al, 2010). Information is also lacking about the characteristics and extent of most marine habitats.

INFORMATION FOR MANAGING THE IMPACTS OF FISHERIES IS LIMITED

QMS stock assessments apply to individual fish stocks and do not fully account for interactions between different stocks or interactions with the broader marine environment, like how catching fish affects other species through a food chain. About half of our fish stocks (mainly minor fished species) have too little information to reliably assess their stock status.

There is insufficient information about tipping points in our marine ecosystems, as well as the environmental limits around the sustainable use of marine resources. For example, little is known about how seabed trawling changes the functioning of an ecosystem and the benefits that ecosystems derive from habitats on the seabed. This makes it difficult to assess the full impact of seabed trawling and limits our ability to make informed decisions about managing the marine environment.

A MĀTAURANGA MĀORI PERSPECTIVE IS LACKING

There is a critical gap in our knowledge around the impact of fishing and gathering seafood from a te ao Māori perspective, especially characterising the impacts through mātauranga Māori and tikanga Māori, and on kaitiakitanga, customary use, and mahinga kai.

THEME 5

Our changing climate

Photo credit: Alan Blacklock, NIWA

Greenhouse gas emissions are causing significant changes to Earth's oceans, atmosphere, and climate. We expect these changes to be very long-lasting – some will be irreversible.

We are already seeing changes in our climate and marine environment, and these are expected to become more severe. These changes reach across the length and breadth of Aotearoa New Zealand, with some regional differences. As an island nation with a large marine zone, long coastline, and an economy based mainly on primary production and international tourism, we are vulnerable to the impacts of climate change.

This theme looks at two climate change issues:

1. How our activities in New Zealand are contributing to global increases in greenhouse gases.
2. How changes in the climate are already affecting our environment, and how they will affect our lives now and into the future.

This theme does not contain an assessment of our current knowledge about climate change. That information is provided by the Intergovernmental Panel on Climate Change (IPCC), whose reports the New Zealand Government has accepted. (See *Our atmosphere and climate 2017*.)

Some other aspects of climate change are discussed in other issues and themes:

- **Issue 1:** Our native plants, animals, and ecosystems are under threat – describes the effect of climate change on our ecosystems and biodiversity.
- **Issue 2:** Changes to the vegetation on our land are degrading the soil and water – how these may affect climate.
- **Theme 4:** How we use our freshwater and marine resources – noting how changes in rainfall and glacier melt patterns affect freshwater flows.

ISSUE 8

New Zealand has high greenhouse gas emissions per person

Our per-person rate of greenhouse gas emissions is one of the highest for an industrialised country. Most of our emissions in 2016 came from livestock and road transport.

Why does this issue matter?

SPATIAL EXTENT

Sources of emissions that contribute to our high per capita rate exist nationwide.

DEPARTURE FROM NATURAL CONDITIONS

Since 2000, greenhouse gases in Earth's atmosphere have increased 10 times faster than at any other time in the past 800,000 years (IPCC, 2018a).

IRREVERSIBILITY

Greenhouse gas emissions from human activities are mostly under our control. Once in the atmosphere they can affect our climate for thousands of years.

IMPACTS ON WHAT WE VALUE

Climate change is projected to affect many of the things we value.

KNOWLEDGE GAPS

Levels of future global emissions are uncertain, as is how New Zealand will be affected.

What is the current state of this issue?

GLOBAL HUMAN-GENERATED EMISSIONS ARE AT A RECORD HIGH

For 2017, the average concentration of carbon dioxide (CO_2) in the atmosphere was 405 parts per million (ppm), about 46 percent higher than the pre-industrial level of 280 ppm (IPCC, 2014b; NOAA, n.d.). Globally, in 2013 agriculture contributed 11 percent of all greenhouse gas emissions, 78 percent came from energy production, of which 43 percent was from electricity or heat generation. (See indicator: Global greenhouse gas emissions.)

The global mix of the main greenhouse gas emissions in 2013 was carbon dioxide (produced from fossil fuels, cement, land-use change, and forest harvesting) 76 percent, methane 16 percent, and nitrous oxide 6 percent.

The top 12 emitting countries emitted nearly twice as much as all other countries combined. The five countries with the largest percentages of total global emissions were China (26 percent), United States (14 percent), European Union (28 countries; 9 percent), India (6 percent), and the Russian Federation (5 percent). New Zealand contributed 0.17 percent *(Our atmosphere and climate 2017)*.

Global warming potential and carbon dioxide equivalents

Global warming potential (GWP) is a term used to describe how much global warming a greenhouse gas may cause over a given time period (usually 100 years) compared with carbon dioxide. It takes into account how long the gas stays in the atmosphere and how strong a warming effect it has.

Carbon dioxide equivalent (CO_2-e) uses GWP to convert a given amount of a greenhouse gas like methane into an equivalent amount of carbon dioxide so they can be compared and reported consistently.

For example, emitting 1 kilogram of methane (GWP of 25) is equivalent to emitting 25 kilograms of carbon dioxide (25 kilograms carbon dioxide equivalent). One kilogram of nitrous oxide (GWP of 298) is equivalent to 298 kilograms of carbon dioxide.

OUR EMISSIONS PER PERSON ARE HIGH INTERNATIONALLY

While we make a small contribution to global emissions, our country has one of the highest rates of emissions per person. In 2015, New Zealand emitted 17.5 tonnes of carbon dioxide equivalent greenhouse gases per person. This was 33 percent higher than the Annex I (industrialised countries) average of 13.2 tonnes, and higher than all but five of the 43 Annex I countries (UNPD, n.d.).

In 2016, New Zealand emitted 78,727 kilotonnes of carbon dioxide equivalent greenhouse gases, mainly carbon dioxide (44 percent), methane (43 percent), and nitrous oxide (12 percent). (See indicator: New Zealand's greenhouse gas emissions.)

Our emissions profile is unusual for a developed country. In most developed countries emissions are dominated by fossil fuel combustion, especially burning coal to produce electricity, and burning petrol for transport. By contrast, we produced 85 percent of our electricity from renewable sources in 2016, primarily in hydroelectric schemes (MBIE, 2017). (See Theme 2: How we use our land for information about physical changes to land related to hydro-generation and Theme 4: How we use our freshwater and marine resources.)

Nearly half of our gross emissions in 2016 (mainly methane and nitrous oxide) came from agriculture, which reflects the important role of this industry in our economy. In 2016, livestock digestion was responsible for 82 percent of all methane emissions. Ninety-four percent of all nitrous oxide emissions were from agricultural soils, mainly from the urine and dung of grazing animals.

Our carbon dioxide emissions in 2016 were mainly from using fossil fuels in road transport and manufacturing. Road vehicle emissions made up 39 percent of all carbon dioxide emissions, while manufacturing and construction contributed 20 percent, energy industries 12 percent, and industrial production and product use 9 percent.

As well as greenhouse gases, our larger cities tend to have high levels of black carbon. This is the sooty black material produced during combustion. In New Zealand it mainly comes from burning wood and coal for home heating, and from diesel engines. Although black carbon concentrations have decreased in some places (including Whangarei, Auckland, and Nelson), they remain high in others, compared with cities in Europe and the United States (Davy & Trompetter, 2018). (See indicator: Black carbon concentrations.)

Black carbon is estimated to be one of the most important contributors to global warming behind carbon dioxide (IPCC, 2014c). When it lands on ice and snow, like mountain glaciers, it speeds up melting because its dark colour absorbs heat. The tiny particles that make up black carbon also have serious health effects when they are inhaled. (See Issue 5: Our environment is polluted in urban areas.)

What has changed?

GLOBAL GREENHOUSE GAS EMISSIONS HAVE INCREASED AT AN UNPRECEDENTED RATE

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, 2014b).

Global carbon dioxide concentrations have risen by about 20 ppm per decade since 2000. This rise is up to 10 times faster than any sustained rise during the past 800,000 years. Global temperatures have already increased by about 1 degree Celsius above pre-industrial levels due to human activities. If temperatures continue to increase at the current rate, it is projected that global warming is likely to reach 1.5 degrees Celsius above pre-industrial temperatures between 2030 and 2052 (IPCC, 2018b).

These global-scale rates of human-driven change far exceed the rates of change driven by other forces that have altered Earth in the past. Even sudden events, like volcanic eruptions, do not approach the current rates of change (IPCC, 2018a).

Gross emissions, removals, and net emissions

Gross greenhouse gas emissions are the total emissions from agriculture, energy, industrial processes and product use, and waste. This total includes all greenhouse gases.

Some types of land use, especially forestry, remove carbon dioxide from the atmosphere. Net emissions are gross emissions combined with removals and emissions from land use, land-use change and forestry.

Our net emissions are strongly influenced by forest planting and harvesting cycles. Land use, land-use change and forestry removed 23 percent less carbon dioxide from the atmosphere in 2016 than in 1990, because the harvest rate of planted forest increased during this time.

OUR EMISSIONS PER PERSON ARE LOWER THAN 10 YEARS AGO

New Zealand's gross greenhouse gas emissions increased by 20 percent since 1990, but have been relatively steady in the last decade (see figure 20), despite increases in population and gross domestic product (GDP).

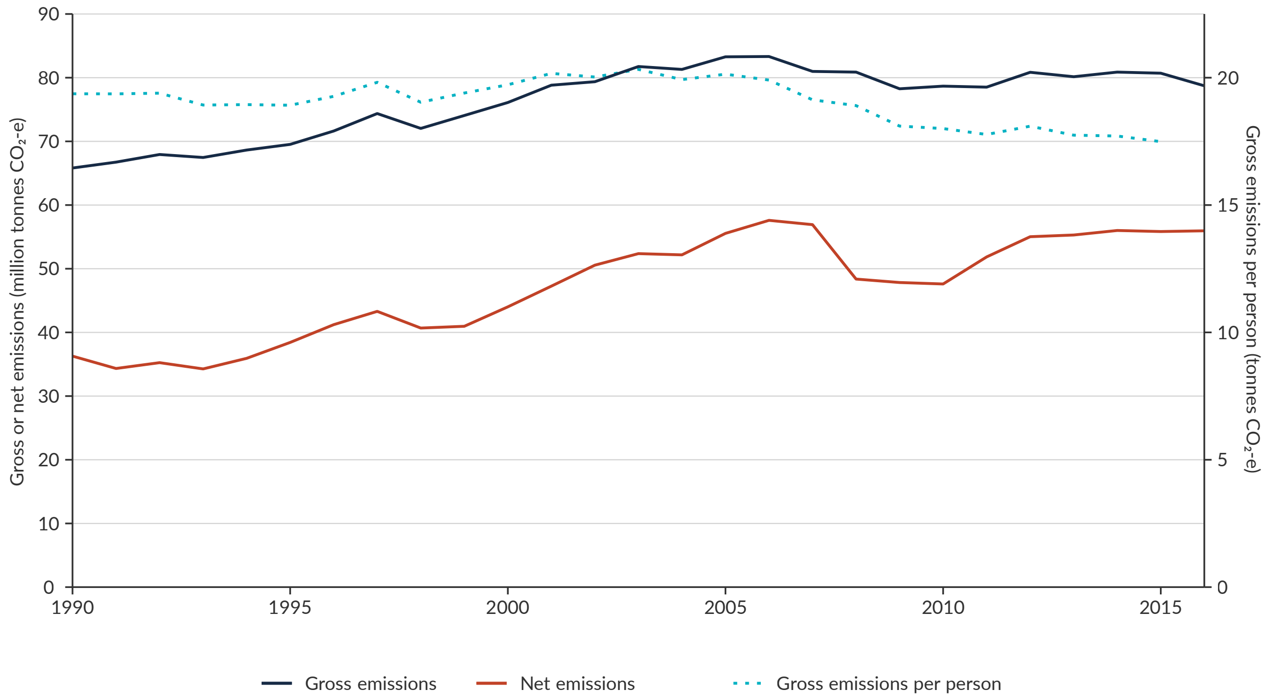
Per-person carbon dioxide equivalent greenhouse gas emissions were 12 percent lower in 2015 than 2006 (a decrease from 19.9 to 17.5 tonnes per person) because our population increased while emissions remained steady. Per-person emissions in 2015 (17.5 tonnes per person) were also 10 percent lower than in 1990 (19.4 tonnes per person) (UNPD, n.d.).

New Zealand's greenhouse gas emissions per unit of GDP were 43 percent lower in 2016 than in 1990, but still high internationally – the fourth highest in the OECD in 2016 (OECD, n.d.).

From 1990 to 2016, road transport emissions increased by 82 percent, and manufacturing and construction emissions by 45 percent. Gross emissions from agriculture increased by 12 percent during this time. Methane emissions from livestock increased by 6 percent, mainly due to a doubling in the total number of dairy cows, which produce more methane per animal than non-dairy cattle and sheep (MfE, 2018).

In the decade from 2007 to 2016, livestock emissions were relatively stable, but this stability masks a shift in emissions sources. Methane emissions from sheep decreased 23 percent but this was offset by an increase in methane emissions from dairy cattle.

Figure 20: New Zealand's greenhouse gas emissions, 1990–2016



Data source: Ministry for the Environment; United Nations Population Division

Note: Gross emissions exclude emissions and sequestration from land use, land-use change and forestry, while net emissions include these. Gross emissions per person are available only until 2015. Carbon dioxide equivalent (CO_2-e) is a measure used to compare the emissions from various greenhouse gases based on their global warming potential.

CHANGING OUR RATE OF EMISSIONS IS POSSIBLE

Our high per-person emissions are reversible if we adopt policies, technologies, or other means that reduce our production of greenhouse gases. The benefits of doing this must be evaluated alongside the impacts these reductions would have on our society and economy.

According to the IPCC (2018a), global warming is driven by emissions from human activities – this means the world can choose to limit future global warming and climate change by reducing greenhouse gas emissions. Even small reductions in greenhouse gas concentrations will reduce the changes that our grandchildren and their descendants will experience.

Although it is possible to reduce or offset our emissions of greenhouse gases, how that affects the concentrations of greenhouse gases in the atmosphere depends on the gas. Some gases only remain in the atmosphere for a relatively short time (about a week for black carbon particles and a decade for methane). Because these gases and particles tend to have a greater warming effect than carbon dioxide, reducing or eliminating short-lived emissions will have a more immediate effect on the climate.

Nitrous oxide remains in the atmosphere for more than 120 years; carbon dioxide for centuries or longer. Even if emissions stopped today, the impacts of the carbon dioxide that has already been emitted will continue for many centuries. We are set to experience the effects of today's emissions for many years to come.

What has contributed to this issue?

NEW ZEALAND HAS A UNIQUE GREENHOUSE GAS EMISSIONS PROFILE

Our high per-person emissions are partly due to the large proportion of methane and nitrous oxide we emit. Because these gases warm our atmosphere more strongly than an equivalent amount of carbon dioxide, they increase our per-person carbon dioxide equivalent greenhouse gas emissions significantly.

The high per-person emissions also reflect our high rate of car ownership – the highest in the OECD (OECD, 2017). The carbon dioxide emissions per kilometre of the vehicles entering our fleet decreased from 2005 to 2012, but have been steady since then. Although the number of vehicles entering the fleet in 2017 was a record high, the number exiting it was low. This makes our light vehicle fleet relatively old by OECD standards – 14 years on average for a petrol-powered vehicle. Older vehicles tend to be more wasteful of petrol for each kilometre travelled and emit more carbon dioxide (Ministry of Transport, 2017).

Our ageing vehicle fleet also contributes to black carbon emissions (as older vehicles emit more) (Davy & Trompetter, 2018). The contribution that burning wood and coal for home heating makes to urban pollution, including black carbon, is discussed in Issue 5: Our environment is polluted in urban areas.

What are the consequences of this issue?

Although our global contribution is small, New Zealand's emissions, and the cumulative emissions of other small countries, contribute to the warming of our atmosphere and oceans. The rate of warming is also unprecedented, and may be faster than some organisms and ecosystems can adapt to.

The impacts of these changes are already being felt globally:

- scientists have documented shrinking ice sheets and arctic sea ice
- loss of habitat and shifting ranges for some plants and animals
- earlier onset of spring and winter starting later
- mismatches in timing between some species and their food sources
- new types of pests and diseases affecting agricultural production, biodiversity, aesthetics, and recreation
- more coastal erosion
- rising groundwater and saltwater intrusion to aquifers, agricultural lands, and river mouths.

Impacts already being experienced in New Zealand are detailed in Issue 9: Climate change is already affecting Aotearoa New Zealand.

Our high rate of per-person emissions compared with other industrialised countries also carries a reputational risk for a country where international trade and tourism are strongly linked to our environmental credentials.

Where are the gaps in our knowledge about this issue?

OUR UNDERSTANDING OF HOW GLOBAL EMISSIONS WILL CHANGE IN THE FUTURE IS INCOMPLETE

Knowing how global emissions will increase or decrease in the future, and what actions would be implemented to curtail emissions, is the biggest gap. Some countries such as the UK and Germany have emissions that are now lower than they were in 1990, but globally, greenhouse gas emissions continue to increase (IPCC, 2014b; OECD, n.d.).

INFORMATION ON THE RELATIVE STRENGTHS OF DIFFERENT CARBON SOURCES AND SINKS IS LIMITED

Other uncertainties concern the relative strengths of various sources and sinks for greenhouse gas emissions. Trees remove carbon dioxide from the air and store it as biomass, which offsets some of our emissions. It is possible for example that the native forests on the west coast of the South Island may be a bigger carbon sink than previously recognised, but more work is needed to confirm this (Steinkamp et al, 2017).

POOR UNDERSTANDING OF TIPPING POINTS

There are significant gaps in our knowledge around global tipping points, particularly in situations where levels of carbon dioxide above a threshold precipitate feedback with even faster rates of emissions and warming (Steffen et al, 2018).

ISSUE 9

Climate change is already affecting Aotearoa New Zealand

Changes to our climate are already being felt in our land, freshwater, and marine environments. We can expect further wide-ranging consequences for our culture, economy, infrastructure, coasts, and native species.

Why is this issue important?

SPATIAL EXTENT

Climate change is affecting all parts of New Zealand. Impacts vary by region and sector.

DEPARTURE FROM NATURAL CONDITIONS

Some changes are not yet detectable (extreme rainfall), others are already significantly different from pre-industrial conditions (temperature, sea-level rise).

IRREVERSIBILITY

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

IMPACTS ON WHAT WE VALUE

Environmental, cultural, and economic systems are already impacted and impacts are expected to increase.

KNOWLEDGE GAPS

Uncertainty about future global emissions makes it hard to plan for impacts. The cumulative effects of different impacts are not known.

What is the current state of this issue?

NEW ZEALAND IS ALREADY AFFECTED BY CLIMATE CHANGE

Many significant changes in New Zealand's climate have already been observed across the country, but regional variations can also be seen, particularly for rain and snow fall. Changes include alterations to temperature, precipitation patterns, sea-level rise, and ocean acidification, wind, and sunshine.

Annual average land-surface temperature in New Zealand for 2018 tied for the second highest average since records began in 1909. Four of the past six years were among the warmest on record (NIWA, 2018). The average annual temperature has not been this warm in the past 10,000 years, which is likely to be near or already outside the range that humans and current ecosystems have experienced here (MfE, 1997).

Climate change is already impacting New Zealand, and the effects will intensify with time. 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 level, are already significantly different from pre-industrial conditions.

What has changed?

NEW ZEALAND'S CLIMATE IS CHANGING

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

- **Temperature:** New Zealand's annual average temperature has increased by 1 degree Celsius between 1909 and 2016. (See indicator: National temperature time series.)
- **Frost and warm days:** The number of frost days (below 0 degrees Celsius) decreased and the number of warm days (over 25 degrees Celsius) increased at about one-third of measured sites from 1972 to 2016. No statistically significant change was detected at about two-thirds of the sites. Where change was identified, it was skewed toward what would be expected in a warming climate – the number of warm days increased at eight sites and decreased at one, while the number of frost days decreased at 10 sites and increased at one. (See indicator: Frost and warm days.)
- **Soil moisture:** Since 1972/73, soils at around one-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: Soil moisture and drought.)
- **Glacier ice:** From 1977 to 2016, our 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:** Coastal sea levels measured at New Zealand ports have risen 14–22 centimetres from 1916 to 2016, which is consistent with global trends. (See indicator: Coastal sea-level rise.) The rate of sea-level rise has increased in recent decades and some places like Nelson have experienced flooding during the highest high tides even in calm weather (MfE, 2017a).
- **Sea temperature:** The average sea-surface temperature around New Zealand increased 0.7 degrees Celsius from 1909 to 2009 (Mullan et al, 2010). (See indicator: Oceanic sea-surface temperature.) The greatest warming was off the Wairarapa Coast and off the northwest coast of the North Island. Slight cooling was found in the Southern Ocean off the Otago coast (Sutton & Bowen, 2019).
- **Ocean acidity:** The subantarctic ocean off the Otago coast has become more acidic since 1998 (oceans acidify as they absorb carbon dioxide from the atmosphere). This site has the longest monitoring record in New Zealand. (See indicator: Ocean acidification.)
- **Wind:** Between 1972 and 2016, extreme wind decreased at about one-third of sites across New Zealand (in frequency and magnitude). No change was detected at about two-thirds of sites. (See indicator: Extreme wind.)
- **Sunshine:** From 1972 to 2016, sunshine hours increased at 27 out of 30 locations around New Zealand. (See indicator: Sunshine hours.)
- **Rainfall:** From 1960 to 2016, most locations did not show changes in extreme rainfall. As at 2016, the proportion of annual rainfall occurring in intense events (in the 95th percentile) decreased at four of 30 locations (Auckland, New Plymouth, Rotorua, and Taupō) but increased at Napier and Timaru. (See indicator: Rainfall intensity.) The inability to detect trends may be partly due to the short time period there is data for. This makes it difficult to detect changes in infrequent events, like extreme rainfall. Studies have identified that climate change played a role in recent flooding events in Golden Bay in 2011 (Dean et al, 2013) and Northland in 2014 (Rosier et al, 2015), and contributed to the cost of floods in the last decade (Frame et al, 2018).

Stopping further emissions will not return us to a normal climate. As discussed in Issue 8: New Zealand has high greenhouse gas emissions per person, carbon dioxide remains in the atmosphere for centuries to millennia and will affect our climate for generations to come. The risk of impacts generally increases as global temperatures increase, so as long as greenhouse gas concentrations remain elevated, the risk from extreme events like heat waves, droughts, and storms will be elevated. Other impacts can be considered permanent – erosion from extreme rainfall or species extinctions for example cannot be reversed.

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

What has contributed to this issue?

Carbon dioxide and other greenhouse gases are building up in the atmosphere and causing changes to global climate. (See Issue 8: New Zealand has high greenhouse gas emissions per person.)

What are the consequences of this issue?

ALL ASPECTS OF LIFE IN NEW ZEALAND WILL BE IMPACTED

New Zealand's position in the South Pacific does not isolate us from the risks posed by a warming climate. Many impacts, like rising seas and melting glaciers are already being experienced here. Others are expected to become important, including increased risk of extreme fires and storms. A warmed climate will impact us directly, from larger and more frequent floods and droughts for example, and indirectly through impacts to our economic, social, and cultural systems (New Zealand Climate Change Centre, 2014).

The changing climate will exacerbate the issues discussed in this report, placing additional stresses on already stressed systems. Projections for our future climate under different emissions scenarios are available from NIWA (Climate change scenarios for New Zealand).

COASTAL FLOODING AND EROSION WILL INCREASE

Our long coastline and large areas of coastal land will be more affected by flooding and erosion in the future, affecting homes, habitats, and cultural heritage sites. Extreme coastal flooding, usually due to storm surges coinciding with very high tides, already contributes to disruption and damage in some low-lying places like South Dunedin (*Our atmosphere and climate 2017*).

With rising seas we can expect tides, waves, and storm surges to reach further inland more regularly, resulting in more frequent and serious flooding (PCE, 2015). Even a modest sea-level rise of 0.3–0.4 metres (which we may see by 2050–60) will mean that a previously rare 1-in-100-year storm-tide inundation would occur on average once a year (MfE, 2017a).

Sea-level rise will make coastal erosion worse. It will also make drainage for low-lying or coastal farms and urban areas more challenging. New risks, such as liquefaction during earthquakes, could also arise, as well as increased exposure to tsunami inundation. Salt water intrusion and erosion may cause ecosystems such as sand dunes, wetlands, mangroves, and estuaries (and their diverse habitats) to be reduced or lost (MfE, 2017a).

THE AVAILABILITY AND DEMAND FOR OUR WATER RESOURCES WILL CHANGE

Warmer temperatures and reduced rainfall are projected to make water flows more variable, and to increase the demand for irrigation in some places (Rutledge et al, 2017). These changes may increase the time when there are low water flows or warmer water temperatures, which could affect our biodiversity and the native species that are not adapted to the new conditions.

The frequency and intensity of drought in drought-prone regions is expected to increase further, with potentially serious implications for our primary industries. This is expected to increase the demand for water by agriculture, resulting in competition for freshwater resources as well as pressure to develop water storage options, which again can affect river water quality and flows (Royal Society of New Zealand, 2016). (See Issue 6: Taking water changes flows which affects our freshwater ecosystems.)

Extreme rainfall events are likely to increase in most areas and could cause increased erosion and flooding. Computer models for Horizons Regional Council show that even with mild climate change, sedimentation in fresh water from erosion is likely to increase by at least 10 percent (Manderson et al, 2015). Increased sediment from increased erosion due to flooding and land-use change would also stress aquatic species. (See Issue 2: Changes to the vegetation on our land are degrading the soil and water.)

About two-thirds of New Zealand's population live in areas prone to flooding (Waugh et al, 1997). Flooding can impact on housing, transport, energy, stormwater, and wastewater systems. Often, these areas also have long-lived infrastructure that is difficult to retrofit (Royal Society of New Zealand, 2016).

Many urupā (burial sites) are on river flood plains or coastal areas that could be subject to increased flooding.

THE RISK OF EXTREME FIRE CONDITIONS WILL INCREASE

A warmed climate will increase the risk of extreme fire weather. Most of New Zealand's native forests have evolved without regular fires. Their recovery from a fire may take several centuries because of slow seed dispersal and the fact that the first vegetation to grow after a fire (eg shrubs) is more likely to burn again (Tepley et al, 2018). Loss of ecosystems and habitat from more frequent or intense fires could affect vulnerable species and biodiversity. Fires also increase our emissions because greenhouse gases are released and the carbon sink effect of the forest is affected.

Since plantation forests are a long-term investment and require about 30 years to grow to maturity, increased fire risk is an especially important issue facing the forestry industry. It is also significant because one important pathway to reducing greenhouse gas emissions is planting new forests.

VULNERABLE SPECIES ARE ALREADY AFFECTED

Vulnerable native flora and fauna are already being affected. For example, warming temperatures were found to have played a role in shifting the distribution of two wētā species studied (Bulgarella et al, 2014). In another study, the number of invasive wasps in the Nelson area increased when springs were warm and dry (Lester et al, 2017).

Climate change is likely to have major impacts on many habitats and shift where some native species are found. Some species may survive by moving south or to higher altitudes, but others are expected to be lost from some places. We also expect large-scale changes in ecological communities and species interactions, as well as changes in seasonal activities such as flowering, breeding, and migration, but the extent of these is unknown (McGlone & Walker, 2011).

There is growing community recognition of these effects with kaitiaki, hapū, and whānau fishers noting seasonal shifts that are affecting local kaitiakitanga practices and harvest times, as well as in the indicators that signal them (Deep South National Science Challenge: vision mātauranga, 2018).

Stresses from climate change could also make ecosystems and organisms more susceptible to other disturbances like pollution and fire.

RISKS FROM UNWANTED PESTS AND DISEASES WILL INCREASE

Increases in temperature could allow new exotic pests, weeds, and diseases to establish here. Subtropical and 'sleeping' pests (species that are already in New Zealand but could flourish with a change in climate) could spread and have significant impacts (Pearce et al, 2017).

We rely on international shipping for trade and are vulnerable to pests and diseases from America, Australia, and Asia carried in the ballast water and on the hulls of vessels from these more tropical waters (Gordon et al, 2010).

Risks from other unwanted pests could increase, including an increase in the abundance of a root-feeding nematode and a rise in the severity of Swiss needle cast disease (IPCC, 2014a). Human health could also be threatened by diseases new to this country (IPCC, 2014b).

CULTURALLY IMPORTANT SITES MAY BE LOST

Concerns are increasing about the impacts of coastal erosion and sea-level rise on cultural sites, including early settlement sites and burial grounds (McFadgen, 2007). As sites are lost to erosion or to the encroaching sea, we lose the knowledge they offer about early Māori and European settlement, and their impact on New Zealand's ecosystems. We also lose our intergenerational connection to these spaces, along with the knowledge and understanding of those connections. Many coastal iwi and hapū have marae and other sites (eg urupā), important to the identity and well-being of their people, located in vulnerable areas.

A 2013 study of the impact of climate change on the archaeology of the Whangarei coastline suggested that detrimental impacts on archaeological sites were likely to increase in likelihood and severity. One-third of such sites were already threatened by other pressures. Middens containing pre-historic or historic domestic rubbish like discarded shells or animal bones, and smaller early Māori occupation sites, are particularly at risk (Bickler et al, 2013).

OUR MARINE ECOSYSTEMS WILL BE AFFECTED

Increased storminess, changes in ocean currents, sedimentation, algal blooms, and marine pests may have compounding effects on New Zealand's marine environment. Ocean acidification may cause widespread harm to our ecosystems, particularly to organisms with carbonate shells like pāua, mussels, and oysters. Ocean warming may affect ocean currents and modify habitats by expanding, reducing, or shifting the areas where certain species live. (See Issue 7: The way we fish is affecting the health of our ocean environment.)

These changes will bring challenges (and potentially opportunities) for industries like aquaculture and fishing, and affect recreational fishing. This is a significant issue for Māori who have substantial customary and commercial interests in our marine environment that are vital to supporting the health and well-being of iwi, hapū, and whānau. Any impact from invasive species or change in the quantity or distribution of any marine species will be economically important (MacDiarmid et al, 2013). Aquaculture and growers and harvesters of shellfish will be especially vulnerable to ocean acidification, reduced oxygen levels, increased water temperature, and increased run-off from flooding and erosion (MacDiarmid et al, 2013).

INFRASTRUCTURE AND URBAN AREAS ARE AT RISK

Sea-level rise has substantial implications for urban areas and infrastructure. Stronger and more frequent heat waves, coupled with the urban heat island effect will increase the incidence of heat stress, especially among vulnerable people (IPCC, 2014b).

More extreme weather events mean more cost to repair and upgrade infrastructure such as transport and communications networks, water supply, and waste systems. A recent report estimated that more than $2.7 billion worth of local government infrastructure is at risk from a sea-level rise of 0.5 metres, a level that could be reached as soon as 40–90 years (LGNZ, 2019; MfE, 2017a).

Our energy system and its infrastructure will also be impacted. Warmer temperatures and changes in rainfall patterns are likely to affect the supply and demand of electricity. More precipitation in the Southern Alps would increase hydro-generation, especially in winter, but more rain and less snow could create water shortfalls in summer and autumn when the need for irrigation is also greatest (Royal Society of New Zealand, 2016).

The insurance industry is also likely to be affected. Some places that flood repeatedly or are subject to other climate-related natural hazards may eventually become uninsurable. This is a particular issue for areas at risk from rising sea levels.

OUR AGRICULTURE, HORTICULTURE, AND TOURISM ARE LIKELY TO BE AFFECTED

Agriculture and primary industries are likely to be strongly affected by climate change through an increase in climate variability, changed average rainfall and temperatures, and more extreme events (Climate Change Adaptation Technical Working Group, 2017).

There are likely to be more droughts and flood events. Droughts reduce the growth and yield of crops, and long dry spells 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 (Pearce et al, 2017). Floods can also affect the growth and yield of crops, as well as affecting the distribution networks needed to move goods to market.

The decreasing volumes of ice in our glaciers are affecting not only the environment around them but also related tourism. The West Coast's Fox and Franz Josef glaciers have each retreated about 3 kilometres since 1940, despite a period of advance between 1980 and 2005 (Macintosh et al, 2017). In 2012 Fox Glacier and in 2014 Franz Josef became too dangerous for tourists, marking an end of almost a century of glacier guiding from the valley floor *(Our atmosphere and climate 2017).*

WE MAY NEED TO ADAPT AND FIND NEW OPPORTUNITIES

On the plus side, increasing temperatures will likely extend the growing season in parts of the country. Changes in temperature and precipitation patterns would also change the soil and the conditions for plant growth, potentially increasing the yields of pasture and forestry, and shifting the viable areas for crops like kiwifruit and maize (Rutledge et al, 2017; Tait et al, 2017).

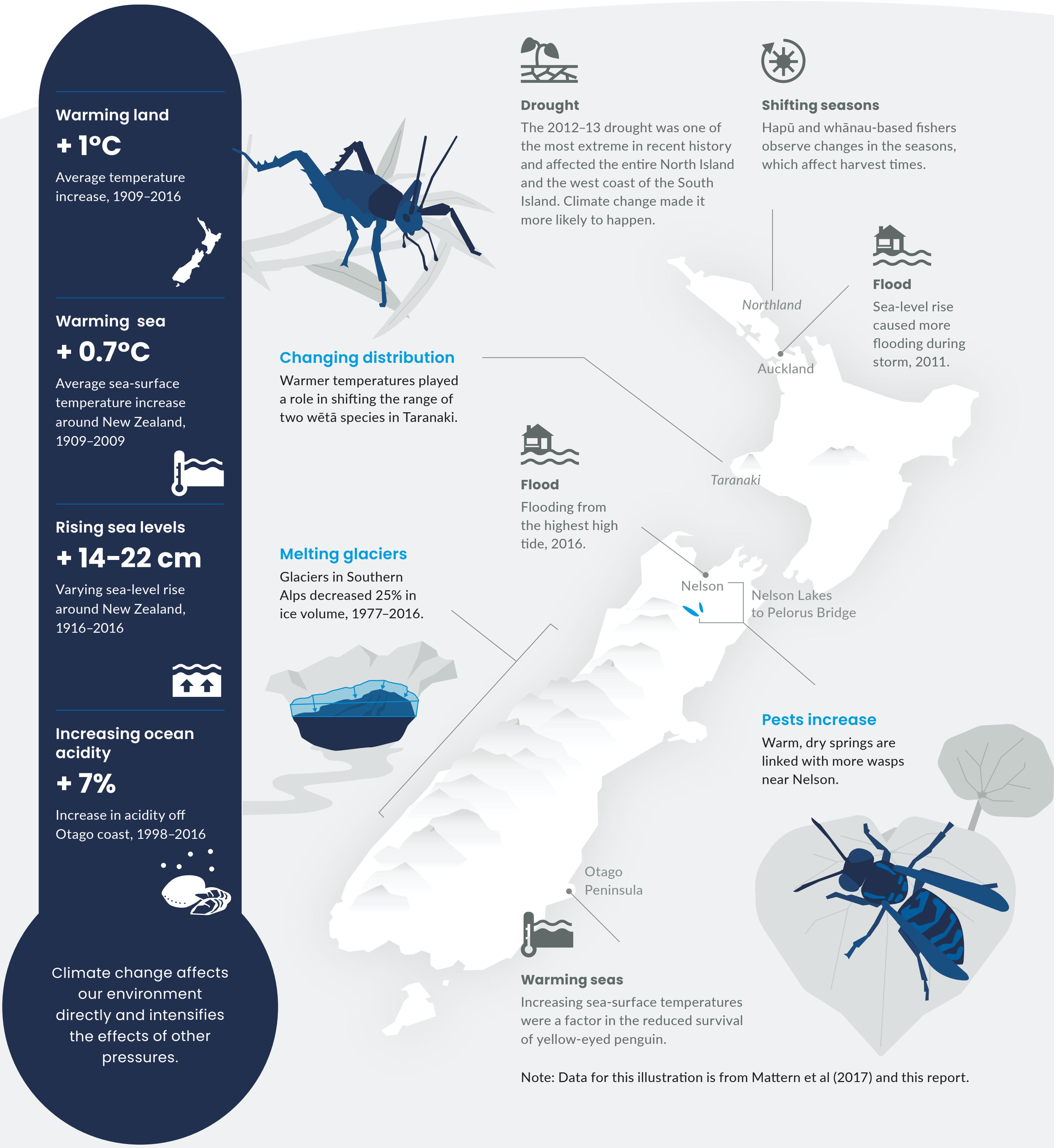
This change could benefit some areas in the short term if sheep, beef, and dairy farms are managed to take advantage of a predicted increase in grass growth (Climate Change Adaptation Technical Working Group, 2017). Higher concentrations of carbon dioxide are also likely to increase pasture production on average by up to 4–10 percent for much of the country by 2050.

Warmer winter temperatures are also likely to result in less wood burning for home heating, which would improve air quality.

Impacts of climate change

Relatively small changes in our climate can have big effects on our ecosystems.

CHANGES ARE ALREADY AFFECTING NEW ZEALAND



Note: Data for this illustration is from Mattern et al (2017) and this report.

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 relates to the total global emissions we can expect. The amount that the climate and oceans warm, and the impacts on New Zealand from these changes, is totally dependent on the concentrations of greenhouse gases in our atmosphere. The uncertainty of the global emissions trajectory makes quantifying and planning for projected impacts difficult.

INFORMATION ON CUMULATIVE AND CASCADING IMPACTS IS LIMITED

Better information about cumulative and cascading impacts of climate change is also needed. For example, studies have assessed the effects of carbon dioxide on fertilisation for individual species and crops, but better knowledge about the interaction of all the factors that will affect their growth in a warmer climate is crucial. Increased carbon dioxide may increase plant growth, but less rainfall or fewer nutrients may partially or totally offset the increase.

There is a need for better information about the cascading effects brought about by climate change. An example is how flooding affects transport and distribution networks, which affect local businesses and government, and which in turn affect communities, whānau, and individuals (Lawrence et al, 2018). These issues have begun to be addressed, but a more thorough understanding of the complex impacts will improve our ability to plan for and adapt to projected changes in our climate.

PART 3

Towards a better understanding of our environment

Environmental reporting depends on information gathered from many different sources. This part of the report sets out the challenges that affect our understanding of the environment.

Photo credit: photonewzealand

Understanding our environment

The environmental system operates at many different scales and has innumerable dimensions, intricacies, and interdependencies – these are nature's premises that we cannot change. But we can, through understanding our environment, adjust our actions and decisions to improve the way we manage and protect the environment that supports and sustains us.

The purpose of this report is to provide a diagnosis of the health of our environment. It should give all decision-makers – elected representatives, iwi leaders, businesses, environmental groups, and members of the public – a firm basis for comparing one environmental issue with another (PCE, 2016).

In noting knowledge gaps it identifies:

- the features of our environment around which our knowledge and reporting systems should be designed
- recommendations to build our knowledge system (the data and science that is collected for various purposes) and strengthen the translation of that knowledge to improve our reporting system.

Features of the environment

ONE WHOLE, MANY PARTS

The complexity of our environment as a system means that both a full understanding of cause and effect and the cumulative effect of multiple pressures is lacking. This is especially true for our freshwater and coastal ecosystems (Larned et al, 2018a) where the effects of pollution, for example, may be compounded by other pressures like habitat modification, introduced species, and climate change.

UNCERTAINTY IS A GIVEN

Because of its complexity, it is very difficult to be certain about the effects of our actions in one place on other parts of the environmental system. There may be many uncertainties preventing our understanding, such as how unforeseen events and hazards (such as earthquakes) may affect the system, or the likely transmission pathways, and effects of emerging risks like diseases and new pollutants (Gluckman, 2016).

CHANGE HAPPENS AT DIFFERENT RATES

The very nature of the environment is to continually change and evolve. Some change is barely perceptible, while some happens at rates that we can see and find concerning. We lack knowledge about whether some observed trends will continue, reduce, or amplify, and if some changes become significant enough to cause larger, more significant change when a tipping point is reached. The time that passes between a cause and an observed effect can be significant (termed 'lag time'), which means our knowledge of a change can be slow to emerge.

DIFFERENT PEOPLE VALUE DIFFERENT THINGS

The environment provides us with many goods and services and contributes to our well-being. We all have our own sets of values and preferences, so coming to a shared view about value is often challenging. Similarly, the way people assign value to the many ways we connect with nature also varies across monetary, quantitative, and qualitative approaches.

Making informed decisions

THE ROLE OF THE REPORTING SYSTEM

Some decisions that relate to environmental management are framed by legislation that helps deliver on the stewardship goals of Aotearoa New Zealand. The Resource Management Act 1991, for example, legislates for many decisions that relate to air, soil, land use, fresh water, and coastal areas.

But everyone has an effect on the environment through their individual activities and choices. Making informed decisions about those actions depends on being equipped with relevant data and accurate knowledge.

Environmental stewardship – the responsible use and protection of the natural environment – requires a holistic approach to decision-making at both a national and individual level. A well-functioning reporting system should bring data and knowledge together so decisions:

- can be made on the basis of authoritative data and knowledge, using common measures and language
- are as effective as possible and consider the whole environment (ideally bringing co-benefits and avoiding unintended consequences on another part of the environment)
- are made in a way that allows people to comprehend their longer-term and cumulative consequences
- reflect the values that are important to us (and relevant information is conveyed in a way that everyone finds useful and easy to understand)
- are able to be made around local action and decision-making
- support Māori, in particular allowing a voice for the concerns of kaitiaki and nature.

HAVING ENOUGH INFORMATION TO ACT

Good progress has been made on understanding specific aspects of our environment. Nevertheless there are still a number of gaps in the coverage, consistency, accuracy, and representation of data that limit our ability to understand and report in some areas. These are well documented in previous domain reports (see *Our marine environment 2016*, *Our fresh water 2017*, *Our atmosphere and climate 2017*, *Our land 2018*, and *Our air 2018*).

The gaps in our knowledge that prevent us from making informed decisions are highlighted at the end of each issue in this report. Taken together, these gaps describe an opportunity to create knowledge that relates specifically to a place – the state of the environment in a place, the activities we do in a place, and what people who live in a place value and want to achieve.

Gaps appear in a number of the issues, including:

- **missing data** that prevents us from knowing what is happening where and when includes:
  - a national dataset to describe land use so we can link local activities to local changes
  - a timely description of land cover (beyond the 2012 version of the Land Cover Database) to quantify the rate of change and loss (eg habitats or high-class soils)
  - quantitative data for the number of species, including those under threat (eg marine species)
- **limited knowledge** about the effects of human activities that relate to decision-making, such as:
  - data to determine exactly where, when, and what activities or practices have contributed to change (eg stocking density on degraded water quality)
  - data related to the effectiveness of interventions (eg community restoration schemes)
- **incomplete understanding** of the impacts on our well-being and what we value, such as:
  - a paucity of indicators that relate to mātauranga Māori and tikanga Māori
  - a poor understanding of the effects of change on our cultural, economic, and social well-being, that make it difficult to prioritise choices and target resources.

Collectively these gaps challenge our ability to address the issues raised here and in previous environmental reports (PCE, 2018).

The knowledge system and environmental reporting

Those that collect environmental information do so for many different reasons – not always for environmental reporting. There is no overarching requirement to collect information at the national level (PCE, 2018). The Ministry for the Environment and Stats NZ therefore have to reuse and re-analyse data from a variety of sources and incorporate it into the reporting framework.

A further challenge is that the knowledge system iteratively and organically evolves as more information and understanding are developed, whereas the reporting system has prescriptive and reproducible requirements for robust indicators. Diverse data collection practices that are agency or context specific (eg the different types of data collected around water quality), can result in a lack of representative sites, data being omitted to meet consistency standards, and significant holes in what can be reported on.

The data and knowledge available (although not always used) for environmental reporting include:

- scientific data based on close observation of the environment, which is usually shared through peer-reviewed publications
- computer models that summarise observations, explain relationships, and make predictions about what could happen if environmental conditions changed
- monitoring data collected by local government, eg Land, Air, Water Aotearoa and Environmental Monitoring and Reporting
- cultural monitoring systems that use qualitative and quantitative observations over an extended time
- data collected through citizen science projects like the **New Zealand garden bird survey** (Manaaki Whenua – Landcare Research, 2017) and the **beach litter project** led by the charity Sustainable Coastlines.

Many organisations are involved in building knowledge about the environment. These include universities, Crown research institutes, local government, iwi, Māori trusts, government agencies (like the Department of Conservation, Ministry for Primary Industries), National Science Challenges, centres of research excellence, businesses, and community groups.

Strengthening our knowledge and reporting systems

Much could be done to improve our understanding of how the environment works. With limited resources, however, sharp focus is required to act where the impact is likely to be greatest. This includes aligning, coordinating, and leveraging efforts across knowledge and reporting systems as well as acknowledging the contribution te ao Māori has within environmental reporting in Aotearoa New Zealand.

Table 3: Improving our systems

Making better use of the knowledge system

Aim	*Activity*
Work to understand the environment as a whole	▸ Find ways to use data from localised observations to represent the whole. ▸ Improve the connectivity and interoperability between models. ▸ Make greater use of mātauranga Māori understanding of ecosystems and their components. ▸ Initiate research to fill gaps and reduce uncertainty in areas of particular concern to the public where little is known, like waste, mining, or emerging pollutants.
Look backwards and forwards to anticipate change	▸ Secure and protect time-series datasets to understand change, lag times, and legacies. ▸ Make use of the long association Māori have with the environment through stories, waiata, moteatea, and haka. ▸ Use 'what if' scenarios and models to project and anticipate future change.
Make it easier to understand and use valuable science and data	▸ Invest in building capability to translate complex science so it can be easily understood and used by government, environmental reporting, and the public. ▸ Make succession plans for knowledge holders (including elders and other traditional knowledge holders) to pass on what they know.

Building a better environmental reporting system

Set direction and agree on some priorities	▸ Bring together agencies who undertake environmental reporting to establish a common view of what is required in an effective data system. ▸ Set some priorities on what should be measured, when, and where. ▸ Establish and agree on core indicators (measures that help explain how the environment works).
Design the system and underpin frameworks and infrastructure	▸ Design an environmental reporting architecture that uses agreed conceptual frameworks to link data that is collected and managed to meet agency or context-specific needs. ▸ Specify authoritative populations and units of measurement as well as standard methodologies to allow data to be shared, integrated, and interrogated easily through the system. ▸ Agree some simple but essential principles around open data, good metadata, and appropriate data stewardship.
Fill critical gaps and assure regular maintenance and updating of these assets	▸ Establish the data gaps that stand out (ie those required as core indicators or 'baseline data' fundamental to understanding patterns and trends in environmental quality, (PCE, 2018). ▸ Ensure adequate long-term funding for their maintenance and regular updating.

The Ministry for the Environment and Stats NZ can and should play a critical role in driving improvements in the country's data collection and management systems, both through responsibilities under the Environmental Reporting Act 2015, and broader stewardship roles within the public sector (PCE, 2018). But as outlined above, it will require a whole team to resolve these systemic challenges.

Addressing these next steps will be fundamental to ensuring the next domain reports in the series, such as *Our marine environment 2019* and *Our fresh water 2020*, as well as future synthesis reports, provide valuable commentary about the effects we are having on the environment and how we may choose to respond.

Glossary, Domain reports, Environmental indicators, and Acknowledgements

Photo credit: photonewzealand

Glossary

A glossary of terms used in the report, including te reo terms, is available on the environmental reporting website.

Te ao Māori content is based on the glossary in Scheele et al (2016), *Reporting environmental impacts on Te ao Māori: A strategic scoping document*, prepared by Manaaki Whenua – Landcare Research for the Ministry for the Environment (with permission of Garth Harmsworth, one of the authors). Supplemented with definitions from the *Te Aka online Māori dictionary*.

Domain reports

Our previous domain reports include:

- Our marine environment 2016
- Our fresh water 2017
- Our atmosphere and climate 2017
- Our land 2018
- Our air 2018

Environmental indicators

NEW AND UPDATED INDICATORS FOR 2019

Available from www.stats.govt.nz/topics/environment

- Coastal and estuarine water quality
- Conservation status of indigenous freshwater species
- Conservation status of indigenous land species
- Conservation status of indigenous marine species
- Groundwater quality
- Heavy metal load in coastal and estuarine sediment
- Highly erodible land
- Irrigated land
- Lake water quality
- Livestock numbers
- New Zealand's greenhouse gas emissions
- Nitrate leaching from livestock
- Nitrogen and phosphorus in fertilisers
- River water quality: clarity and turbidity
- River water quality: *Escherichia coli*
- River water quality: macroinvertebrate community index
- River water quality: nitrogen
- River water quality: phosphorus

OTHER INDICATORS REFERRED TO IN THIS REPORT

Available from www.stats.govt.nz/topics/environment and archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home.aspx

- Active sand dune extent
- Agricultural and horticultural land use
- Air pollutant emissions
- Annual glacier ice volumes
- Artificial night sky brightness
- Black carbon concentrations
- Bycatch of fish and invertebrates
- Bycatch of protected species: Hector's and Māui dolphins
- Bycatch of protected species: seabirds
- Bycatch of protected species: sea lion and fur seal
- Carbon monoxide concentrations
- Coastal sea-level rise
- Consented freshwater takes
- Cultural health index for freshwater bodies
- Estimated long-term soil erosion
- Extreme wind
- Freshwater pests
- Frost and warm days
- Global greenhouse gas emissions
- Ground-level ozone concentrations
- Groundwater physical stocks
- Health impacts of PM_{10}
- Lake submerged plant index
- Land cover
- Land pests
- Marine non-indigenous species
- National temperature time series
- Nitrogen dioxide concentrations
- Ocean acidification
- Oceanic sea-surface temperature
- $PM_{2.5}$ concentrations
- PM_{10} concentrations
- Predicted pre-human vegetation
- Rainfall intensity
- Rare ecosystems
- Selected barriers to freshwater fish in Hawke's Bay
- Soil moisture and drought
- State of fish stocks
- Sulphur dioxide concentrations
- Sunshine hours
- Urban stream water quality
- Wetland extent

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