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Tatauranga Aotearoa

>> New Zealand's Environmental Reporting Series

Our fresh water 2017

DATA TO 2016

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Message to our readers

He taura whiri kotahi mai anō te kopunga tai no i te pu au
From the source to the mouth of the sea all things are joined together as one

Our freshwater environments support our way of life – water sustains our agriculture, industries, tourism, and the health and well-being of people and communities. For Māori, fresh water is a taonga and fundamental to the cultural identity of iwi.

Ki uta ki tai (from the mountains to the sea) recognises the movement of water through the landscape and the numerous interactions it may have on its journey. Fully appreciating this helps us understand the true impact of what we do in the environment. If water quality is degraded at one point, it will be felt downstream. Similarly if it is enhanced, the value will resonate in other places.

New Zealand is fortunate to have plenty of fresh water, but like the rest of the world, it is becoming increasingly clear our natural resources are limited if we continue to use them in the same way we have done. Good science, data, and information have the potential to transform the impact we have – especially if we are committed to increasing the value we get from our primary industry-based economy and supporting our growing population.

Environmental reporting is about unleashing the power of data to benefit the environment and people. Our environmental reporting series provides a national picture of our environment while acknowledging the significance of regional and local variation. This helps us see where the greatest pressures are and where we are performing well so we can learn from each other and lift New Zealand's environmental performance as a whole.

Our fresh water 2017 is the first dedicated report on fresh water in New Zealand's Environmental Reporting Series and will be a baseline for tracking change over time. A key takeaway from this report is the need to get better at collecting and reporting consistent data on fresh water. We present a story with the information we have, but there are things we inherently know are an issue, but we lack the quantitative evidence to show exactly how these affect the freshwater environment.

Based on the data we do have, we know many of our native freshwater species are under pressure, water quality varies across the country, and the way we use our land impacts our fresh water.

It will take time and collaboration with others to get the reliable, well-structured, and relevant statistics we need, and we are continually looking at ways to improve data for future reports. But we can't wait for perfect information to make decisions.

We hope this report helps New Zealanders better understand our fresh water, supports informed discussions, and ultimately leads to good decisions about freshwater priorities and management.

Vicky Robertson
Secretary for the Environment

Liz MacPherson
Government Statistician

About this report

Our fresh water 2017 presents information about the state of our fresh water, the pressures on this state, and what that means for us and the environment. This report will support policy makers, businesses, iwi, community groups, and individuals to make informed decisions about freshwater issues and priorities.

Our fresh water 2017 focusses on three themes:

- water quality
- water quantity and flows
- ecosystems, habitats, and species.

Purpose of *Our fresh water 2017*

The Environmental Reporting Act 2015 (the Act) requires the Ministry for the Environment and Stats NZ to report on the state of our environment, the pressures that affect the state, and how this state influences aspects of the environment and our well-being. These aspects include ecological integrity, public health, economy, te ao Māori (Māori world view), and culture and recreation. We do not report on response under the Act due to the requirement to be independent of the government of the day. Therefore, *Our fresh water 2017* does not include any recommendations for management or policy responses for freshwater issues.

The Environmental Reporting Regulations 2016 identify the topics we will report on for each of the five 'domains' (fresh water, atmosphere and climate, land, air, and marine).

The Act requires data that are of sufficient quality for national-level reporting. We must be satisfied that any statistics used follow best practice principles and protocols and that they accurately represent the topic they aim to measure. We follow a similar quality assurance process for environmental statistics as for all official statistics, while recognising the nuances of environmental data. It will take time to refine the system and get all the reliable, accurate, and relevant statistics we need. Limitations in the quality of available data mean there are gaps in our information. In the absence of suitable data, we have supported our findings with information from other reports and scientific literature, which we reference.

Our fresh water 2017 is the fourth environmental report produced in the spirit of the Act, and the second to be produced under the Act (*Our marine environment 2016* was the first). While we report on each domain individually, the information will inform an interconnected view of the environment in *Environment Aotearoa 2019* (the synthesis report that we produce every three years). We are still learning, and our environmental reports will continue to evolve over time.

Changes since *Environment Aotearoa 2015*

This report focusses on adding breadth, rather than depth, of available information about our fresh water since we reported on fresh water in *Environment Aotearoa 2015*. There are still many gaps in our national reporting on our fresh water, so we chose to focus on filling some of those gaps, rather than adding an additional year or two of data to our existing indicators – environmental change is generally not seen in one or two years.

To support our findings and help improve understanding where there are gaps in our data, we added references to peer-reviewed literature.

Some of the new information includes:

- modelled river water quality data, to create a more complete national picture
- trends in river water quality with sites grouped by land-cover class
- a more in-depth analysis of urban water quality
- pesticide concentrations in groundwater
- ecological condition of lakes
- trends of freshwater species and some of the physical changes that prevent migrations and affect habitats.

For the first time in this environmental reporting series, you will find a national picture of the cultural health of our rivers and lakes, where tangata whenua assessed and reported the cultural health index of freshwater sites.

Our fresh water reports will continue to evolve over the next few reporting cycles as we build the appropriate indicators needed to report on this domain.

Other products

Download our infographic for an overview of our findings

New Zealand's fresh water at a glance is a visual representation of our key findings. Use this resource if you want basic information about our fresh water.

Go to our webpages and data service for more detailed scientific information

Environmental indicators Te taiao Aotearoa: Fresh water – has graphs, maps, tables, and more detailed scientific descriptions of our key findings.

Access the data service to conduct your own analysis of the data. The data service and the publication section of the Ministry for the Environment's website provide reports that explain the methodologies we used in our analysis.

Give us your feedback

We welcome your feedback on this and future reports in New Zealand's Environmental Reporting Series. You can email your feedback to environmental.reporting@mfe.govt.nz.

Data collection, analyses, and limitations

For the analyses in this report, we collected information from many sources. This report would not be possible without the ongoing support and contribution of a large number of people and organisations.

The water quality information largely comes from regional and unitary councils, NIWA, and GNS monitoring networks. For the regional council networks in particular, many monitored sites tend to be in areas of known, or suspected, issues so that regional councils can make management decisions; however, this potentially leads to a biased view of national water quality. To overcome this issue, we used modelled water quality data to estimate water quality in areas where we do not have data. We also use models to estimate nitrate leaching and periphyton growth, to help us build the story around water quality pressures and impacts. We currently have limited data on the pressures and impacts related to water quality, particularly monitored data at a national scale.

The chapter on water quantity focuses on information about consents to take fresh water, which was supplied by all 16 regional and unitary councils. We rely on consent information, because actual data on water use is not yet available nationally. However, the water metering regulations introduced in 2010, and which were fully in force in November 2016, will allow us to report on more actual water use data over time. We currently have very little data in this report on the state of freshwater flows compared with natural levels, and the impact any altered flows are having on freshwater ecosystems and species.

In the ecosystems, habitats, and species chapter, information comes from a wide range of sources including regional councils, Crown research institutes, Cawthron Institute, and Department of Conservation. There is little national data, collected over a period of time, on ecosystems, habitats, and species. Exceptions include the conservation status of plants, fish, and invertebrates from the Department of Conservation, and the New Zealand Freshwater Fish Database administered by NIWA. As with the other two chapters, data on the pressures and impacts on our ecosystems, habitats, and species are limited.

Environmental issues, by their nature, are specific to catchments or regions. New Zealand has a diverse range of river systems, lake types, wetlands, and groundwater systems. The state of fresh water depends on, for example, the physical characteristics of the water body and catchment, historical impacts, and how the land was used in the catchment (including the extent or intensity of this use). Although some of New Zealand's freshwater bodies and their surrounding catchments were studied extensively, we know little about others. We aim to continue to build on a national picture of the pressures on our fresh water, the state of fresh water, and the impact the state is having on our ecosystems and our well-being.

Executive summary

Introduction

Fresh water supports almost every aspect of life. We use fresh water to drink, enjoy it for recreation, and use it to produce goods and services. Māori tribal identity is linked to fresh water, for whom each water body has its own mauri (life force).

Ki uta ki tai (from the mountains to the sea) captures the movement of water through the landscape and the many interactions it may have on its journey. Ki uta ki tai acknowledges the connections between the atmosphere, surface water, groundwater, land use, water quality, water quantity, and the coast (see *Our marine environment 2016*). It also recognises the connections between people and communities, people and the land, and people and water.

As a society, we have seen a clearing of native vegetation, the draining of wetlands, farming, forestry, and urbanisation, which have all placed increasing pressure on our water bodies and their ecosystems. As our population and agriculture-based economy grow, our need for fresh water is likely to increase in the future.

The way we use the land differs across New Zealand so the impacts on our fresh water, whether positive or negative, are often specific to a catchment or region. This makes it difficult to paint a national picture. It can also take decades for water (and any contaminants it contains) to cycle from the earth's surface through the ground to aquifers, and back to surface water systems. This means some effects we see today are legacies of past activities, and the impact of our activities today, both positive and negative, may not be seen in our waters for a long time.

Summary of top findings

Here is a selection of findings grouped by the three key themes of this report – Water quality; Water quantity and flows; and Ecosystems, habitats, and species.

In some instances, we talk about areas we see as important, although we did not have access to appropriate data. These gaps are where more work is needed, so that in future we could provide a more complete understanding of the freshwater environment.

We used four principles to select our top findings:

- spatial scale of impact to natural systems
- magnitude of change
- scale of impact on culture, recreation, health, and the economy
- irreversibility or long-lasting effects of change.

The symbols show the amount of data we had to support a top finding:

A blue circle indicates we had a lot of data.

A circle, the bottom half blue and the upper half white, indicates we had limited data.

Water quality

Water quality relates to the condition of water and includes factors like how well it can support plants and animals, and whether it is fit for us to use.

This summary focuses on two nutrients, nitrogen and phosphorus, which can tell us something about the risks of algal blooms; and *E.coli* (an indication of faecal contamination), which can tell us whether water bodies are safe for recreation.

Nutrients occur naturally and are necessary for plants to grow. However, high nutrient concentrations can result in too much growth of algae in water (this algae is generally periphyton in rivers and phytoplankton in lakes). Excessive algae in water can decrease oxygen levels, prevent light from penetrating water, and change the composition of freshwater plant and animal species that live there. High concentrations of nitrogen can be toxic to species and make water unsafe to drink.

The activities we do on the land, mainly urban and agricultural activities, can cause excess nutrients and *E.coli* to wash into our water bodies through run-off or filter through the land into groundwater. Phosphorus often enters surface water attached to sediment.

In urban environments, contaminants enter water bodies mainly through stormwater and wastewater networks, illegal connections to the networks, and leaky pipes, pumps, and connections.

In agricultural areas, nutrients and pathogens (organisms that can cause disease) come from animal waste and urine, and fertilisers. Since the late 1970s, agricultural practices have intensified in some areas of New Zealand, indicated by higher stocking rates and yields, increased use of fertiliser, pesticides, and food stocks, and moves to more intensive forms of agriculture, such as dairying. Agricultural land use is the world’s greatest contributor to diffuse pollution (run-off from the land or filtration through the soil). However, since diffuse discharges are hard to measure, it is difficult to determine the relationship between specific land use and water quality.

In our findings for nitrogen, we report on nitrate-nitrogen, which is highly soluble, leaches through soils easily, and is available for plant and algal growth. For phosphorus, we report on dissolved reactive phosphorus, which can be released from fertilisers or dissolved from soil or sediment and becomes available for plant and algal growth.

Nitrate-nitrogen concentrations were worsening at more monitored river sites than improving. Dissolved reactive phosphorus concentrations were improving at more monitored river sites than worsening.

In monitored rivers, nitrate-nitrogen was worsening (55 percent) at more sites than improving (28 percent), and dissolved reactive phosphorus was improving (42 percent) at more sites than worsening (25 percent) between 1994 and 2013. However, the trends for nitrate-nitrogen and dissolved reactive phosphorus vary across the country. For some monitored sites, nitrate-nitrogen concentrations were improving and dissolved reactive phosphorus concentrations were worsening. For some sites we could not determine a trend direction.

Both concentrations and ratios of nitrogen and phosphorus in a water body are important, as there needs to be a supply of both nutrients for excessive algal growth to occur. We know that concentrations of nitrogen and phosphorus are much higher in urban and pastoral areas than in native areas, so the likelihood of algal growth is higher in these environments.

We lack information on how the impact of worsening nitrate-nitrogen concentrations is affecting our fresh water, but it is estimated the vast majority of rivers do not have nitrate-nitrogen levels high enough to be toxic to most freshwater species.

We do not know the direct cause of improving dissolved reactive phosphorus concentrations in rivers. In rural areas, these may be due to improved farming practices and the targeting of areas highly susceptible to phosphorus loss. In urban areas, it may be due to improvements in treating wastewater.

Supporting findings

- Nitrate-nitrogen concentration was 18 times higher in the urban land-cover class, and 10 times higher in the pastoral class compared with the native class for the period 2009–13. We classify sites by land cover: pastoral, urban, exotic forest, and native.
- Of 175 monitored river sites in the pastoral class, nitrate-nitrogen trends were worsening at 61 percent and improving at 22 percent of sites for the period 1994–2013. Similarly in the exotic forest and native classes more sites were worsening than improving, but there were few monitored sites in these classes.
- Nitrogen leaching from agricultural soils was estimated to have increased 29 percent from 1990 to 2012.
- More than 99 percent of total river length was estimated not to have nitrate-nitrogen concentrations high enough to affect the growth of multiple sensitive freshwater species for the period 2009–13.
- Dissolved reactive phosphorus concentration was 3 times higher in the urban class and 2.5 times higher in the pastoral class compared with the native class (2009–13).

- Of 145 monitored river sites in the pastoral class, trends in dissolved reactive phosphorus were improving at 46 percent and worsening at 21 percent of sites for the period 1994–2013. Similarly, in the urban and native classes more sites were improving than worsening, but there were few monitored sites in these classes.
- Of total river segment length of large rivers, 83 percent was not expected to have regular or extended algal blooms. This is because it was modelled to either meet the periphyton national bottom line in the National Objectives Framework (60 percent) or had fine sediment (23 percent) that does not usually support algal growth (2009–13).

E.coli concentrations affect our ability to swim in some rivers.

Animal or human faeces in fresh water can increase the risk of illness for swimmers in the area. When *Escherichia coli (E.coli)*, a group of bacteria usually found in the intestines of mammals, is detected in rivers or lakes, this indicates that faecal matter is present in fresh water. Concentrations of *E.coli* in a water body are used to measure risk to public health.

Of monitored sites, most had indeterminate trends for *E.coli* for the period 2004–13, meaning we have insufficient data to determine a trend at those sites.

We do not have *E.coli* data for lakes. We also do not assess trends in *E.coli* for groundwater sites because of the large number of values below detection limits.

Supporting findings

- *E.coli* concentration was 22 times higher in the urban land-cover class and 9.5 times higher in the pastoral class compared with the native class (2009–13). We classify sites by land cover: pastoral, urban, exotic forest, and native.
- Of 268 monitored river sites in the pastoral land-cover class, *E.coli* trends were indeterminate at 65 percent, improving at 21 percent, and worsening at 14 percent of sites for the period 2004–13. Sites in the urban, exotic forest, and native classes had similar results, but there were few monitored sites in these classes.

Developing a national indicator for swimmability

We are assessing whether modelled *E.coli* data can be used as a suitable indicator to track over time the risks of infection associated with swimming in water bodies. Although this is still in development, we recognise this topic is an area of great public interest, so we are providing some initial results of this work.

The Clean Water Package, launched by the Government in February 2017, proposed a new approach to measuring the swimmability of water bodies. The package proposes a definition of swimmable based on *E.coli* concentrations for rivers and cyanobacteria for lakes. For a river to be swimmable under the new guidelines, the risk of getting sick from infection averaged across time is between 1 and 3.5 percent. See Public health considerations for swimming in rivers for more information.

Water quantity and flows

New Zealand has plenty of fresh water, but because the flow of our rivers varies naturally over time and different water bodies, it is not always there where or when we need it. When the flows of rivers are reduced, algae and fine sediment can build up, reducing the amenity and recreational value of water resulting in a poor habitat for freshwater species. This can also affect the mauri of water bodies in their ability to support abundance of life.

Our activities influence the quantity and flow of water, for example, when we take water or physically alter water bodies. We take water for farming (irrigation and stock drinking water), power generation, drinking water, and industrial uses. We physically alter water bodies when we create diversions, build dams, and drill bores. Larger effects on water flow happen when we take higher volumes of water from multiple locations, particularly in dry periods. Surface water and groundwater are often connected, so taking water from one affects both.

Climate change is projected to increase the pressures on water flows and the availability of water – in New Zealand, annual rainfall is expected to decrease in the east and north.

This summary focuses on how much water councils allow to be taken for various uses (which are specified in consents to take water). This shows us how much water may be used, although it does not necessarily match what is actually used.

More than half the water allocated (or consented) by councils is for irrigation, but we do not know how much of this is actually used.

Regional councils allocate water by giving consents for industrial, energy, agricultural, and domestic use. It is called consumptive use when the water is not immediately returned to water bodies, and non-consumptive use when water is returned to downstream water bodies after use (such as in most hydroelectricity schemes).

In 2013–14, irrigation was the largest consented user of consumptive water by volume, followed by household use and industry.

Data quality and the completeness of records on actual takes (as opposed to consented) is mixed across the regions, so it was not possible to report on how much water is actually taken at a national scale. In some cases, actual use is less than consented use for a number of reasons, for example, when water flows drop below a certain level restrictions on use can be applied.

From November 2016, legislation requires most water users to provide continuous records of water takes each year. In future reports we aim to provide a more complete national picture of how much water is actually used.

Supporting findings

- In 2013–14, excluding hydroelectricity use, New Zealand's total consented water volume was allocated for irrigation (51 percent), followed by household consumption (14 percent), and industry (13 percent).
- Canterbury accounted for 64 percent of the total consented volume of water for irrigation.

Ecosystems, habitats, and species

The health and mauri of some of our freshwater ecosystems face multiple pressures, which may compound one another. These pressures negatively affect biodiversity – many of our freshwater species are threatened with, or at risk of, extinction.

Most of the pressures come from the way we are changing freshwater environments. Land-based activities, infrastructure development, and the deliberate modification of water bodies, such as draining wetlands or channelling rivers, contribute to the degradation and loss of habitats. These activities can degrade cultural health, reduce water quality, increase sediment yields, alter water flows, introduce pests, and modify or degrade habitats or the connections to habitats.

This summary focuses on the conservation status of our freshwater biodiversity, the cultural health of rivers and lakes, and some of the pressures affecting freshwater ecosystems.

Of the native species we report on, around three-quarters of fish, one-third of invertebrates, and one-third of plants are threatened with, or at risk of, extinction.

New Zealand is vulnerable to biodiversity loss as many of our native species are endemic (found nowhere else in the world). Freshwater biodiversity supports opportunities for recreational activities such as fishing, and customary activities such as mahinga kai.

Our freshwater environment supports approximately 53 known resident native freshwater fish species, 630 known native freshwater invertebrate types, and 537 known native freshwater-dependant plant and algae types. We report on the conservation status of our freshwater species where we have sufficient information on taxonomy, distribution, and abundance.

Freshwater fish

More than half our known fish species migrate between the sea and fresh water to complete their life cycles, meaning they can be severely affected by barriers to migration in rivers and streams. Other pressures negatively affecting native fish include pests that outcompete and prey on our fish, and habitat loss and deterioration.

We report on the conservation status of 39 of our native freshwater fish. However, long-term, national level information on native fish is currently limited, but we have enough data to report on the trends of eight fish species.

Supporting findings

- Of the 39 native freshwater fish species we report on, 72 percent were either threatened with (12 species), or at risk of (16 species), extinction in 2013.
- Native freshwater fish threatened with, or at risk of, extinction include taonga species such as inanga, shortjaw kōkopu, giant kōkopu, kōaro (all are whitebait species), kanakana/piharau (lamprey), and one species of tuna (longfin eel).
- Declines in conservation status were observed for four species between assessment periods (2009 and 2013) – Central Otago roundhead galaxias, Canterbury galaxias, black mudfish, and kanakana/piharau (lamprey).
- Of eight native fish species, two were estimated to have increased in abundance (shortfin eel and upland bully), and four decreased in abundance (longfin eel, kōaro, Canterbury galaxias, and common bully) between 1977 and 2015.

Freshwater invertebrates

Freshwater invertebrates include many organisms such as crustaceans, molluscs, worms, and freshwater insects. Invertebrates perform important ecosystem services – they graze on periphyton (algae) and break down leaves and wood. They also provide food for native fish and birds and some provide food for people. Our native invertebrates are negatively affected by pests that prey on them for food, and other pressures that result in habitat deterioration.

Supporting findings

- Of the 435 native freshwater invertebrate types we report on, 34 percent were either threatened with (66 types), or at risk of (82 types), extinction in 2013.
- Three of the freshwater invertebrate types experienced a decline in conservation status, and none had an improvement between assessment periods (2005 and 2013).
- The South Island kōura (freshwater crayfish) and all three species of kākahi/kāeo (freshwater mussel) are included in the at-risk or threatened categories.

Freshwater plants

The habitats that support native freshwater plants only cover a small proportion of New Zealand's land area, but are rich in abundance of diverse freshwater plant species.

Plants dependent on fresh water include vascular plants, mosses, hornworts and liverworts, and green algae that live in and around fresh water. These plants are negatively affected by invasive weeds, drainage, and when vegetation is grazed, trampled on, and cleared.

Supporting finding

- Of the 537 plant types we report on, 31 percent were either threatened with (71 types), or at risk of (97 types), extinction in 2013.

Some water bodies have been physically changed, but we do not know the extent or the impact this is having.

Our rivers have changed because we placed structures in them (such as weirs and culverts), and redefined river channels to prevent water from damaging infrastructure and houses.

Physically changing our rivers makes floodplains available for urban and agricultural development and improves flood control and security. However, these changes have altered the natural character of rivers, which can cause river banks to erode and more sediment to be deposited downstream. The structures we place in rivers can also hinder fish migration (some fish species move from fresh water to the sea as part of their lifecycle).

Physical changes to rivers reduce how floodplains (and associated lakes and wetlands) are connected to rivers, which affects flood pulses. A flood pulse is the periodic flooding of a river, and is considered to be good for a river's ecosystem. It aids in dispersing seeds, establishing plants, cycling nutrients, scouring, depositing sediments, and maintaining the richness of species.

Changes to physical habitats have significant effects, but we currently have limited data on the extent or impacts these changes are having on ecosystems.

Fine sediment deposited on riverbeds is estimated to have increased, but we don't know the national extent or impact this is having.

Deposited sediment occurs naturally in the beds of rivers and streams, but too much fine sediment (particles less than two millimetres in size) can severely degrade streambed habitat, carry excess nutrients into surface water, and affect water clarity and recreational activities. Fine sediment levels greater than 20 percent cover can have negative effects on streambed life.

Our marine environment 2016 reported that some sediment can wash out to estuaries where it smothers important nursery habitats of marine animals.

Our activities can affect the natural cycle of sediments by accelerating the delivery of sediment to streams. Models suggest a significant increase in sediment cover has occurred since human occupation. Over the past 800 years, the clearing of native forests, along with farming practices and earthworks, resulted in sediment in rivers being deposited above natural levels. There are not many sites across the country where fine sediment has been observed over time using consistent methods. This makes it difficult for us to report on the status of deposited fine sediment cover at a national level, so in this report we rely on modelled estimates.

Supporting findings

- Modelled results suggested fine sediment would cover an average of 8 percent of riverbeds in the absence of humans.
- The same model suggested an average fine sediment cover of 29 percent of riverbeds in 2011.

Wetland extent has greatly reduced and losses continue.

Wetlands perform many functions. They filter nutrients and sediment from water, absorb floodwaters, and provide habitat for plants, fish, and other animals.

We have no national information on the health of our wetlands, but we do have information on their extent. The vast draining of our wetlands due to the way we use our land has left only a small portion of original wetland extent. This led to a loss of biodiversity and natural function in some areas.

We are less clear on recent changes in national wetland extent, but we know that losses are still occurring.

Supporting findings

- In 2008, the extent of wetlands was only 10 percent of their original extent (before humans settled New Zealand).
- As an example of recent wetland loss, Southland's wetlands not on conservation land were reduced in area by 1,235 hectares, or 10 percent, between 2007 and 2014–15.
- The West Coast has the greatest extent of wetlands (84,000 hectares), followed by Southland (47,000 hectares), and Waikato (28,000 hectares).

Cultural health is rated moderate at most tested freshwater sites.

For Māori, fresh water is a taonga and essential to life and identity. Freshwater ecosystems provide valuable resources, and support Māori values and practices including healing and harvesting kai (food).

Cultural health indicators support kaitiakitanga (the cultural practice of guardianship) and how Māori use the environment. These indicators provide a holistic understanding of the cultural aspects of our freshwater environment to the benefit of all New Zealanders.

The cultural health index measures the factors that are of cultural importance to Māori. It provides an overall indication of the cultural health of a site on a waterway. A cultural health index score cannot be produced without local indigenous knowledge. Three components make up the overall cultural health index score: site status, mahinga kai (customary food gathering) status, and cultural stream health status.

Tangata whenua and hapū/rūnanga groups across the country determined cultural health index scores at 41 sites between 2005 and 2016. As more tangata whenua monitor water bodies for cultural health, we will incorporate these into future reports.

Supporting findings

- Of the 41 sites assessed, 11 had a good or very good overall cultural health index rating. Twenty-one sites had a moderate rating, and nine had a poor or very poor rating.
- Of the 39 sites assessed, 28 had a poor or very poor mahinga kai status. Seven sites had a moderate status, and four sites had a good or very good status.

Data gaps

We identified many gaps in available data and information that if (and when) they are filled would improve future environmental reports. We want to build a fuller and more representative picture of the pressures on our freshwater environment and the effects of these pressures on the environment and our well-being.

Data and information we would like to get more information about include:

- the extent of our rivers affected by excessive algal growth
- how much water is actually being used and how it is affecting flows, water availability, and habitats
- the extent of physical change to water bodies
- the amount of sediment deposition
- the extent and impact of barriers to fish migration
- a fuller understanding of the cultural health of our water bodies
- the national abundance and distribution of many of our native species
- the health of our wetlands and recent changes in extent.

Some of this information is being gathered now, such as recording freshwater takes. The next steps for this programme are to work with others to prioritise and determine how we start to fill these, and other, important gaps that may arise.

Introduction to our fresh water

Fresh water is present in many physical forms. These include fresh water in rivers, lakes, streams, wetlands, aquifers, snow, and glaciers, and the animals, vegetation, processes, and structures associated with them. For Māori, fresh water is a taonga essential to life and identity.

This chapter covers:

- Our freshwater environments
- Why fresh water is important
- Māori ways of knowing and monitoring the freshwater environment
- Ki uta ki tai – from the mountains to the sea
- The way we use our land creates legacy effects.

Our freshwater environments

New Zealand is a relatively narrow country (450 kilometres at its widest point) dominated by mountains, in which many of our rivers and streams originate. In total, New Zealand has over 425,000 kilometres of rivers and streams, 249,776 hectares of wetlands, and more than 50,000 lakes, about 4,000 of which are larger than one hectare in area. New Zealand's fresh water is also stored in reservoirs (artificial lakes, or natural lakes with raised water levels) ranging from small-farm dams to the 7,500-hectare Lake Benmore in Canterbury. A considerable amount of our fresh water is groundwater in aquifers. We do not cover glaciers and snow in *Our fresh water 2017* – we will do that in *Our atmosphere and climate 2017*, to be published in October 2017.

In this report, we discuss the freshwater environments of the North and South islands. We note that Stewart Island, the Chatham Islands, other outlying islands (eg Raoul and Campbell), the Ross Dependency, and Tokelau, are all part of, or associated with, New Zealand. But due to lack of data, or access to data from these outlying areas, we do not cover them in this report.

Why fresh water is important

Fresh water underpins almost every aspect of life. Our freshwater environments provide a range of ecosystem services (the benefits we get from the natural environment) that support agriculture, industry, tourism, and the health and well-being of people and communities. The quality and quantity of fresh water are linked to the ecosystem services our fresh water can provide. For example, freshwater ecosystems can provide food, help control flooding, and naturally filter contaminants from water (eg Schallenberg et al, 2013).

We rely on having clean and plentiful water for ceremonial, recreational, and cultural activities, and for food gathering and drinking. Reduced water quality increases risks to public health and affects our ability to use freshwater environments for recreational purposes (McBride et al, 2002).

We value our fresh water for the aesthetics, spiritual associations, and sense of place we experience (Land Environment & People, 2010). These values are often not well defined and not easily measurable; some are also very localised. How a particular water body is valued will vary by person and depends on each individual's experience (Berkett et al, 2013).

Every iwi and hapū has associations with particular freshwater bodies – streams, springs, rivers, lakes, wetlands, groundwater – that are reflected in their whakapapa (ancestral lineage), waiata (song), and whaikorero tuku iho (stories of the past) (New Zealand Government, 2014). Protecting the health and mauri (life force) of our freshwater ecosystems is also important for food, materials, customary practices, te reo Māori (Māori language), and overall well-being.

The varied freshwater ecosystems in New Zealand are rich in animal and plant biodiversity and have complex ecosystem processes. Modified water bodies and reduced water quality and quantity can have negative consequences for ecosystem function and species richness (Weeks et al, 2016).

Our economy depends on having a plentiful supply of water. Many aspects of primary industries, tourism, and hydroelectricity generation rely on the availability of fresh water. Primary industries and tourism significantly contribute to our gross domestic product and form a large part of our export market (Ministry of Business, Innovation and Employment, 2013; Tourism New Zealand, 2015). Tourism's contribution to total exports was $11.8 billion (17.4 percent of exports) in 2015, just behind dairy products, which totalled $14.2 billion (21 percent of exports) (Statistics NZ, 2015b). Primary industries and tourism are also among our country's largest employers, directly employing an estimated 136,500 and 155,502 people, respectively, in 2012 (Statistics NZ, 2015b; Ministry for Primary Industries, 2014).

Māori ways of knowing and monitoring the freshwater environment

Te ao Māori (the Māori world view) acknowledges the interconnectedness of all living things, their dependence on each other, and the links between the life-supporting capacity of healthy ecosystems and people's well-being (Harmsworth & Awatere, 2013). Mātauranga Māori (Māori systems of knowledge) have developed over hundreds of years since Polynesian settlement and are intricately interwoven with te reo Māori and whakapapa (ancestral lineage).

For Māori, the deep kinship between people and the natural world creates an obligation to care for the environment and maintain it for future generations. This obligation is expressed as kaitiakitanga – the cultural practice of guardianship and environmental management grounded in mātauranga Māori (Royal, 2015).

Māori cultural heath indicators can support environmental decision-making

Māori communities are putting kaitiakitanga into practice around New Zealand to restore environmental health and reclaim their traditional knowledge (Royal, 2015). Some iwi and hapū/rūnanga (Māori tribes and sub-tribes) regularly monitor freshwater areas using cultural health indicators to show trends or changes in the health of these areas. Cultural health indicators support kaitiakitanga and the ways Māori use the environment, but they can also benefit all New Zealanders by providing a deeper understanding of the freshwater environment (see *Kaitiakitanga of the Waikouaiti catchment*).

We use information gathered by iwi and hapū to report on the cultural health index scores of some freshwater bodies. We also tell the story of how one iwi is using a traditional fishing method to monitor the abundance of kōura (freshwater crayfish) in Te Arawa Lakes.

We are committed to developing our programme to support Māori decision-making and well-being through increased reporting on freshwater cultural health indicators in future reports.

Kaitiakitanga of the Waikouaiti catchment

Kaitiakitanga is the custodianship role tangata whenua have over their freshwater environments. As kaitiaki (custodians) of the Waikouaiti river catchment in Otago, Kāti Huirapa ki Puketeraki have focused on measuring the factors that affect their ability to access mahika kai (Ngāi Tahu dialect for the term 'mahinga kai') from the river.

To assess the current state of the Waikouaiti river catchment, including important mahika kai sites, Kāti Huirapa ki Puketeraki used a combination of mātauranga Māori (Māori systems of knowledge) and other methods. Kaitiaki observations based on whakapapa and historical records describe the native biodiversity and the river's ecosystem within the Waikouaiti catchment and how these have changed over time. Other methods rated four freshwater mahika kai sites in the Waikouaiti River based on habitat, invertebrates, and periphyton (algae). Results showed the overall health of two sites had a 'moderate' status, and two had 'very poor' status in 2015 (Kāti Huirapa Rūnaka ki Puketeraki, 2016). For the Kāti Huirapa ki Puketeraki, the degradation of the river and their reduced ability to access mahika kai sites have a negative effect on the mauri (life force) of the river and the mana (prestige) of the hapū.

For more detail see *Environmental indicators Te taiao Aotearoa*: Kaitiakitanga of the Waikouaiti catchment.

Note: Kāti Huirapa ki Puketeraki is the hapū who hold tangata whenua status over the river catchment and is part of the Ngāi Tahu iwi. The hapū is one of 18 papatipa runanga that make up the Ngāi Tahu iwi. Each papatipa runanga is responsible for upholding the mana of the people and environment within their area (New Zealand Government, 1996).

Ki uta ki tai – from the mountains to the sea

Freshwater bodies cannot be viewed in isolation because they are strongly interconnected with land (rock and soils), coast, atmosphere, and living things (plants and animals, including humans). These connections mean what happens in one can have flow-on effects in another.

Māori have emphasised the need to consider the environment in its entirety through a concept referred to as ki uta ki tai (Tipa et al, 2016). Māori use this concept to describe their holistic understanding of freshwater ecosystems and how the health and well-being of the people are intrinsically linked to the natural environment.

Ki uta ki tai (from the mountains to the sea) recognises the movement of water through the landscape and the numerous interactions it may have on its journey (see figure 1). Ki uta ki tai acknowledges the connections between the atmosphere, surface water, groundwater, land use, water quality, water quantity, and the coast. It also acknowledges the connections between people and communities, people and the land, and people and water.

The ki uta ki tai journey begins with precipitation falling on land, where the water flows over the ground as surface water. A portion of surface water enters rivers and streams and flows towards the oceans. Water emerging from the ground (groundwater) and some surface water may be stored as fresh water in lakes. Some surface water will also soak into the ground where it replenishes deep and shallow aquifers and seeps back into water bodies (and the ocean). Along the way, water can be modified through human activities, such as when we take water for power generation and irrigation, discharge contaminants to water bodies, and channelize rivers. Surface water in rivers, along with the material it carries, eventually flows into estuaries and the ocean. The journey ends with the water returning to the atmosphere through evaporation and transpiration (moisture carried through plants from roots and then evaporated from leaves).

Figure 1


The movement and interactions of water through the landscape
Precipitation
Transpiration
Run-off
Evaporation
Run-off
Infiltration
Subsurface flow
Outflow
Source: Ministry for the Environment and Stats NZ

The way we use our land creates legacy effects

The way we have managed our land and fresh water has negatively affected the state of New Zealand's freshwater environment (see *A potted history of freshwater in New Zealand*). Natural factors, such as climate, geology, and topography, determine how human pressures affect the state of water bodies. This means that water in different catchments responds to pressures in different ways, so we need to consider the specific context for each water body.

It can sometimes take decades, or even longer, for water (and any contaminants it contains) to cycle from the earth's surface through the ground to aquifers, and back to surface-water systems – this delay is referred to as lag time. For example, in the Te Arawa (Rotorua) lakes, the average lag time is generally around 50 years – and is over 100 years in one catchment (Morgenstern et al, 2015). This means some effects we see today are legacies of past activities, and the impact of our activities today, both positive and negative, may not be seen in our waters for decades.

A potted history of fresh water in New Zealand

About 1250 – 1300 AD – First people arrive in Aotearoa New Zealand from East Polynesia.

1300 – 1800 – About 50 percent of the country's forests destroyed by fire (Quinn & Phillips, 2016).

1840 – Organised settlement of New Zealand by Europeans begins. Over the next half-century, more forest is cleared to make way for urban and rural land uses (Quinn & Phillips, 2016).

Mid-to late1800s – As towns and industrial activity grow, sewage and industrial waste are piped directly into rivers and streams (NIWA, nd).

Late 1800s – Large-scale irrigation in New Zealand begins (Irrigation New Zealand, nd).

1903 – Water Power Act 1903 introduced, giving the Crown the sole and unfettered right to use water in rivers, streams, and lakes for generating electricity.

1915 – Swamp Drainage Act 1915 introduced, leading to the draining of extensive areas of wetlands for pastoral use in the 1920s – around 90 percent of wetlands to date (Ministry for the Environment, 2007).

1940s – Catchment boards established under the Soil Conservation and Rivers Control Act 1941 to reduce soil erosion and prevent damage from floods.

1953 – Waters Pollution Act 1953 introduced, creating the Pollution Advisory Council to regulate end-of-pipe discharges into water.

1967 – Water and Soil Conservation Act 1967 sets in place a single consenting system to regulate water use, including discharges.

1975 – Waitangi Tribunal established. The Tribunal and Treaty processes become highly influential in shaping policy about fresh water, particularly in better recognising Māori rights and interests in fresh water.

1981 – Wild and Scenic Rivers Bill passed into law, enabling water conservation orders to be created in the face of mounting pressure to dam rivers for hydroelectricity schemes.

1987 – For the first time, dairy farming exceeds sheep farming as New Zealand’s highest-value primary industry export (Te Ara, nd).

1991 – Resource Management Act 1991 introduced, creating an integrated consenting system for land, water, and air, guided by the principle of ‘sustainable management’. Point sources of water pollution become increasingly tightly controlled, sparking investment in upgrading wastewater treatment.

2009 – Land and Water Forum established as a cross-sector collaborative with the objective of developing a common direction for freshwater management in New Zealand and providing advice to government.

2011 – National Policy Statement on Freshwater Management introduced, with the primary objective of improving freshwater management by regional councils.

2014 – National Policy Statement (NPS) on Freshwater Management amended, and national bottom lines for water quality established through the National Objectives Framework. Regional councils have until 2025 to implement the NPS.

Water quality

Top findings

Nitrate-nitrogen concentrations were worsening (55 percent) at more monitored river sites than improving (28 percent). Dissolved reactive phosphorus concentrations were improving (42 percent) at more monitored river sites than worsening (25 percent).

E.coli concentrations affect our ability to swim in some rivers.

What is happening?

The main pressures on the quality of our fresh water result from land-based activities.

Water quality at sites where the upstream land cover is mainly urban and pastoral tends to be poorer than sites where native land cover is dominant. Urban and pastoral sites have higher nutrient (nitrate-nitrogen and dissolved reactive phosphorus) and *E.coli* concentrations, and lower visual clarity and macroinvertebrate community index scores.

Nitrate leaching from agricultural soils has increased, which may be associated with the worsening trends in nitrate-nitrogen at sites in catchments where pastoral land cover is dominant. We are seeing improving trends in dissolved reactive phosphorus at many sites where pastoral, urban, and exotic forest land cover are dominant.

Why does it matter?

When water quality declines, it influences the way people and communities use the water and the water's ability to support freshwater ecosystems and social and economic activities. High nutrient concentrations can result in excessive plant and algal growth, which can reduce oxygen levels and change the composition of plant and animal communities. Low visual clarity, toxic algal blooms, and elevated *E.coli* concentrations negatively affect aesthetic values and our ability to use fresh water for drinking or recreation. Heavy metals (such as mercury, arsenic, cadmium, lead, copper, and zinc) can be toxic to freshwater fish and invertebrates and can accumulate in food sources like fish and watercress, which may make them unsafe to eat. Many activities that support our tourism industry also rely on good water quality.

Water quality is a complex concept related to the physical, chemical, and biological characteristics of water. Water quality relates to the 'condition' of water as it affects a range of water values, including biological habitat and human use (Davies-Colley, 2013).

This chapter covers:

- Land-based activities are putting pressure on water quality
- Modelled river water quality
- Monitored water quality
- Monitored river water quality
- Monitored lake water quality

- Monitored groundwater quality
- Implications of deteriorating water quality
- Data gaps.

Land-based activities are putting pressure on water quality

What we do on the land can affect our fresh water (Parliamentary Commissioner for the Environment, 2012). The clearing of native vegetation, New Zealand's growing population, urbanisation, and farming/forestry, the drainage of wetlands, and the damming and modification of rivers and streams have all had significant effects on our land and placed increasing pressure on our water bodies and their ecosystems.

Land-based activities can discharge nutrients to surface water and groundwater (see *The relationship between nutrients and algal growth in fresh water*). The nutrients of most concern in New Zealand's fresh water are nitrogen and phosphorus, as they cause excessive algal blooms and undesired plant growth (Davies-Colley, 2013). These nutrients occur naturally in rivers, streams, lakes, and groundwater and are essential for plants to grow. However, high nutrient concentrations can result in the excessive growth of freshwater plants and algae (periphyton in rivers or phytoplankton in lakes), which can reduce oxygen levels and prevent light from penetrating water, negatively affecting freshwater plant and animal species. Very high concentrations of nitrogen, either as nitrate-nitrogen or ammoniacal nitrogen, can be toxic to freshwater life; high nitrate-nitrogen concentrations can make water unsafe for humans to drink.

As of 2012, pastoral land covered about 40 percent of New Zealand (Ministry for the Environment and Statistics NZ, 2015). We assume pastoral land is used for livestock production; however, we recognise some areas are used for other purposes, such as turf production. In 2012, native forest land covered 24 percent, while exotic forest land covered 8 percent, cropping and horticulture land covered 2 percent, and urban land covered less than 1 percent of New Zealand. Even though agricultural land (pastoral, exotic forest, and cropping and horticulture) covers around 50 percent of New Zealand, 87 percent of New Zealanders live in urban areas so many people are potentially affected by degraded urban rivers.

The relationship between nutrients and algal growth in fresh water

Nitrogen and phosphorus come in many forms, which behave differently in water. This means they have different effects when they move through the environment. Nitrate-nitrogen is a soluble form of nitrogen and is highly mobile in water bodies. Once dissolved in water, nitrate-nitrogen can travel across the land surface or leach through soil into groundwater, ending up in rivers, lakes, and aquifers where it can affect water quality. Phosphorus tends to adhere to soil particles. When these soil particles are transported to rivers and lakes, sediment-bound phosphorus can accumulate on river and lake beds. Most phosphorus in water is bound to sediment, but under certain conditions, it is transported in dissolved form and can be taken up by plants and algae.

The concentrations and ratios of nitrogen and phosphorus in a water body are important. A supply of both nutrients is needed for excessive algal growth to occur (generally exhibited through periphyton in rivers and phytoplankton in lakes). An excess of nitrogen or phosphorus alone will not lead to excessive algal growth – both need to be present in the right ratio. If a river or lake has plenty of nitrogen to stimulate unwanted algal growth but not enough phosphorus, it is said to be phosphorus-limited. Conversely, water bodies with plenty of phosphorus but not enough nitrogen are nitrogen-limited. In theory, if a water body is phosphorus-limited, then there is less need to control inputs of nitrogen to prevent excessive algal growth. However, in many situations controlling one nutrient may be inadequate because the limiting nutrient in a water body can be different at different times, and it can be different in different parts of the same water body.

Periphyton is the algae found on the bed of streams and rivers. Healthy river ecosystems are characterised by the presence of periphyton (Biggs, 2000), but high periphyton abundance can reduce the diversity and productivity of invertebrates and fish, and erode recreational values such as swimming and fishing. Maximum periphyton abundance is mainly determined by the time available for biomass to accrue between floods (ie flow regime), and by nutrient (nitrogen and phosphorus) concentrations, temperature, and light.

Source: Parliamentary Commissioner for the Environment, 2012

For more detail see *Environmental indicators Te taiao Aotearoa*: Land cover and Land use.

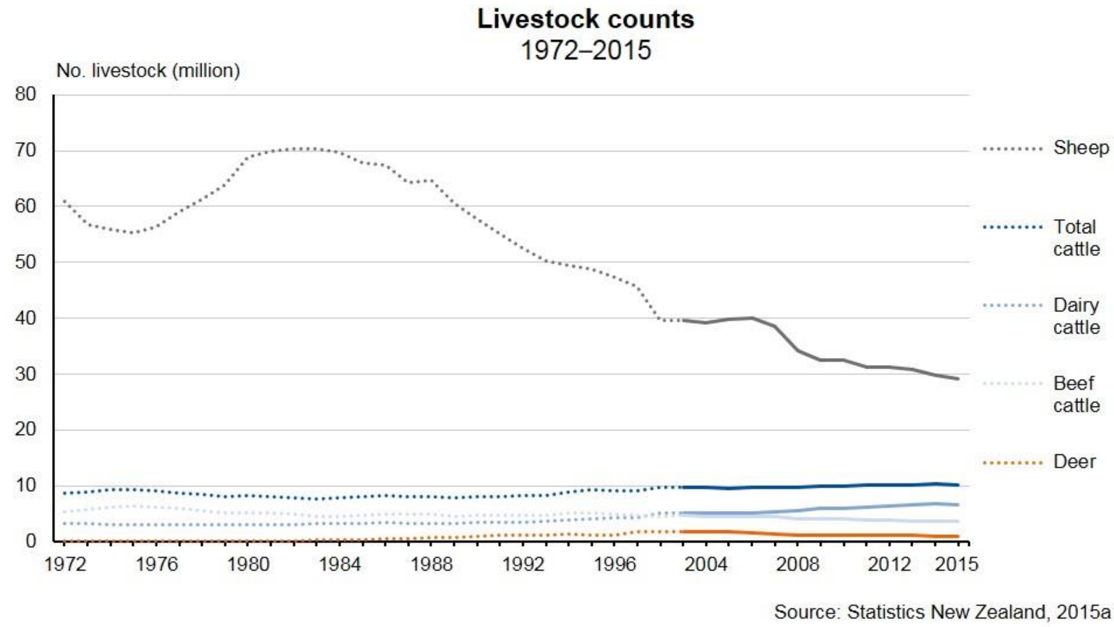
Agricultural practices have increased losses of contaminants to water bodies

New Zealand has one of the world's highest rates of agricultural land intensification over recent decades (but our agricultural practices have yet to reach the intensity of other areas, such as the European Union) (OECD/Food and Agriculture Organization of the United Nations, 2015). Intensified agricultural practices put increasing pressure on our water bodies due to the increased use of fertiliser; urine and faecal matter deposited by livestock; the taking of fresh water for irrigation; accelerated erosion from forestry, livestock, and cultivated soils; and infrastructure and housing development (Davies-Colley, 2013).

Agricultural intensification has been underway in parts of New Zealand since the late 1970s, as indicated by increased stocking rates and yields; increased fertiliser, pesticides, and food stock inputs; and conversion to more intensive forms of agriculture, such as dairying (MacLeod & Moller, 2006). The rates of land-use change and the rates of intensification (both increasing and decreasing) vary in different parts of New Zealand (Anastasiadis & Kerr, 2013).

As dairy products have become more profitable over recent decades, many farmers have moved away from sheep farming to more intensive dairy farming (DairyNZ, 2013; see figure 2). In 2015, New Zealand farmed about 29 million sheep, 10 million cattle (6.5 million for dairy), and 900,000 deer. From 1994 to 2015, sheep numbers decreased 41 percent and dairy cattle increased 69 percent (Statistics NZ, 2015a). The largest numbers of dairy cattle are in Waikato (1.76 million), followed by Canterbury (1.25 million) and Southland (0.73 million). Canterbury and Southland also had the largest increases in dairy cattle numbers from 1994 to 2015 (excluding Nelson, see table 1). By percentage, Southland had the largest increase, with dairy cattle numbers rising by about 539 percent.

Figure 2



Note: The current version of the Agricultural Production Survey started in 2002. Before 2002, the questionnaire design, coverage, and collection method varied, and the survey was conducted only in certain years. Numbers before 2002 are shown as a dotted line to indicate a change in livestock numbers; however, the data are not suitable for inclusion in time-series analysis. The current survey population (from 2002) includes businesses registered for goods and services tax.

Table 1: Dairy cattle numbers by region, 1994–2015

Region	Percent change, 1994–2015	Number, 2015
Northland	7	380,616
Auckland	–26	124,668
Waikato	23	1,761,949
Bay of Plenty	25	357,039
Gisborne	66	10,341
Hawke’s Bay	158	81,738
Taranaki	–10	541,931
Manawatu-Wanganui	47	451,421
Wellington	31	109,992
Tasman	59	77,863
Nelson	499	8,459
Marlborough	19	27,040
West Coast	130	182,298
Canterbury	490	1,253,993
Otago	368	384,979

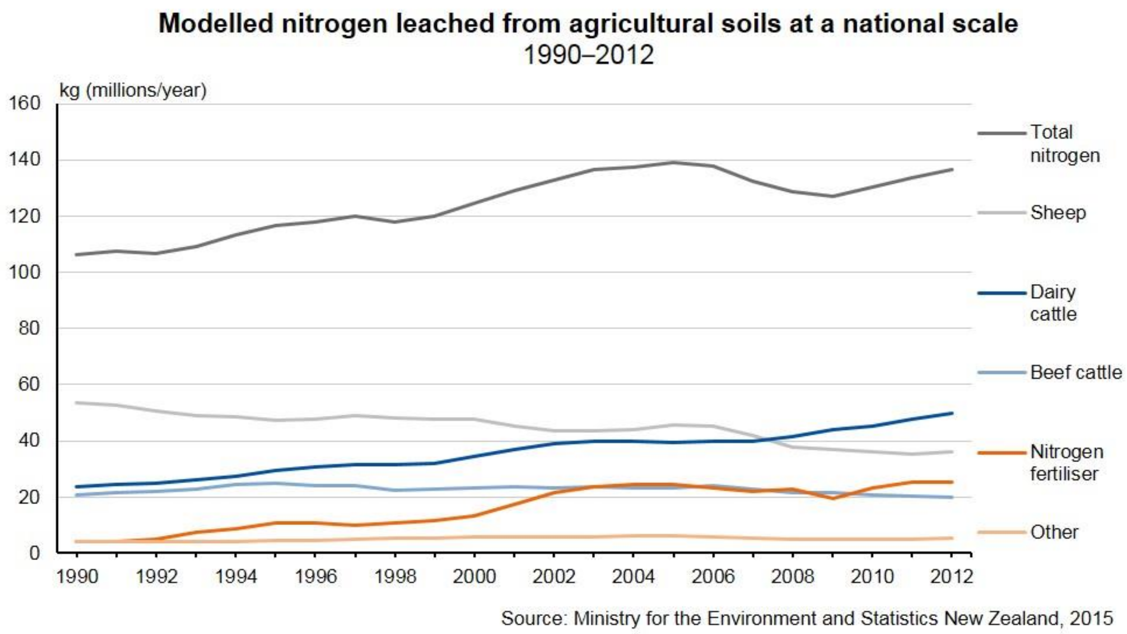
Region	Percent change, 1994–2015	Number, 2015
Southland	539	731,209
Chatham Islands	–100	0
Total New Zealand	69	6,485,535

Note: The current version of the Agricultural Production Survey started in 2002. Before 2002, questionnaire design, coverage, and collection method varied, and the survey was conducted only in certain years. The current survey population (from 2002) includes businesses registered for goods and services tax.

Agricultural intensification can increase the discharge of nutrients into surface water and groundwater due to increased livestock urine and waste and the application of fertiliser containing nitrogen and phosphorus (Parfitt et al, 2008). To estimate agricultural nitrogen leaching (nitrogen lost from the root zone and potentially reaching groundwater), we used the Greenhouse Gas Inventory (a model that estimates livestock contributions to soil nitrogen). We assumed a 7 percent leaching rate of nitrogen applied to land – this value was adopted for New Zealand's greenhouse gas reporting. In 2012, an estimated 137 million kilograms of nitrogen was leached from agricultural soils, an increase of 29 percent since 1990 (Ministry for the Environment, 2014; see figure 3).

Using the OVERSEER model (a model for estimating nutrient flows in a farm system), the main source of nitrogen leached from agricultural soils was livestock urine, accounting for an estimated 78 percent of nitrogen leached in 2012; the rest of the nitrogen leached was from fertiliser (Dymond et al, 2013). Waikato and Taranaki had the highest estimated agricultural nitrogen leaching rate per hectare (see figure 4 shows data only for agricultural soils).

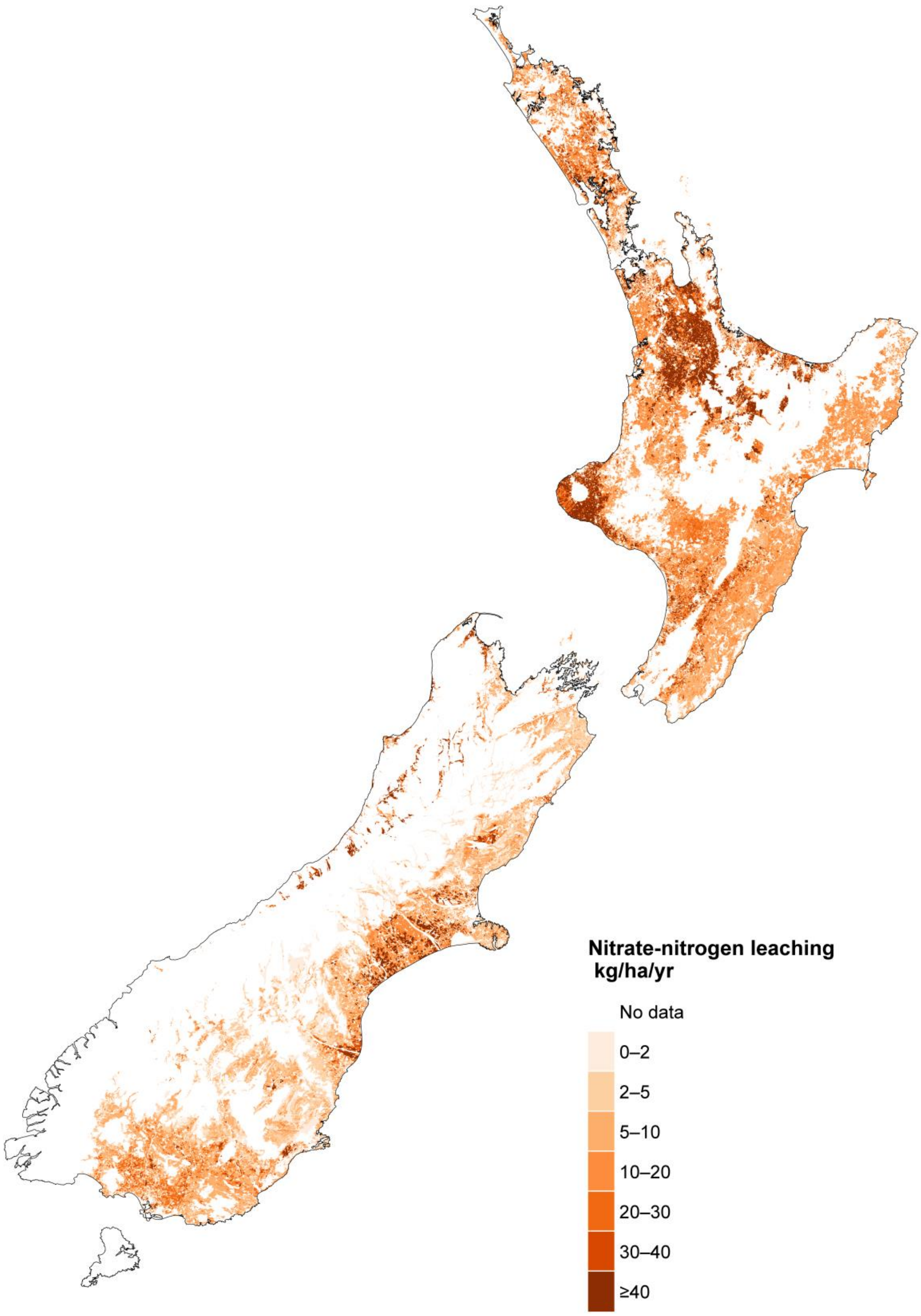
Figure 3



For more detail see *Environmental indicators Te taiao Aotearoa*: Livestock numbers, Trends in nitrogen leaching from agriculture and Geographic pattern of agricultural nitrate leaching.

Figure 4

Estimated rates of agricultural nitrate-nitrogen leaching, 2011



Source: Dymond *et al.* 2013

Urban run-off and modification of water bodies are degrading water quality

New Zealand's population grew 17 percent from 1996 to 2013 (Statistics NZ, 2013) driving a 10 percent (20,922 hectares) increase in urban land area over a similar period from 1996 to 2012 (Ministry for the Environment and Statistics NZ, 2015).

Urban streams typically have flashy flows (rapid increases and decreases in peak flows), elevated concentrations of nutrients and contaminants, highly modified channels, and reduced biodiversity with more 'tolerant' species that can thrive in streams with poor water quality (Walsh et al, 2005). These streams typically have increased bank erosion and sediment transport, compared with native streams, which results in more sediments deposited in estuaries (NIWA, nd).

Urban areas have three types of water infrastructure – stormwater (rainwater plus any contaminants it picks up on surfaces and carriers through the system), wastewater (water used in houses, businesses, or industrial processes), and potable water (for drinking water supply). In this section we discuss the negative effects stormwater and wastewater can have on urban streams.

Stormwater run-off can contain elevated concentrations of heavy metals (Lewis et al, 2015). These metals come from sources such as vehicle wear (copper from brake pads and zinc from tyres), metal roofing, and industrial yards (Kennedy & Sutherland, 2008). Metals are transported by stormwater into urban streams (either by pipes or run-off from surfaces directly into streams), and can accumulate in sediment and plant and animal tissue to concentrations that are toxic to freshwater life. Nutrients can also enter urban streams through the stormwater system, from spills, fertiliser used on lawns, and golf courses (eg Webster & Timperley, 2004).

Urbanisation causes vegetation to be removed and soil to be covered by impervious surfaces such as roofing, asphalt and concrete that do not absorb water. This leads to increased stormwater volumes and peak flows (Suren & Elliot, 2004). The degree of contamination of surface water is linked to the amount of impervious area, as impervious surfaces and pipes sometimes direct stormwater run-off straight into urban streams (Lewis et al, 2015). Permeable areas in urban environments (eg lawns and gardens) allow run-off to soak into the ground rather than wash off hard, impervious areas, directly entering streams and stormwater systems. Currently, we do not have national information on the extent of impervious surfaces in New Zealand.

Wastewater networks carry waste from houses and businesses to treatment plants. Wastewater can contain many contaminants, in particular nutrients and faecal pathogens (indicated by *E.coli*).

Combined stormwater/wastewater networks, illegal connections to the network, and leaky pipes, pumps, and connections in urban environments have caused nutrients and pathogens to enter urban streams. Many combined stormwater/wastewater networks also have consented overflows for storm periods, meaning that wastewater is permitted to overflow into stormwater systems during storms (NIWA, nd). In some areas, we have moved away from historic combined stormwater and wastewater systems to networks that only convey and treat wastewater and minimise the risk of overflows.

Infrastructure not appropriately designed, maintained, and replaced when necessary can have negative impacts on urban streams. The replacement value of the entire national infrastructure network for wastewater and stormwater is $36.7 billion (Department of Internal Affairs analysis of local authority annual reports). This does not include any new infrastructure, only the replacement of existing infrastructure. From a national perspective, one-quarter of wastewater assets are more than 50 years old, with between 10 and 20 percent of the graded network requiring significant renewal or replacement (Local Government NZ, 2014). Some councils have made recent investments (such as Tauranga), whereas other councils have much older networks.

Modelled river water quality

River water quality guidelines

Having discussed the pressures on freshwater quality in New Zealand, we now examine the current state of water quality.

New Zealand has compulsory values that regional councils must set objectives and limits for – these values are for 'ecosystem health' and 'human health for recreation'. The compulsory values, and their associated water quality attributes, are in the National Objectives Framework (NOF) that is part of the National Policy Statement for Freshwater Management (New Zealand Government, 2014). The framework consists of 'attribute states' that describe different effects pertaining to an attribute and a 'bottom line' for the minimum acceptable state, which should not be exceeded. These are regulations set by the Government.

We also look at the macroinvertebrate community index, a water quality indicator that scores a water sample in four groups from 'poor' to 'excellent'. Macroinvertebrate taxa tolerate contaminants in different ways – the composition of invertebrates at a site provides information about the site's water quality. This information is the basis for the macroinvertebrate community index.

We compare river water quality results against the attribute states for the compulsory value in the National Objectives Framework and the macroinvertebrate community index guidelines (see table 2; New Zealand Government, 2014; Stark & Maxted, 2007).

Table 2: River water quality guidelines and attribute states

River water quality compulsory value or guideline	Status	Water quality attribute or variable	What it means
Ecosystem health (trophic state) – National Objectives Framework national bottom lines in the National Policy Statement for Freshwater Management (New Zealand Government, 2014)	Regulatory	Algae (periphyton)	The attribute states consist of four bands, A–D, with A being the best state and D the worst. The national bottom line (the boundary between bands C and D) for periphyton is the level where regular and/or extended-duration nuisance blooms occur, reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.
Ecosystem health (toxicity) – National Objectives Framework attribute states in the National Policy Statement for Freshwater Management (New Zealand Government, 2014)	Regulatory	Nitrate-nitrogen, ammoniacal nitrogen	The attribute states consist of four bands, A–D, with A being the best state and D the worst. The national bottom line (the boundary between bands C and D) for median nitrate toxicity and pH adjusted ammonia toxicity is the level that would have some growth effects on up to 20 percent of sensitive fish species.
Macroinvertebrate community index – Stark & Maxted, 2007	Non-regulatory	Macroinvertebrate community index	The macroinvertebrate community index is a water quality indicator that groups sites into four categories: excellent, good, fair, and poor. The macroinvertebrate community of a stream lives with the stresses and changes that occur in the freshwater environment, whatever their cause, human-induced or natural.

This report does not include the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC) because they are currently under review and the numbers are expected to change. We do report on ANZECC guidelines in our webpages, which can more readily be updated than this report (see Environmental indicators Te taiao Aotearoa – Fresh water).

Modelled data estimates water quality for all river segments in the digital river network

We used the River Environment Classification (Snelder & Biggs, 2002) to group river monitoring sites by land-cover class: pastoral, urban, exotic forest, and native. A large proportion of site monitoring is in the pastoral class. To reduce the impact of sites influenced by pastoral land cover being over-represented in our analysis, we used statistical models to estimate median water quality in each of about 560,000 unique river segments in New Zealand's river network (Snelder & Biggs, 2002) for the period 2009–13 (Larned et al, 2017). The water quality medians were estimated using Random Forest models based on results from river water quality monitoring and a set of explanatory variables that represent catchment characteristics.

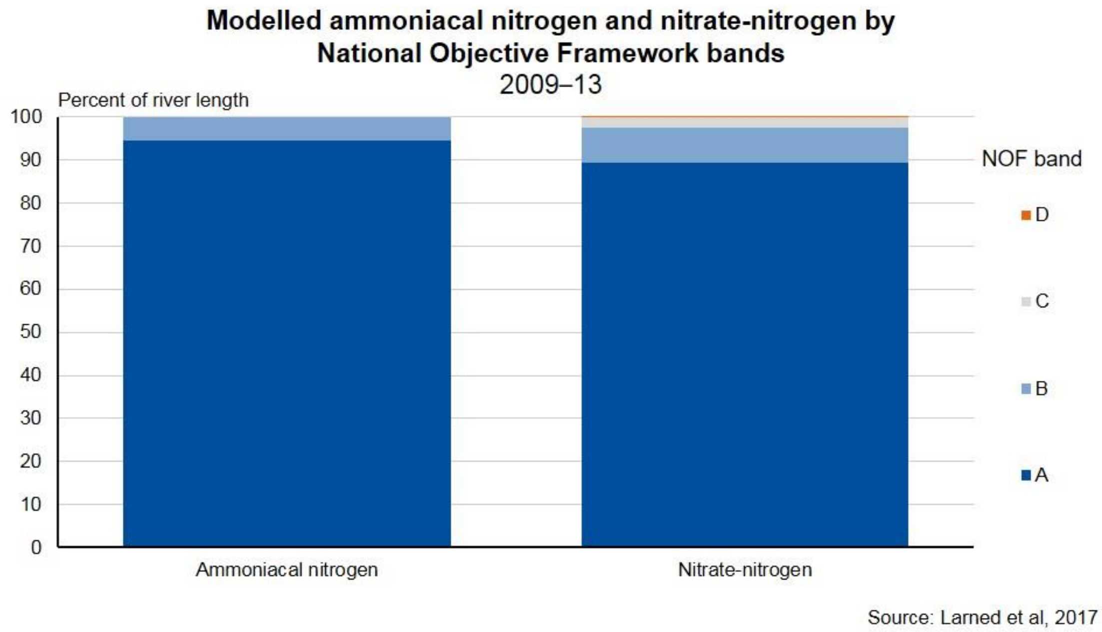
Modelled patterns of water quality in New Zealand for four water quality variables are shown in figure 7, figure 8, figure 9, and figure 10 for the period 2009–13 (see Environmental indicators Te taiao Aotearoa – Fresh water for additional maps). Overall, the modelling showed that medians for all water quality variables tended to be worse in low-elevation areas on the east coasts of the North and South islands, inland Waikato, Wairarapa Valley, Rangitikei-Manawatu coastal plain, Taranaki ring plain, and the Auckland region (Larned et al, 2017). These areas coincide with land used for intensive agriculture and most of New Zealand's urban centres. Medians, of all the water quality variables, were estimated to be better in the major mountain ranges, large areas of the Department of Conservation estate, and in smaller areas dominated by native forests in Northland and the Coromandel Peninsula.

For each modelled water quality variable, we compared estimated median concentrations or scores with threshold values (macroinvertebrate community index) and attribute states (nitrate toxicity and ammonia toxicity in the National Objectives Framework) for New Zealand river segments over the five-year period 2009–13, where available.

For a small proportion of total river length, estimated median nitrate-nitrogen and ammoniacal nitrogen concentrations did not meet the national bottom lines for toxicity, or had macroinvertebrate community index scores in the 'poor' category (1 percent or less of 560,000 river segments by length, see figure 5 and figure 6). These results suggest that with some localised exceptions, nitrate and ammonia levels in our rivers are not toxic to freshwater species (0 kilometres of river length for ammoniacal nitrogen, 2.3 kilometres for nitrate-nitrogen). Our rivers also appear to generally have good macroinvertebrate community index scores, with most river segments in the 'excellent', 'good', or 'fair' categories (4,606 kilometres of river length have a 'poor' score; this index does not tell us about the diversity or abundance of macroinvertebrate taxa present).

For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality: nitrogen, River water quality: phosphorus, River water quality: clarity, River water quality: *Escherichia coli*, and River water quality: macroinvertebrate community index.

Figure 5



Note: Bands A through D represent different states, with A being the best state and D being the worst. The national bottom line is the boundary between bands C and D. At this level, negative impacts on growth and mortality of multiple sensitive species are expected.

Figure 6

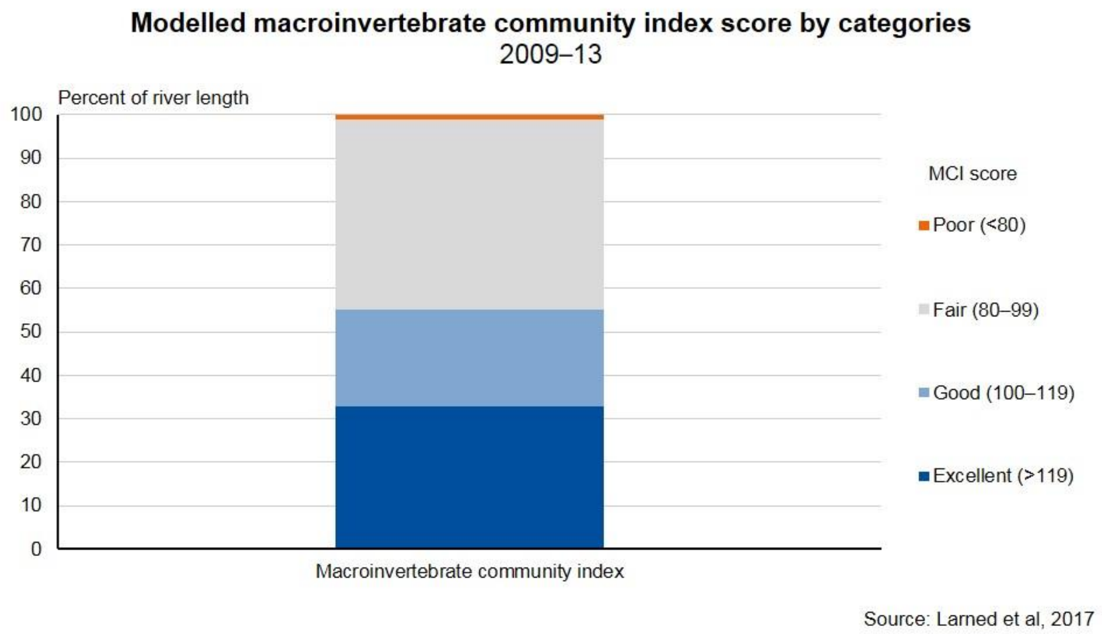
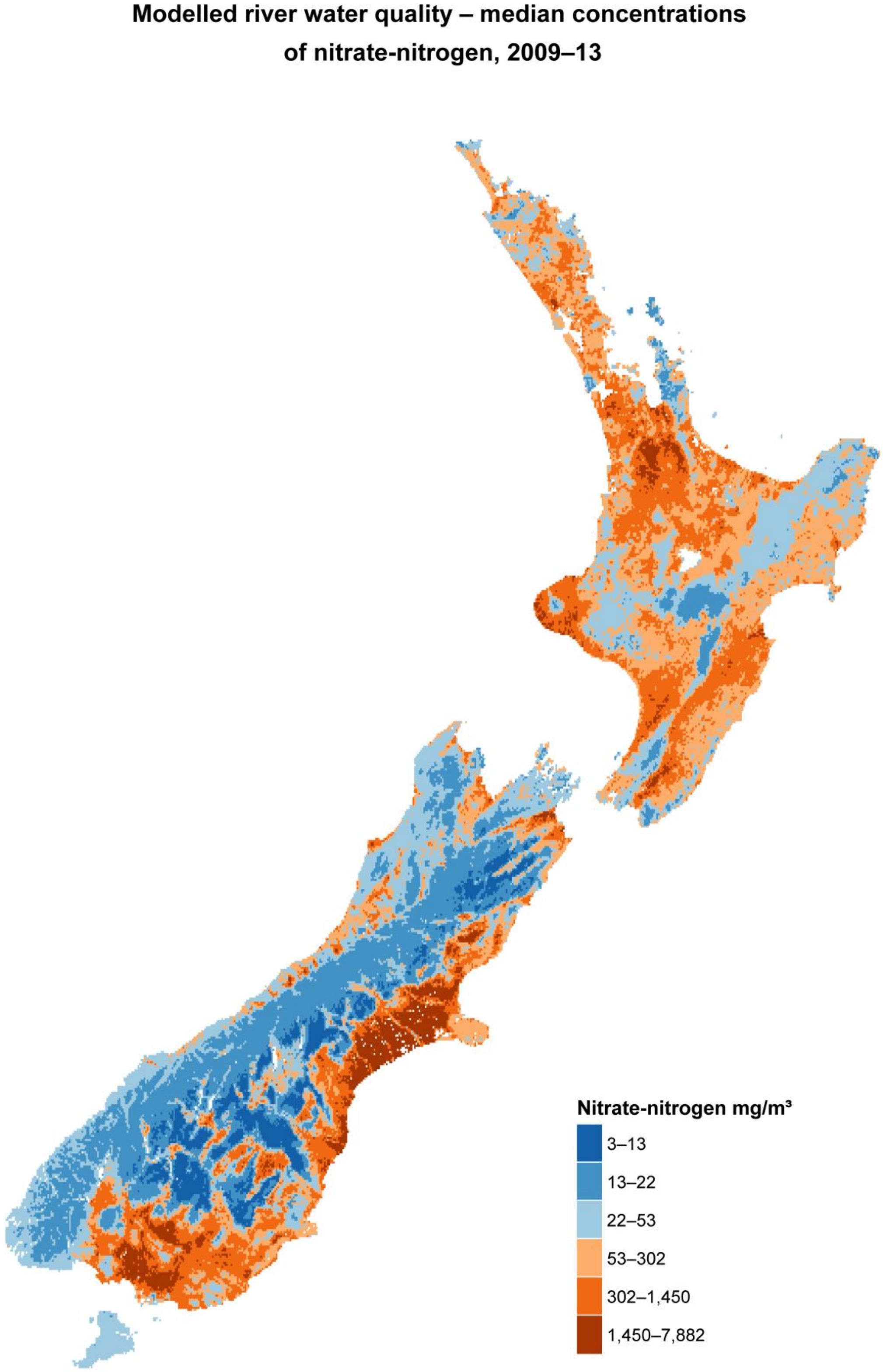
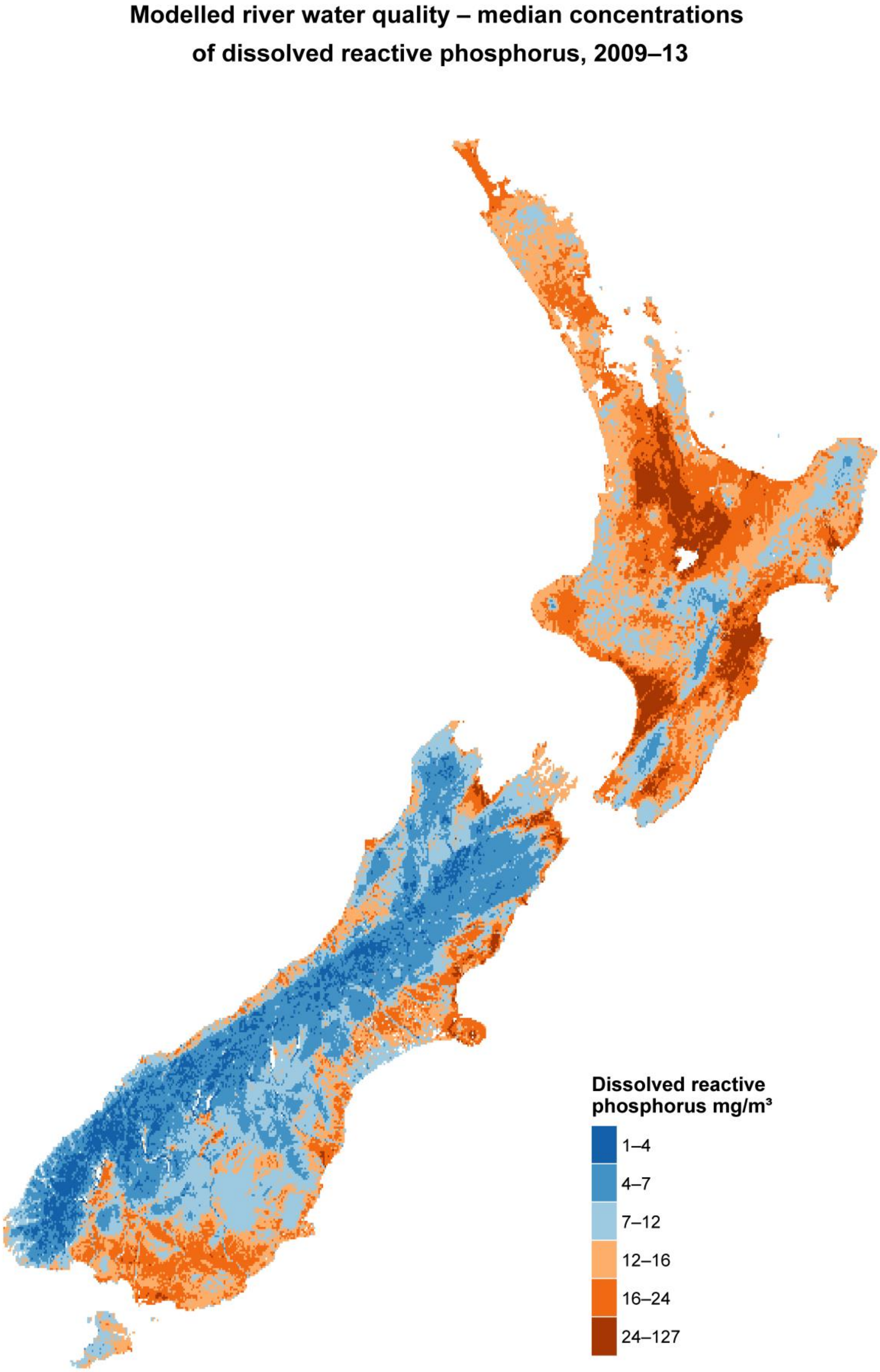


Figure 7



Source: Larned et al, 2017

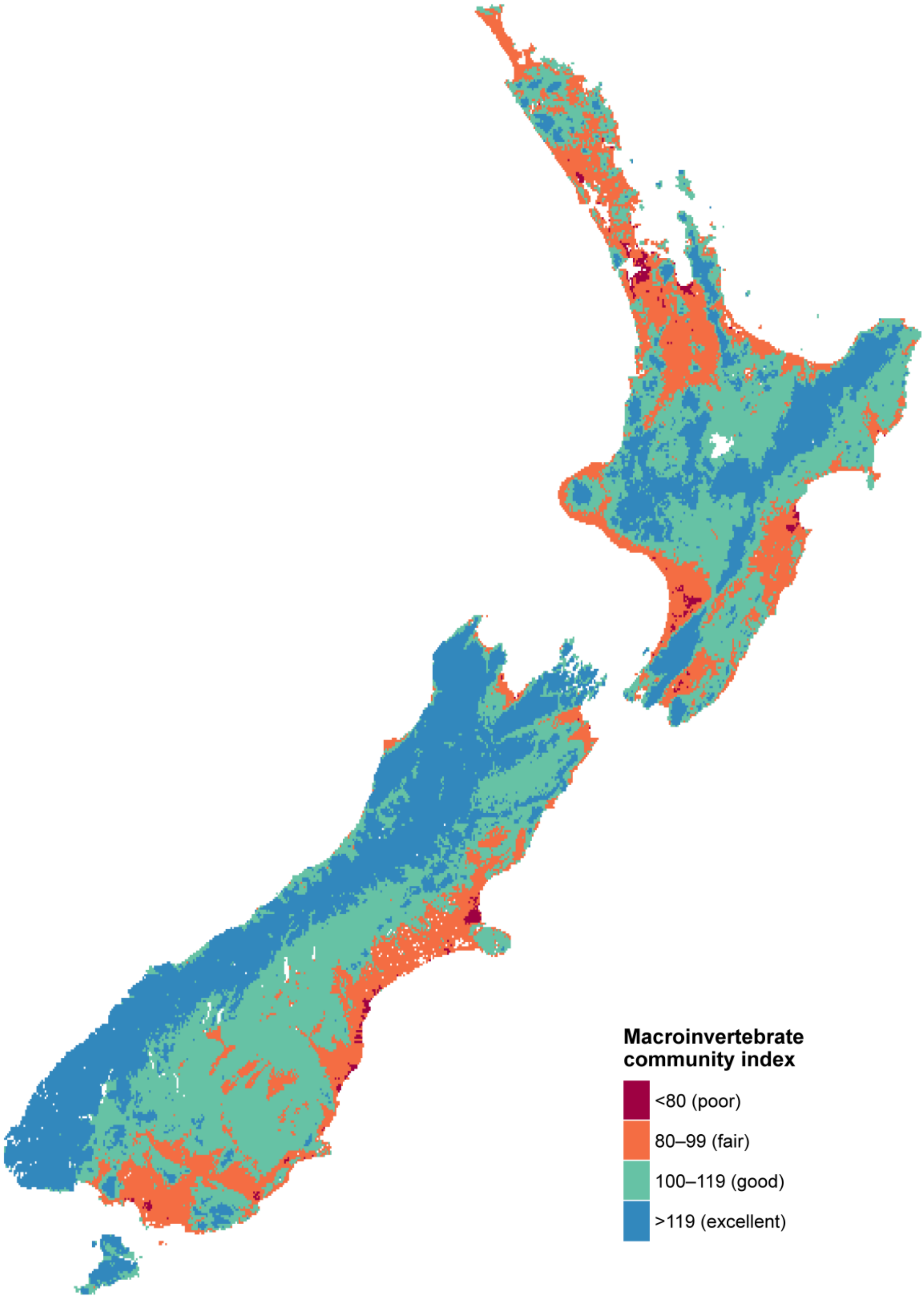
Figure 8



Source: Larned et al, 2017

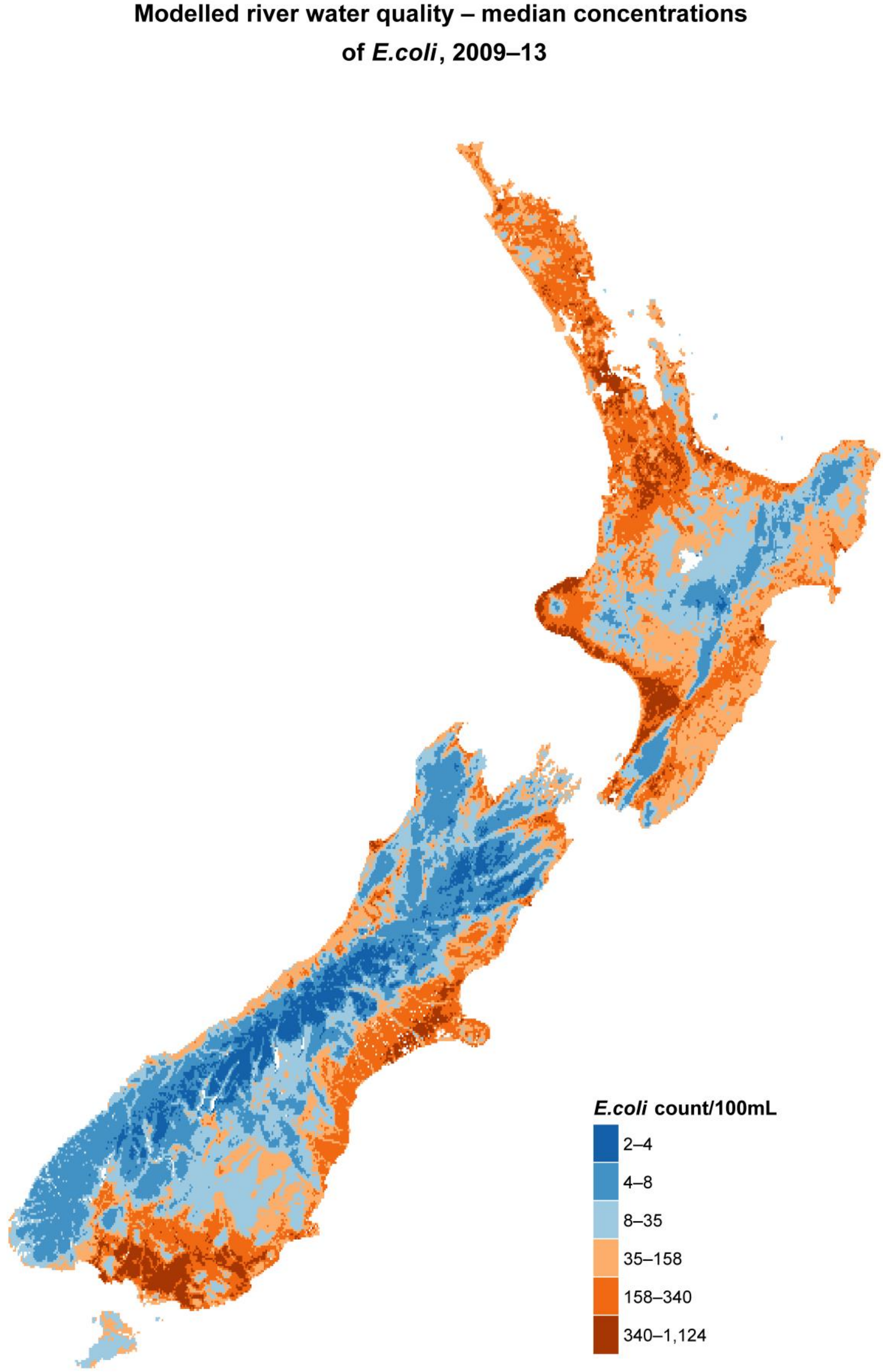
Figure 9

Modelled river water quality – median scores of the macroinvertebrate community index, 2009–13



Source: Larned et al, 2017

Figure 10



Source: Larned et al, 2017

Models suggest 83 percent of total river length for large rivers was not expected to have regular or extended algal blooms

Many studies both nationally and internationally indicate that the responses of stream periphyton to nutrients are complex and influenced by many factors such as light, flow history, and species composition (Larned, 2010). Nutrient concentration thresholds to achieve periphyton objectives are therefore always uncertain and must be considered along other factors such as river flow regime and shading. In New Zealand, several guidelines and decision-support systems help define nutrient thresholds to manage periphyton growth. The most robust thresholds are specific to different stream types because of the strong influence that variation in flow regime, substrate, and other factors have on periphyton abundance.

To quantify the geographic extent of potential nutrient-periphyton issues, this report combined national nutrient thresholds with modelled nitrogen and phosphorus concentrations (Larned et al, 2015). The resulting analysis estimates the extent of river segments by length that do not achieve the national bottom line for periphyton in the National Objectives Framework (New Zealand Government, 2014).

National scale models of periphyton abundance were derived using the method of Snelder et al (2014) for the 77 National River Water Quality Network (NRWQN) sites. The models predict periphyton abundance as a function of total nitrogen, dissolved reactive phosphorus, hydrological indexes, measures of sunlight, and temperature. The model response variable (periphyton cover) was converted to chlorophyll-a concentration using a correlation between the two abundance measures described by Larned et al, (2015). The models were then used to derive total nitrogen and dissolved reactive phosphorus concentration thresholds for each of 23 River Environment Classification (REC) 'source of flow' classes (source of flow distinguishes different river types based on the catchment climate and topography) (Larned et al, 2015).

An assessment of every segment of the REC digital river network, stream order 3 and greater, was made by comparing estimated total nitrogen and dissolved reactive phosphorus concentrations (Larned et al, 2017) with the relevant total nitrogen and dissolved reactive phosphorus criteria. Only segments of order 3 and greater were included, because the input periphyton data to the model was from large river sites (NRWQN sites), so we do not have confidence in the model for lower stream orders.

The assessment first considered whether the segment was able to support conspicuous periphyton. This assessment classified bed substrate into fine or coarse using predicted bed material grain size as described by Snelder et al (2013). Segments classified as having fine bed substrate were assumed to not support conspicuous periphyton, so applying nutrient concentration criteria to manage periphyton biomass is not warranted for these segments. These segments occur in low gradient areas where fine sediments accumulate and stream power is insufficient to move larger material (eg gravel and cobbles).

The models underlying this analysis are uncertain and the thresholds were derived from periphyton and environmental data collected from a limited number of sites that are representative of large New Zealand rivers. The resulting analysis is therefore uncertain and should be considered as only indicative of periphyton issues nationally.

Of the total river length in New Zealand's digital river network of stream order 3 and greater, estimated periphyton abundance in 17 percent of total river length (approximately 1,708 kilometres) did not meet the national bottom line for periphyton. In 60 percent of the modelled river length (5,988 kilometres) estimated periphyton abundance was estimated to be less than the national bottom line. The remaining 23 percent of river length (2,355 kilometres) has fine bed substrate, and are presumed to mean that periphyton growth is generally not supported.

Regional council periphyton monitoring has expanded since the National Objectives Framework in the National Policy Statement for Freshwater Management was released in 2014. In future reports, we intend to report on the results of those periphyton monitoring programmes.

Public health considerations for swimming in rivers

Animal and human faeces in fresh water can increase the risk of infection from faecal pathogens for those who come in contact with the water.

E.coli is used as an indicator of faecal matter present in fresh water. High concentrations of *E.coli* are associated with the risk of infection by *Campylobacter* (a gastrointestinal illness).

This section focuses on the public health risks for swimming in rivers , and not on other factors that may affect the ability to swim in a water body. Although we have yet to develop an indicator for tracking the change in risk from faecal contamination over time, we present the results of our initial work on rivers. In future we will expand this work to include lakes.

See Technical note on the initial assessment of modelled *E.coli* data for details on the work completed so far. This is an area where data collection and modelling practices are evolving, so it will take time to develop an indicator.

Many factors determine the health risks from recreational activities in rivers. *E.coli* is one of these. The concentration of *E.coli* varies over time in any given river. The exposure to risk is a complex interaction between a specific activity and its duration, and the *E.coli* concentration of the specific water body at the time of recreation. For example, the risk from *E.coli* would be different if a person was immersed in the water (such as swimming, where water may be swallowed) as opposed to being on the water (such as fishing), and whether it was a quick dip or a longer session.

To provide information on the risk of exposure to *E.coli* during recreational activities in rivers, it is necessary to define what we mean by 'swimmable' and how it relates to the risk of infection from pathogens. Our analysis used the grade and category system outlined in the Clean Water Package released in February 2017 (Ministry for the Environment, 2017), as opposed to current attribute states in the National Objectives Framework 2014. The Clean Water package assigns rivers to one of five grades (excellent, good, fair, poor, and very poor). The top three grades combine to a swimmable category; the last two grades would not be considered swimmable.

Snelder et al (2016) used statistical models to estimate *E.coli* concentrations in each of approximately 560,000 unique river segments in New Zealand's river network. We only looked at river segments of stream order 4 and higher, as these are rivers considered large enough to swim in. The dataset used to inform the model is based on *E.coli* data collected between 1990 and 2013 (monitoring longevity varies across sites).

There are a number of statistics which describe and quantify *E.coli* values. Snelder et al, (2016) used four approaches for quantifying *E.coli* values:

- median *E.coli* concentration (half the values are above/below this value)
- *E.coli* concentration as a 95th percentile (95 percent of the numbers are below this value – this is the statistic used in the National Objectives Framework)
- percent exceedances of the current upper threshold of 540 *E.coli*
- percent exceedances of the lower threshold of 260 *E.coli*.

The 95th percentile statistic was the most imprecisely modelled of all four statistics, so we have excluded it from our results (see Technical note on the initial assessment of modelled *E.coli* data for commentary on its statistical performance) (analysed by Stats NZ). The remaining three statistics have such a high level of agreement that any combination will show an estimated 65–70 percent of segments fall under the 'swimmable' category.

This differs from the 72 percent figure stated in the Clean Water Package which includes both rivers and lakes, and takes into account adjustments made to reflect knowledge from regional councils and other sources.

The overall health risk from the three statistics in the swimmable category averaged over time is between 1 and 3.5 percent (Prime Minister's Chief Science Advisor, 2017). The actual risk depends on the *E.coli* concentration at the time of activity, which is why councils undertake monitoring at popular swimming spots during summer. For the most up-to-date information on your local swimming spot, see Land Air Water Aotearoa.

Along with pathogens from faecal contamination, many other factors affect the ability to swim in a particular water body. These include low water clarity, fast currents, rocks, dense weed beds, and toxic cyanobacteria (see *Toxic cyanobacteria in Greater Wellington rivers*).

Toxic cyanobacteria in Greater Wellington rivers

Toxic cyanobacteria in a water body is another public health concern when swimming. Toxic cyanobacteria form distinctive black or brown to dark green mats, and have an earthy, musty odour, especially when they break free from the riverbed and collect along the shoreline. People should avoid contact with cyanobacteria mats, and dogs and livestock should be kept away from them.

Many regional councils monitor cyanobacteria. Here we present a case study looking at the Greater Wellington region.

When five dogs died in the summer of 2005/06 after consuming toxic cyanobacteria, the Greater Wellington Regional Council began monitoring the abundance of cyanobacteria in its rivers and streams. Cyanobacteria, sometimes called blue-green algae, are an important and naturally occurring component of freshwater ecosystems. Some species produce toxins that can be harmful if present in drinking water or if humans come into contact with them through activities such as swimming. Dogs are particularly susceptible because they are drawn to the odour of some river cyanobacteria, and more than 70 dog deaths have been reported across New Zealand since 2006.

Monitoring and research by the Greater Wellington Regional Council showed large gravel-bed rivers, such as the Hutt and Waipoua rivers, have the largest and most frequent toxic cyanobacteria blooms. Combined low levels of dissolved reactive phosphorus and moderately elevated nitrate-nitrogen concentrations appear to foster the growth of cyanobacteria blooms in some Wellington rivers.

Source: Greater Wellington Regional Council, 2016

Monitored water quality

The data we used for the state and trend analyses in this section come from regional councils (data from monitored rivers, lakes, and groundwater sites), NIWA's National River Water Quality Network, and GNS Science's National Groundwater Monitoring Programme.

Percentages may not add up to 100 percent, as they are rounded to the nearest percent.

Regional compared with national level reporting

Two issues affect national-level reporting of water quality, which is based on a collection of data from regional councils.

1. Regional council monitoring networks in New Zealand are over-represented by sites in the pastoral class, and under-represented by sites in the native class (Larned & Unwin, 2012). This is because most councils monitor areas with known or suspected issues for management purposes. For example, rivers in low-lying and hilly areas in the North and South islands are well represented, while mountainous areas in the South Island and parts of the central North Island are not. This means our current monitoring networks do not provide a representative picture of water quality for all New Zealand rivers.
2. Although our data are sourced from regional councils, we adjusted some datasets to ensure our reports are nationally consistent. The adjustments may include omitting information produced by non-comparable methods. As a result, our evaluations may differ from those based on the original data. If you want detailed regional-level information, we recommend you review the relevant regional council's environmental reports.

We have similar issues in our lake and groundwater quality data.

Very few lakes are monitored in a consistent way. In this report, we report on between 48 and 76 lake sites, depending on the water quality variable.

Inconsistencies in the monitoring of groundwater quality include different sampling methods and frequencies of sampling that make it difficult to create a national picture of the state of, and trends in, groundwater quality. The National Groundwater Monitoring Programme network consists of 106 sites monitored quarterly by GNS Science using a consistent set of variables. The number of sites sampled, sampling frequency (from monthly to annually), sampling methods, and the variables measured for groundwater quality vary between regions.

Due to these issues, we do not show spatial results (ie on maps) of water quality from monitoring sites. Instead, we use numbers and proportions of monitoring sites to report on water quality at a national scale and rely on the water quality models in the previous section to show spatial patterns. If you are interested in seeing spatial representations of water quality from monitoring sites, see our dynamic maps at Environmental indicators Te taiao Aotearoa – Fresh water.

Classification of water quality sites

We classified the results from the monitoring of river water quality by land-cover class under the River Environment Classification (Snelder & Biggs, 2002). We used four land-cover classes: pastoral, urban, exotic forest, and native. The River Environment Classification assigns land-cover classes based on the land cover in the upstream catchment that is presumed to dominate conditions in surface water. Monitoring sites assigned to a particular land-cover class may have other land-cover classes upstream, and this variation in land cover can contribute to variation in water quality between sites. The majority of the monitoring sites we report on for river water quality are in the pastoral land-cover class. Because of this, the results we present in the sections below are for sites in the pastoral class, with supporting graphs that show results for all four land-cover classes.

We did not classify lake water quality sites in this report; we considered classifying them by lake type but the small sample size in each class made the accuracy of this inter-class comparison questionable.

We did not classify our groundwater quality sites in this report.

In future reports, we will explore options for classifying our river, lake, and groundwater sites.

Trend assessments

We used two trend-assessment methods for water quality: one for rivers and lakes, and another for groundwater. We used different trend tests because we trialled a new approach for river and lake water quality (Larned et al, 2015).

1. Trends for river and lake water quality variables were inferred with 95 percent confidence using the Relative Seasonal Sen Slope Estimator (Larned et al, 2015). A trend can either be ‘upwards’, ‘downwards’, or ‘insufficient data to determine trend direction’ (which we refer to as ‘indeterminate’). Data used to determine the trends for river water quality (except for macroinvertebrate community index) were adjusted for the influence of variation in river flow, because values may be correlated with flow. Where flow measurements were not available, flow was estimated using theTopNet national hydrological model (Larned et al, 2015).

2. Stats NZ assessed the trends for groundwater quality using the non-parametric Mann-Kendall test for the presence of positive or negative trends. A p-value of <0.05 was used to determine whether the trend was statistically significant (if not significant, we refer to the trend as indeterminate).

An indeterminate trend does not mean conditions have not varied over the assessment period.

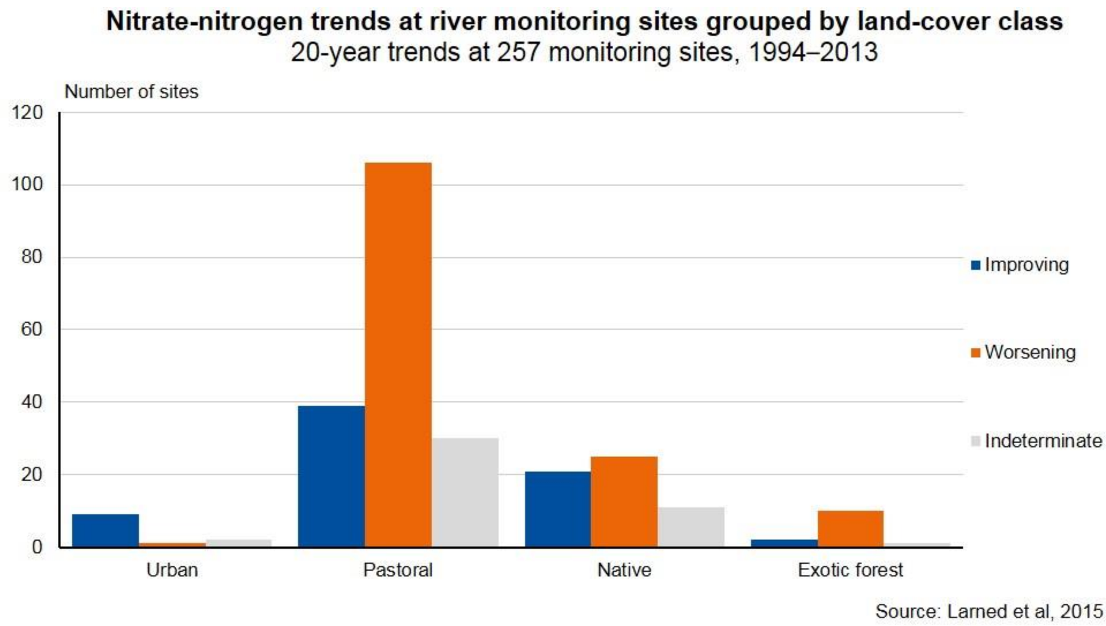
Monitored river water quality

Nitrate concentrations at monitored sites are getting worse in some areas

Median nitrate-nitrogen concentration over the 2009–13 period was 18 times higher in the urban class and 10 times higher in the pastoral class, compared with the native class (Larned et al, 2015).

For the 175 monitoring sites in the pastoral class, trends in nitrate-nitrogen were worsening at 61 percent, improving at 22 percent, or indeterminate at 17 percent of sites between 1994 and 2013 (see figure 11). Similar results were obtained over a shorter period (2004–13), where trends in nitrate-nitrogen for 340 sites in the pastoral class were worsening at 39 percent, improving at 23 percent, or indeterminate at 39 percent of sites.

Figure 11



Note: Monitored sites are classified by land cover class (eg pastoral). However, monitored sites can be downstream of a mix of land covers within the catchment, meaning that the water quality at a particular site can be influenced by different land covers.

For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality: nitrogen.

Phosphorus concentrations at monitored sites in some urban and pastoral rivers are improving

Median dissolved reactive phosphorus concentration over the 2009–13 period was 3 times higher in the urban class and 2.5 times higher in the pastoral class, compared with the native class (Larned et al, 2015).

For the 145 monitoring sites in the pastoral class, trends in dissolved reactive phosphorus were improving at 46 percent, worsening at 21 percent, or indeterminate at 34 percent of sites between 1994 and 2013 (see figure 12). Similar results were obtained over a shorter period (2004–13), where trends in dissolved reactive phosphorus for 277 sites in the pastoral class were improving at 57 percent, worsening at 15 percent, or indeterminate at 29 percent of sites.

A number of factors have been explored that may be associated with improvements in dissolved reactive phosphorus concentrations over time. In urban areas, one of these may be due to improved wastewater treatment (Julian et al, 2017).

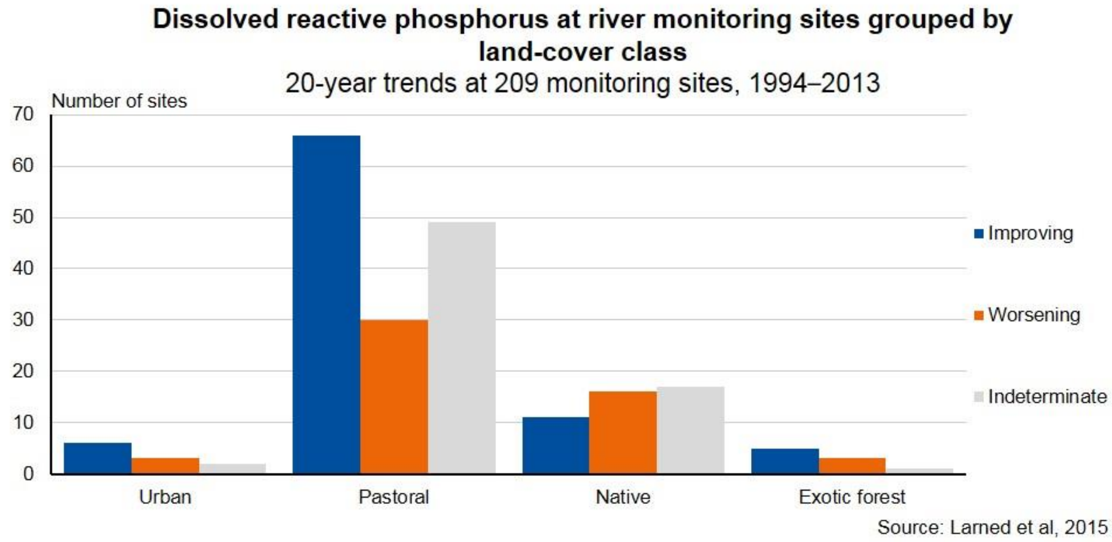
In rural areas, the following factors may have contributed to improvements:

- Various strategies, in addition to those such as stock exclusion, developed since 2003 to mitigate phosphorus loss from land to water (eg McDowell & Nash, 2012).
- The targeting of critical source areas of contaminant loss since 2008 in 77 documents (industry guidelines, farm environment plans, and regional policy). A farm or catchment accounts for the majority of contaminant loss to water. Targeting critical source areas improves the cost-effectiveness of strategies (McDowell, 2014).
- Improved education of farm consultants, fertiliser company representatives, and regional council staff since 2002 on mitigating phosphorus loss, for example through Massey University's Intermediate Sustainable Nutrient Management course.

The following factors may have contributed to improving phosphorus concentrations at specific sites, but there is insufficient evidence of large-scale improvements:

- Decreased sales of phosphorus fertiliser. However, sales have recovered since the 2008 price spike.
- Reduced soil Olsen phosphorus concentrations.
- Increased sales of low water-soluble phosphorus fertilisers (fertilisers less likely to cause phosphorus loss in run-off) (McDowell et al, 2010).
- An increase in nitrogen concentrations causing phosphorus uptake in periphyton. Twenty-one percent of sites with increasing nitrate-nitrogen concentrations had decreasing concentrations of dissolved reactive phosphorus (1994–2013; Larned et al, 2015). Less phosphorus loss in leachate from grasslands was noted where nitrogen use increased (Dodd et al, 2014).
- An increase in nitrate-nitrogen concentrations in groundwater causing the oxidation of iron, which sorbs phosphorus in streams. However, only 1 groundwater site (out of 22) that had improving dissolved reactive phosphorus trends also had worsening nitrate-nitrogen concentrations (2005–14; analysed by Ministry for the Environment and Stats NZ).

Figure 12



Note: Monitored sites are classified by land cover class (eg pastoral). However, monitored sites can be downstream of a mix of land covers within the catchment, meaning that the water quality at a particular site can be influenced by different land covers.

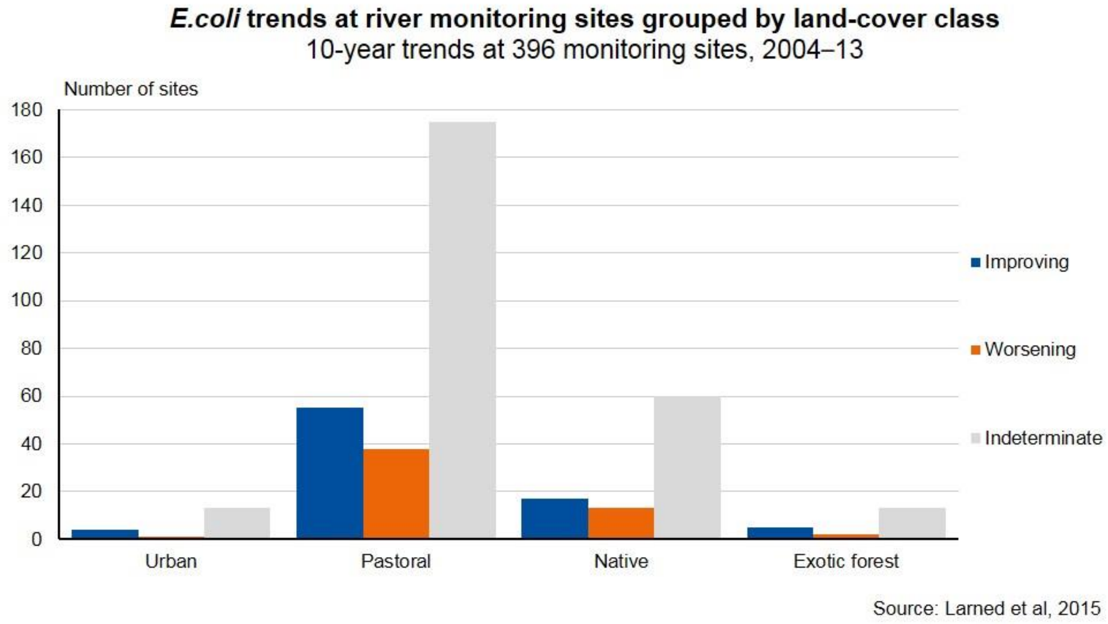
For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality: phosphorus.

E.coli trends at monitored sites are largely indeterminate

Median *E.coli* concentration over the 2009–13 period was 22 times higher in the urban class and 9.5 times higher in the pastoral class, compared with the native class (Larned et al, 2015).

For 268 monitoring sites in the pastoral class, trends in *E.coli* were indeterminate at 65 percent, improving at 21 percent, and worsening at 14 percent of sites between 2004 and 2013 (see figure 13).

Figure 13



Note: Monitored sites are classified by land cover class (eg pastoral). However, monitored sites can be downstream of a mix of land covers within the catchment, meaning that the water quality at a particular site can be influenced by different land covers.

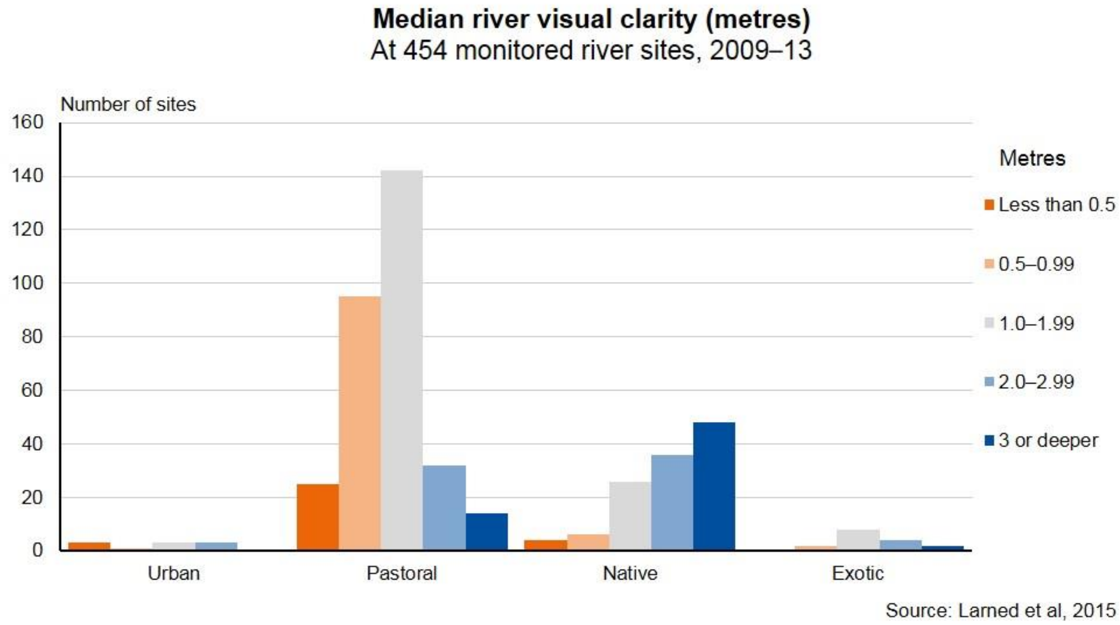
For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality: *Escherichia coli*.

Visual clarity of rivers is better at monitored sites in native areas

Median visual clarity over the 2009–13 period was approximately two times greater in the native class, compared with the pastoral and urban classes (Larned et al, 2015).

For 70 percent of monitoring sites in the native class, median visual clarity was two metres or more (84 of 120 sites), compared with 15 percent of sites in the pastoral class (46 of 308 sites) (see figure 14).

Figure 14



Note: Monitored sites are classified by land cover class (eg pastoral). However, monitored sites can be downstream of a mix of land covers within the catchment, meaning that the water quality at a particular site can be influenced by different land covers.

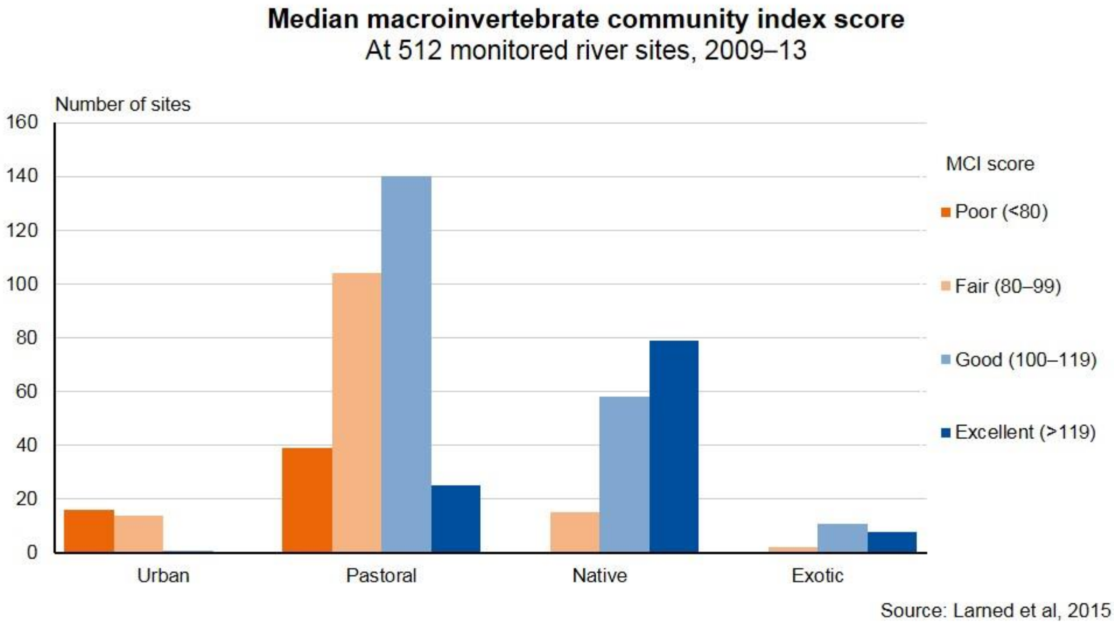
For the 130 monitoring sites in the pastoral class, trends in visual clarity were worsening at 46 percent, improving at 33 percent, or were indeterminate at 21 percent of sites between 1994 and 2013. However, over a shorter period (2004–13) trends in visual clarity across 241 sites in the pastoral class were improving at 31 percent, worsening at 17 percent, or were indeterminate at 51 percent of sites.

For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality: clarity.

Macroinvertebrate community index scores were excellent or good at most monitored sites

For 512 monitored river sites, median macroinvertebrate community index scores (2009–13) were excellent or good at 63 percent, fair at 26 percent, and poor at 11 percent of sites (Larned et al, 2015). For 308 sites in the pastoral land-cover class, 54 percent had scores that were excellent or good, compared with 90 percent of 152 sites classed as native (see figure 15).

Figure 15



We assessed 10-year trends (2004–13) in median macroinvertebrate community index scores (Larned et al, 2015), and found that 83 percent of 462 monitoring sites were indeterminate, with 5 percent of sites improving and 13 percent of sites worsening.

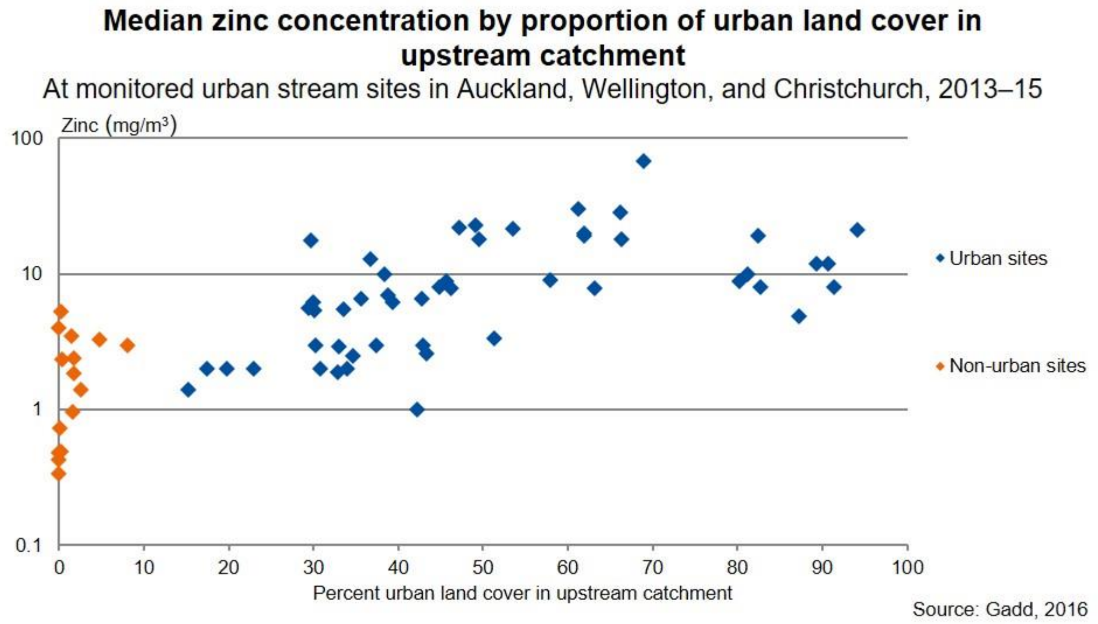
For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality: macroinvertebrate community index.

Zinc and copper concentrations are elevated in some urban streams

Run-off from roofs and roads to rivers and stormwater systems contains heavy metals, such as copper and zinc. Results from monitoring urban streams for water quality in Auckland, Wellington, and Christchurch indicated positive relationships between median concentrations of copper and zinc and the proportion of urban land cover in the upstream catchment (see figure 16 and figure 17; Gadd, 2016).

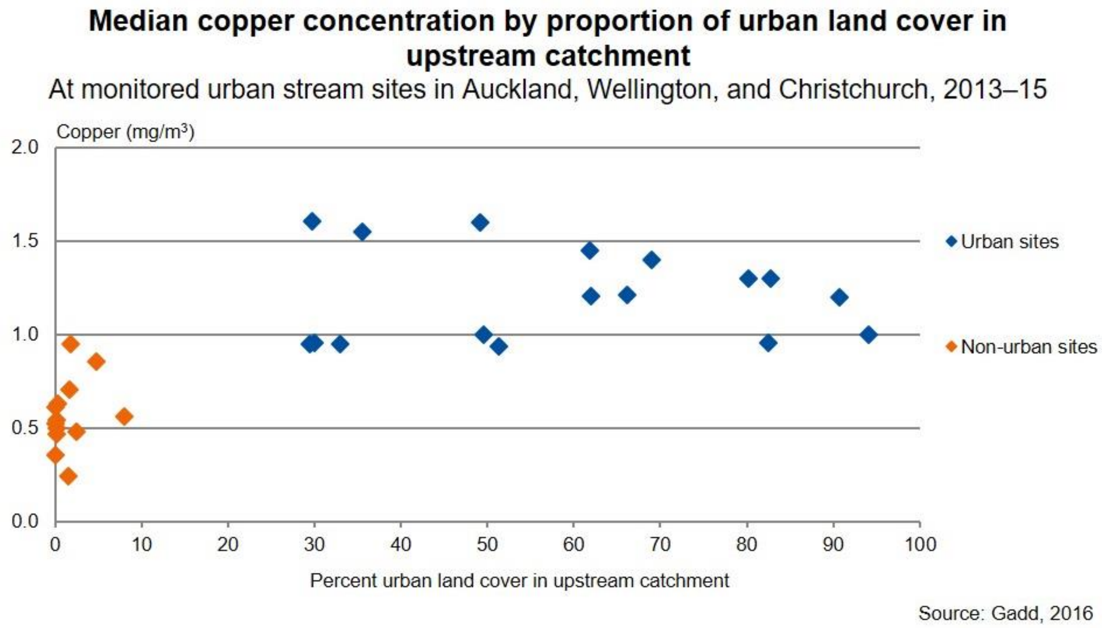
We did not have enough data to determine trends in copper concentrations for 12 of 14 monitoring sites in Auckland, Wellington, and Christchurch for the eight-year period 2008–15 (Gadd, 2016). Trends in zinc concentrations were improving at six sites, worsening at two sites, and were indeterminate at six sites over the same period.

Figure 16



Note: A site with greater than 15 percent urban land cover in the upstream catchment is considered 'urban'.

Figure 17



Note: A site with greater than 15 percent urban land cover in the upstream catchment is considered 'urban'.

For more detail see *Environmental indicators Te taiao Aotearoa*: Urban stream water quality.

Monitored lake water quality

New Zealand has more than 50,000 lakes, but only 3,821 of them are larger than one hectare (10,000 m^2). The different lake types, geology, topography, and human activities are factors that contribute to lake water quality (see Land-based activities are putting pressure on water quality).

Monitored lakes make up a small proportion (less than 5 percent) of all lakes in New Zealand larger than one hectare. Due to the processing and filtering rules for creating a national dataset, the data we used for this section were almost entirely restricted to the Northland, Auckland, Waikato, Bay of Plenty, and Canterbury regions (Larned et al, 2015).

We compare results for lake water quality to attribute states for compulsory values in the National Objectives Framework (New Zealand Government, 2014). These are described in table 3.

Table 3: Lake water quality attribute states

Lake water quality compulsory value	Status	Water quality attribute	What it means
Ecosystem health (trophic state) – National Objectives Framework national bottom lines in the National Policy Statement for Freshwater Management (New Zealand Government, 2014)	Regulatory	Algae (phytoplankton, measured as chlorophyll-a), total nitrogen, total phosphorus	The attribute states consist of four bands, A–D, with A being the best state and D the worst. The national bottom line for phytoplankton is the level at which lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state.
Ecosystem health (toxicity) – National Objectives Framework national bottom lines in the National Policy Statement for Freshwater Management (New Zealand Government, 2014)	Regulatory	Ammoniacal nitrogen	The attribute states consist of four bands, A–D, with A being the best state and D the worst. The bottom line for median nitrate toxicity and pH adjusted ammonia toxicity is the level that would have some growth effects on up to 20 percent of sensitive fish species.

Trophic level index at lake sites varies

When nitrogen and phosphorus enter lakes (referred to as ‘nutrient enrichment’), they stimulate algal growth, which can make lakes turbid and green. In New Zealand, the trophic level index (TLI) is widely used to measure the nutrient status of lakes, and provides an indication of the health of a lake.

Of 65 lake monitoring sites between 2009 and 2013, 24 sites had median TLI scores of very good or good, 17 monitored sites had moderate scores, and 24 monitored sites had poor or very poor scores (Larned et al, 2015). Lakes rated good or very good are clear (unless they have natural turbidity, eg from glacial silt) and have low concentrations of nutrients and algae (eg Lake Pukaki in Canterbury). Those rated poor or very poor tend to be turbid, with high concentrations of nutrients that promote frequent algal blooms. These lakes are rarely suitable for recreation and have habitats unsuitable for some native freshwater species (eg Lake Horowhenua in Manawatu-Wanganui).

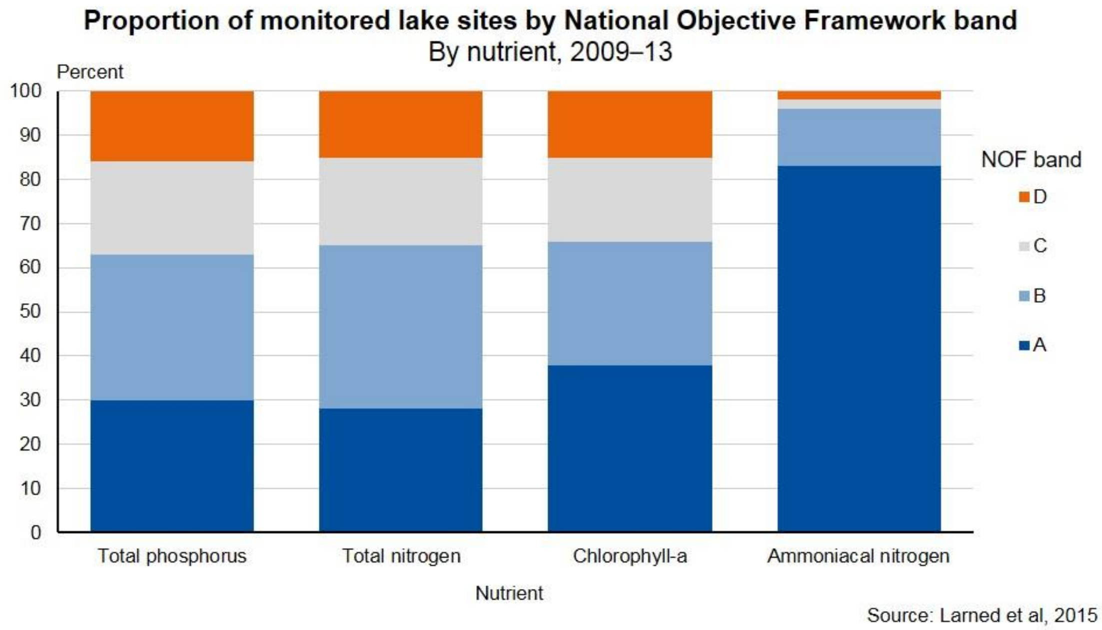
For more detail see *Environmental indicators Te taiao Aotearoa*: Lake water quality.

Most lake sites monitored for water quality meet national bottom lines

We assessed the variables for lake water quality against the attribute states in the National Objectives Framework. Total phosphorus, total nitrogen, and chlorophyll-a concentrations are National Objectives Framework attributes commonly used to assess nutrient enrichment in lakes. We also measured ammoniacal nitrogen in lakes, as it can be toxic to sensitive freshwater species.

For monitored lake sites assessed for water quality from 2009 to 2013, the following did not meet the national bottom lines for ecosystem health: 12 of 76 sites for total phosphorus; 11 of 71 sites for total nitrogen, and 11 of 72 sites for chlorophyll-a (a measure of phytoplankton (algae) biomass in a lake) (see table 3 and figure 18). One of 48 monitored sites did not meet the national bottom line for ammonia toxicity to sensitive freshwater species.

Figure 18



Note: Bands A through D represent different states, with A being the best state and D the worst. The national bottom line is the boundary between bands C and D. At this level, negative impacts on growth and mortality of multiple sensitive species are expected.

For more detail see *Environmental indicators Te taiao Aotearoa*: Lake water quality.

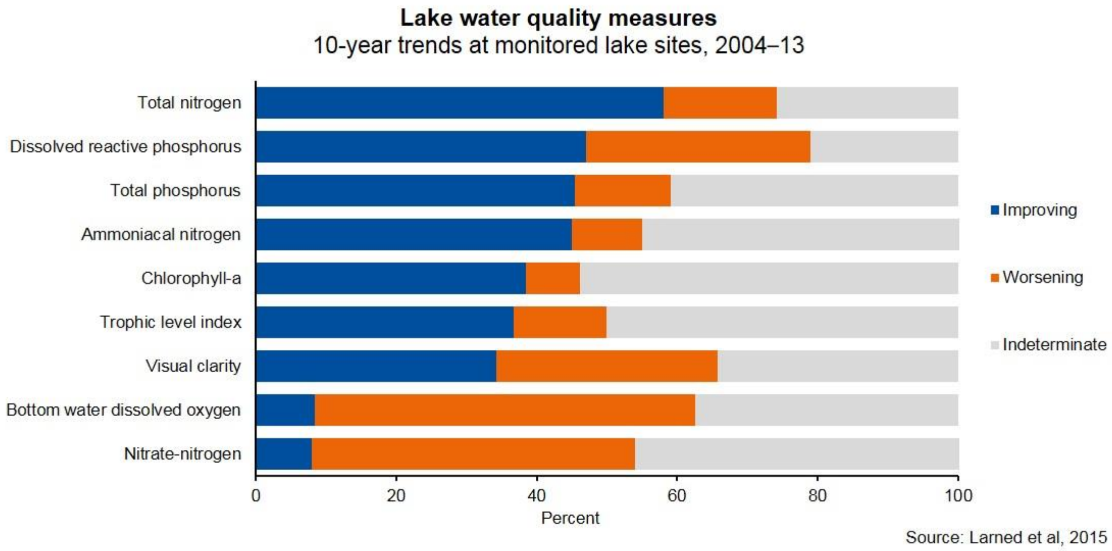
Trends in water quality at monitored lake sites show mixed results

Along with the water quality variables and trophic level index discussed in the previous two sections, we also report on the trends in lake visual clarity, nitrate-nitrogen, dissolved reactive phosphorus, and bottom-water dissolved oxygen for monitored lake sites.

For total nitrogen, dissolved reactive phosphorus, total phosphorus, ammmonical nitrogen, chlorophyll-a, trophic level index, and visual clarity, more trends at monitored sites were improving than worsening over 10 years from 2004 to 2013 (see figure 19). For bottom-water dissolved oxygen and nitrate-nitrogen, more trends at monitored sites were worsening than improving over the same 10-year period.

For more detail see *Environmental indicators Te taiao Aotearoa*: Lake water quality.

Figure 19



Monitored groundwater quality

Groundwater (the water under the ground surface) is an important source of drinking water, irrigation water, and a major contributor to surface water flows. It can sometimes take decades, or longer, for water (and any contaminants it contains) to cycle from the earth's surface and through the ground to aquifers, so the impact of what we are doing today may not be measurable in groundwater for many years. Similarly, the quality of groundwater we see today may be the legacy of activities from many years ago.

Nitrogen and phosphorus occur naturally in groundwater, but additional input from agricultural discharges and urban land use can increase concentrations. High concentrations of nitrogen and phosphorus in groundwater can affect the quality of groundwater-fed rivers and lakes if aquifers have low attenuation capacities (McDowell et al, 2015). High nitrate-nitrogen or phosphorus concentrations may also have a negative effect on groundwater ecosystems. However, very little research has been done in New Zealand to define the effect of these nutrients on groundwater ecosystems. Nitrate-nitrogen and *E.coli* pose a public health concern if concentrations are above drinking water standards in groundwater used for drinking water.

See Land-based activities are putting pressure on water quality for the pressures on water quality.

We report on the results for groundwater quality against the drinking water standards (see table 4), focusing on the variables that could affect public health.

Table 4: Drinking water standards

Drinking water standards	Status	Water quality variable	What it means
Microbial variables – drinking water quality standards maximum acceptable value	Regulatory, for drinking water supplies	*E.coli*	Maximum concentration of *E.coli* in water that, based on current knowledge, constitute no significant risk to the health of a person who consumes two litres of that water a day over their lifetime (usually taken as 70 years).
Inorganic variables – drinking water quality standards maximum acceptable value	Regulatory, for drinking water supplies	Nitrate-nitrogen	Maximum concentration of nitrate-nitrogen in water that, based on current knowledge, constitute no significant risk to the health of a person who consumes two litres of that water a day over their lifetime (usually taken as 70 years).

Some monitored groundwater quality sites are not meeting drinking water standards

In this report, we compare results from monitored groundwater quality sites with the drinking water standards (Ministry of Health, 2008), because there are no other standards for groundwater (eg no standards are available for cultural values or ecosystem protection). We assess the results from each groundwater sampling occasion against the drinking water standards. The sites are those monitored by regional councils and GNS Science in their environmental monitoring networks, which are not set up to monitor drinking water supply. Therefore, these results are not representative of drinking water quality in New Zealand.

The Health (Drinking Water) Amendment Act 2007 requires drinking-water suppliers who serve more than 500 people to implement a water safety plan for their water supply. However, the drinking water standards apply to water intended for drinking by the public irrespective of the water's source, treatment, or distribution system, whether it is from a public or private supply, or where it is used.

The assessment was limited to sites that were sampled on 12 dates or more in the period 2012–14. We determined how many times a site failed to meet the drinking water quality standard. For *E.coli*, 50 of 70 groundwater sites (71 percent) did not meet the drinking water standard at least once (see table 5; analysed by Ministry for the Environment and Stats NZ). For nitrate-nitrogen, 47 of 361 sites (13 percent) did not meet the drinking water quality standard at least once.

Table 5: Number of times a site did not meet the drinking water standard

Number of times a site exceeded the drinking water standard	*E.coli* (number of sites)	Nitrate-nitrogen (number of sites)
0	20	314
1–2	15	19
3–5	14	5
6–10	15	16
Over 10	6	7
Total	70	361

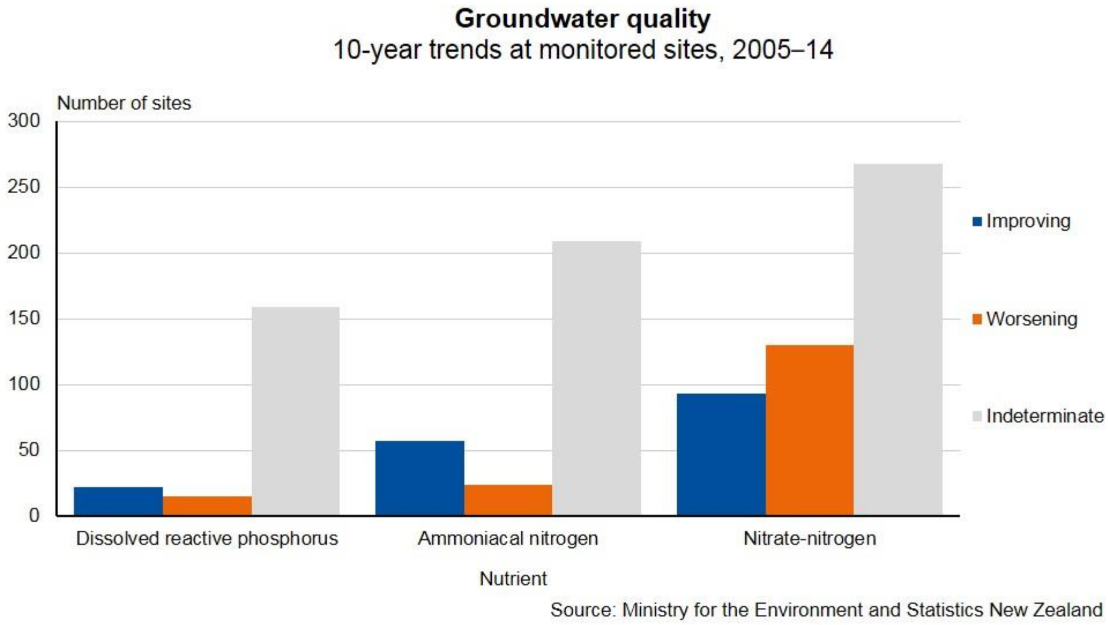
For more detail see *Environmental indicators Te taiao Aotearoa*: Groundwater quality.

We have insufficient data to determine groundwater trends at most monitored sites

Of monitored groundwater quality sites, trends in nitrate-nitrogen were worsening at 26 percent of sites (130 sites), improving at 19 percent of sites (93 sites), and were indeterminate at 55 percent of sites (268 sites) for the period 2005–14 (see figure 20) (analysed by Ministry for the Environment and Stats NZ). Over the same period, trends in ammoniacal nitrogen at monitored groundwater quality sites were indeterminate at 72 percent of sites (209 sites), improving at 20 percent of sites (57 sites), and worsening at 8 percent of sites (24 sites). For dissolved reactive phosphorus, trends were indeterminate for 81 percent of sites (159 sites) for the period 2005–14. Trends were improving at 11 percent of sites (22 sites) and worsening at 8 percent of sites (15 sites) over the same period (analysed by Ministry for the Environment and Stats NZ).

We could not determine *E.coli* trends because a high proportion of samples at each site were below the detection limit.

Figure 20



Note: Over the 10-year period 2005–14, monitored groundwater sites were assessed for trends in nitrate-nitrogen (491 sites), ammoniacal nitrogen (290 sites), and dissolved reactive phosphorus (196 sites).

For more detail see *Environmental indicators Te taiao Aotearoa*: Groundwater quality.

Groundwater monitoring shows there is little health risk from pesticides in groundwater

Pesticides can move through soils and enter groundwater. Of 153 sampled wells in the 2014 survey, no pesticides were detected at 83 percent of the wells. One or more types of pesticides were detected in groundwater from the remaining 17 percent of wells, but only in one well (in Waikato) did the concentration of a pesticide (dieldrin, an insecticide) exceed its maximum acceptable value defined in the drinking water standards (Humphries & Close, 2014).

We report only on pesticides in groundwater as we do not have enough information on pesticide concentrations in surface water.

For more detail see *Environmental indicators Te taiao Aotearoa*: Groundwater pesticides.

Implications of deteriorating water quality

New Zealand has many water bodies with good water quality, but these tend to be in areas of native forest or areas with little impact from human activities. The human occupation of New Zealand has resulted in the spread of urbanisation and agricultural activities, including the move to high-intensity agriculture over recent decades. Some changes in land use are associated with compromised water quality in some rivers, lakes, and groundwater.

Efforts to improve water quality in the 1950s and 1960s focussed on managing and reducing point source discharges, particularly wastewater discharges and treatment plants (Campbell et al, 2004). While reducing point-source discharges was beneficial, diffuse discharges of sediment, nutrients, and other contaminants are still degrading water quality. Using land for agriculture is the greatest contributor of diffuse discharges globally; however, since diffuse discharges are hard to measure and trace, it is difficult to establish cause-and-effect relationships between land use and water quality (Campbell et al, 2004).

New Zealand's population and agriculture-based economy are growing, and it is expected that high-intensity agriculture and urbanisation will continue to expand to new areas, potentially affecting water quality in more water bodies. Climate change is also predicted to put additional pressure on the quality of our fresh water, including increased water temperatures in some areas, which may reduce levels of dissolved oxygen and potentially increase the occurrence of algal blooms (Reisinger et al, 2014). Although substantial effort was directed at monitoring and reducing diffuse sources of contaminants with some success (eg McDowell et al, 2013), the legacy of contaminants from past land uses remain, meaning we may still see the impact of previous land uses on our water bodies in the future (Morgenstern et al, 2015).

Data gaps

We summarise some of many gaps in available data about water quality. We acknowledge that information to fill some of these gaps may already exist, or research is underway. We intend to provide information that will fill these gaps (if available) in our next report on fresh water.

- Information on relationships between land use and water quality.
- Information on the effect various land-use and land-management practices have on water quality.
- Information on the extent of impervious surfaces in urban areas and their impact on water quality and quantity.
- Information on water quality for Stewart Island, the Chatham Islands, and other outlying islands.
- Information on a larger number of lakes, with greater geographic distribution (lake water quality results in this report are largely from the Northland, Auckland, Bay of Plenty, and Canterbury regions).
- Increased information on river, lake, and groundwater quality monitoring sites in native and exotic forest areas, given that pastoral and urban sites are currently over-represented in the monitoring network.
- Consistent information on the monitoring of the quality of recreational water.
- Information on biologically relevant variables such as deposited sediment, continuous dissolved oxygen, periphyton, and benthic cyanobacteria.
- Information on groundwater salinity.
- Information on emerging contaminants.

Water quantity and flows

Top finding

More than half the water allocated (or consented) by councils is for irrigation, but we do not know how much of this is actually used.

What is happening?

Humans have been taking water and modifying water bodies for agriculture and urbanisation, and to produce energy and protect against flooding, which have resulted in altered flow regimes. The most widespread cause of altered river flow from water takes appears to be irrigation, although other uses such as hydroelectricity are important in some catchments. We currently do not have national-scale data on water use, and have relied on consented information for this analysis. Climate change is predicted to exacerbate pressures on water flows and the availability of water.

Why does it matter?

Flow reductions result in less water available for ecosystems and human use. Our current economic dependence on primary industries means we are relying on taking water for irrigation. Altered flows can negatively affect the health and mauri (life force) of freshwater ecosystems by negatively impacting on the habitats of freshwater species, landscape aesthetics, and the suitability of our freshwater environments for recreation.

Water quantity refers to the amount of water present in rivers, streams, lakes, wetlands, aquifers, and glaciers. Flow is the volume of water passing a point over a certain time, which indicates the availability of water for people and the environment. There needs to be a balance between providing water for public, industrial, and agricultural uses and ensuring the protection of freshwater ecosystem functions.

The timing and volume of water (also known as 'flow regime') are components of a healthy freshwater system and are linked to water quality. For example, if freshwater flows are low, little water is available to dilute nutrients and other contaminants that negatively affect water quality.

In this chapter we focus on how water flows are influenced by climate patterns. We also discuss some human activities that influence the flows in our water bodies. Changes in glacier volume will be covered in *Our atmosphere and climate 2017*, to be published in October 2017.

This chapter covers:

- Climate patterns influence freshwater flows
- Human activities are altering the natural flows in our water bodies
- Implications of altered river flows
- Data gaps.

Climate patterns influence freshwater flows

Water flows vary naturally through time and between water bodies due to climate, topography, land cover, and underlying geology. Natural variability in the flow of water is important for the health and mauri of freshwater ecosystems, and the services they provide.

Climate is a natural driver of flow regimes, including the availability of water, which is predicted to change in the future due to the effects of climate change (see *Projected effects of climate change*).

Projected effects of climate change

New Zealand's climate is projected to get warmer through the 21st century (Reisinger et al, 2014). This warming is expected to cause rising snow lines, reduced glacier volumes, increased westerly winds, and changes in the frequency and severity of droughts, rainfall patterns, and evaporation rates. Water flows and water availability are projected to change because of these factors, consequently affecting our freshwater ecosystems and species (Robertson et al, 2016).

A warmer climate will lead to higher water temperatures, which have implications for water quality, including reduced levels of dissolved oxygen and potential increases in algal blooms (Hamilton et al, 2013). This may affect the number and distribution of many freshwater species.

In the South Island, annual rainfall is projected to increase in the west and south and decrease in the northeast (Ministry for the Environment, 2016). In the North Island, annual rainfall is projected to increase in the west, and decrease in the east and north (Ministry for the Environment, 2016). Changing rainfall patterns and increasing evaporation rates may mean irrigation demand will increase in some parts of the country. Water quality may deteriorate because of lower flows (due to reduced rainfall) in areas that get dryer. Higher erosion rates may ensue (due to increased rainfall) in wetter areas, although this will depend on other factors, such as vegetation growth and cover. New Zealand's hydroelectric power generation is also sensitive to changes in rainfall patterns and the availability of water.

New Zealand has plenty of fresh water but it's not always where and when we need it

Rainfall and snow melt influence the amount of water in our rivers, lakes, and aquifers. By international standards, New Zealand has a plentiful supply of fresh water (OECD, 2007). Our low average population density and high average rainfall mean the amount of fresh water per person is higher than most countries. We have approximately 711 billion cubic metres stored as groundwater in aquifers, 320 billion cubic metres in lakes, and 440 billion cubic metres flowing through rivers and streams each year (Ministry for the Environment and Statistics NZ, 2015).

Our rainfall varies year on year. On average, New Zealand receives 550 billion cubic metres of precipitation a year – enough to fill Lake Taupo nine times over (Collins et al, 2015). Rainfall replenishes our rivers, streams, lakes, and groundwater, but it is not uniform across the country. Rainfall is generally much higher on the western side of the North and South islands – the West Coast of the South Island received 26 percent of national precipitation between 1994 and 2014 (Collins et al, 2015). After standardising for different catchment sizes, natural river flows are higher in some catchments than others. For example, river flows are naturally lower on the eastern side of the South Island compared with the western side, except for the large rivers that flow east from the Southern Alps, such as Waitaki, Rakaia, and Rangitata (Booker, 2015).

For more detail see *Environmental indicators Te taiao Aotearoa*: Geographic pattern of natural river flows and Water physical stocks: precipitation and evapotranspiration.

Human activities alter the natural flows in our water bodies

Taking water, creating diversions, dams, and bores, and using land are human activities that influence water flows. We use water for farming (irrigation and stock drinking water), power generation, drinking water, and industry. In some instances, our activities provide benefits in addition to the supply of water – for example, artificial lakes created by dams have the potential to create new recreation opportunities.

Flow regime influences a river's physical form by affecting how sediment is transported and deposited. A flow regime is important because flow combines with river topography to influence the habitat available for freshwater species. Although ecological processes are affected by many factors, flow is important because it influences food delivery, nutrient transport, and channel connectivity. It has been argued that freshwater species have evolved their life cycles in response to natural flow regimes (Bunn & Arthington, 2002). However, examples where changes to natural flow regimes have maintained, or even improved, in-stream values in some New Zealand rivers have also been reported (Jowett & Biggs, 2008). Altered flows can potentially influence fish abundance (Jowett et al, 2005), fish migration (Boubée et al, 2001), fish spawning (McDowall, 1990), the availability of physical habitat for fish (Jowett & Richardson, 1995), and invertebrate communities (Greenwood & Booker, 2014). If the flushing flows of rivers are reduced, algae and fine sediment can build up, reducing amenity and recreation values and degrading the habitat of freshwater species (Biggs, 2000). Māori assert their tribal identity in relation to water bodies, with each water body having its own mauri. Altered flows and water levels can degrade the mauri and mahinga kai values of water bodies (Tipa & Teirney, 2006).

Hydroelectricity and irrigation are the largest consented uses of freshwater takes

For more than a century, we have been using water resources for public use and agriculture, and to produce energy. The number of water takes, together with their position in the river network, rate of take, and timing, combine to determine the impact on flow regimes. Larger impacts on flow occur when larger volumes of water are taken for consumption (meaning the water is used and not returned to the site where the water was taken) from multiple locations, particularly in dry periods.

Water can be taken directly from surface water or from the groundwater system by pumping. Surface water and groundwater are often connected, so taking water from one affects both. However, quantifying the timing and extent of connection between groundwater takes and river flow depletion can be difficult. Resource consent data from all 16 regional and unitary councils show that groundwater takes are particularly common in Canterbury, which accounts for 56 percent of total consented groundwater volume (Booker et al, 2016a).

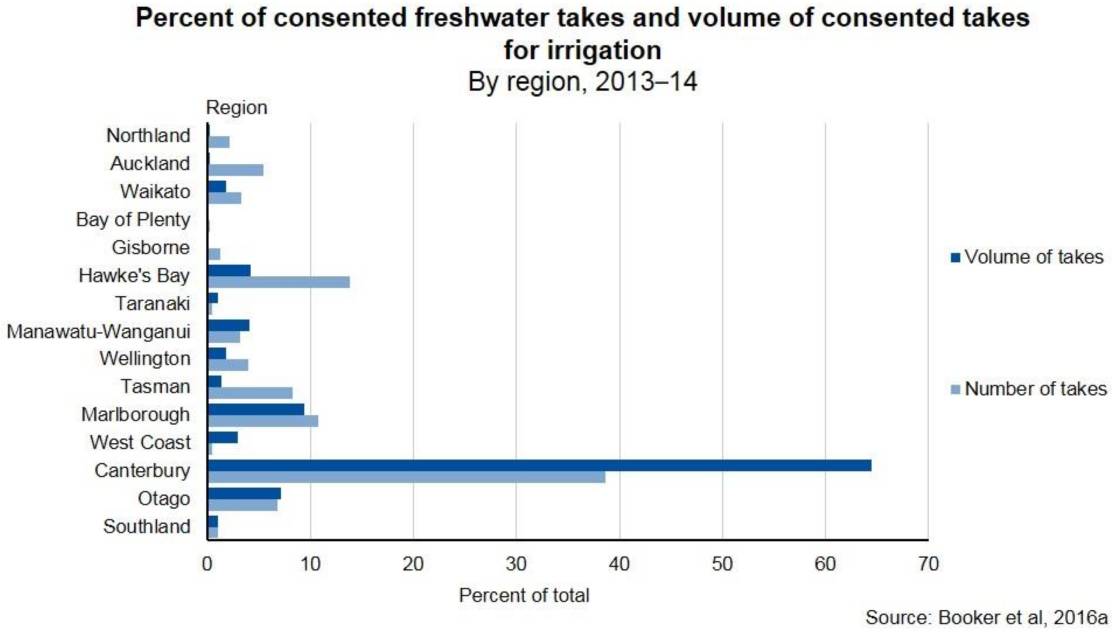
Hydroelectricity generation and irrigation are our largest consented uses of fresh water, with the remainder allocated for industrial, drinking, stock water, and other minor purposes (Booker et al, 2016a). Irrigation in New Zealand has allowed for the significant expansion of a range of farming systems (New Zealand Institute of Economic Research (NZIER) & AgFirst Consultants NZ, 2014). Irrigation gives a greater reliability of production, increased yields, and improved quality of production (NZIER & AgFirst Consultants NZ, 2014).

Water taken for hydroelectricity production is generally non-consumptive, meaning the water is returned to downstream water bodies after use (two notable exceptions are the South Island's Manapouri Power Station, which discharges directly to the ocean in Doubtful Sound Fiordland, and augmentation of the Waikato River from adjacent catchments in the North Island). However, water for hydroelectricity production is often stored behind dams, which alter river flow patterns downstream (Duncan & Woods, 2004).

The hydroelectric potential of New Zealand was recognised in the early 1900s, when construction of the first government scheme was completed in 1914 (Young et al, 2004). New Zealand relies on a plentiful supply of water for its energy supply. Hydroelectricity is our main source of renewable energy, accounting for more than 56 percent of electricity generation in 2015, returning $586 million to hydroelectricity operators (Stats NZ, 2017).

Water consented for irrigation varies by region, with Canterbury accounting for nearly 65 percent of the total consented volume of water nationally (see figure 21). A further 9 percent of the consented volume is in Marlborough, followed by 7 percent in Otago (although 53 percent of surface water consents in Otago had missing values for consented volume, so Otago consented volumes may account for a higher proportion than is expressed here) (Booker et al, 2016a).

Figure 21



For more detail see *Environmental indicators Te taiao Aotearoa*: Value of water resources used for hydroelectric generation and Consented freshwater takes.

We do not know our actual water use but irrigation has the greatest potential to alter river flows

The Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 (the Regulations) requires holders of consents for water takes over five litres per second to install meters and provide a continuous record of water takes, annually, to their regional council.

Takes of less than five litres per second are not covered by the Regulations. Many water takes for permitted activities do not require a resource consent, such as taking water for domestic use, firefighting, and stock drinking. Regional councils use various models and methods for estimating permitted takes, but further work is needed to build a consistent approach for robust national estimates.

Implementing the Regulations varied across New Zealand. In some regions, installing and verifying meters took longer than expected, primarily due to a shortage of accredited providers. Where this is an issue, regional councils used accredited providers from neighbouring regions. The Regulations were implemented in a staged way, with the final stage (takes of 5–10 litres per second) required since November 2016. Data quality and completeness are therefore currently mixed across the regions, meaning we cannot report on actual metered water takes at a national scale in this report (see *Water availability in Canterbury* for a case study on actual water use).

Due to inconsistent data on actual water takes nationally, we rely on consented water takes to indicate the potential impacts of freshwater takes on our rivers. The potential impact on river flows as a result of all upstream consented takes was calculated by summing the consented rates of all upstream consented takes and then dividing by the estimated long-term natural median flow (Booker et al, 2016a).

The cumulative effect of consented water takes on downstream river flows showed that water takes for irrigation have the highest potential to cause widespread reductions in downstream river flows, compared with other water uses (see figure 22 and figure 23) (Booker et al, 2016a). This is especially noticeable in Canterbury and Hawke's Bay where many consents are from groundwater as well as surface water. Note that estimating river flow depletion resulting from groundwater takes is uncertain. Limited evidence also suggests that not all consents are used to their full allocation, and many consents include rules to limit the rate of take during low-flow periods. The figures presented here show a worst-case scenario for river-flow depletion.

Water consented for hydroelectricity, industrial, and drinking uses may also have impacts on downstream flows, but these are concentrated in a few catchments. For example, Auckland experienced temporary drinking-water shortages in the past, and as its population continues to grow, new sources of water are needed (Auckland Council, 2013).

Demand for irrigation is higher in summer and in drought years (Woodward et al, 2001), which can exacerbate water availability issues. To protect the environment during periods of naturally low flow and when there is the greatest demand for water, many councils have restricted consents so that water cannot be taken when river flow at a control site falls below a certain flow rate. These restrictions are complex, and are not accounted for in our estimates of the impact of water takes on river flows. The natural timing of low flows also does not always coincide with peak water demand – freezing creates low flows in winter for cold catchments (eg Poyck et al, 2011).

Water availability in Canterbury

The quality and quantity of data describing actual water use are improving following recent changes to legislation. Canterbury is one region that has some data available on actual water use. For the 2013–14 water year (July to June), their data showed large differences between consented takes (how much water a user is allowed to take) and recorded takes (how much water the user actually took). This indicated that users who supplied records did not use their full allocation, particularly in early and late summer. However, in late February recorded use was near the maximum allowable use (Environment Canterbury puts restrictions on use when flows drop below a certain level). A large proportion of the consents had no associated records, so for many users, we do not know how much water they took.

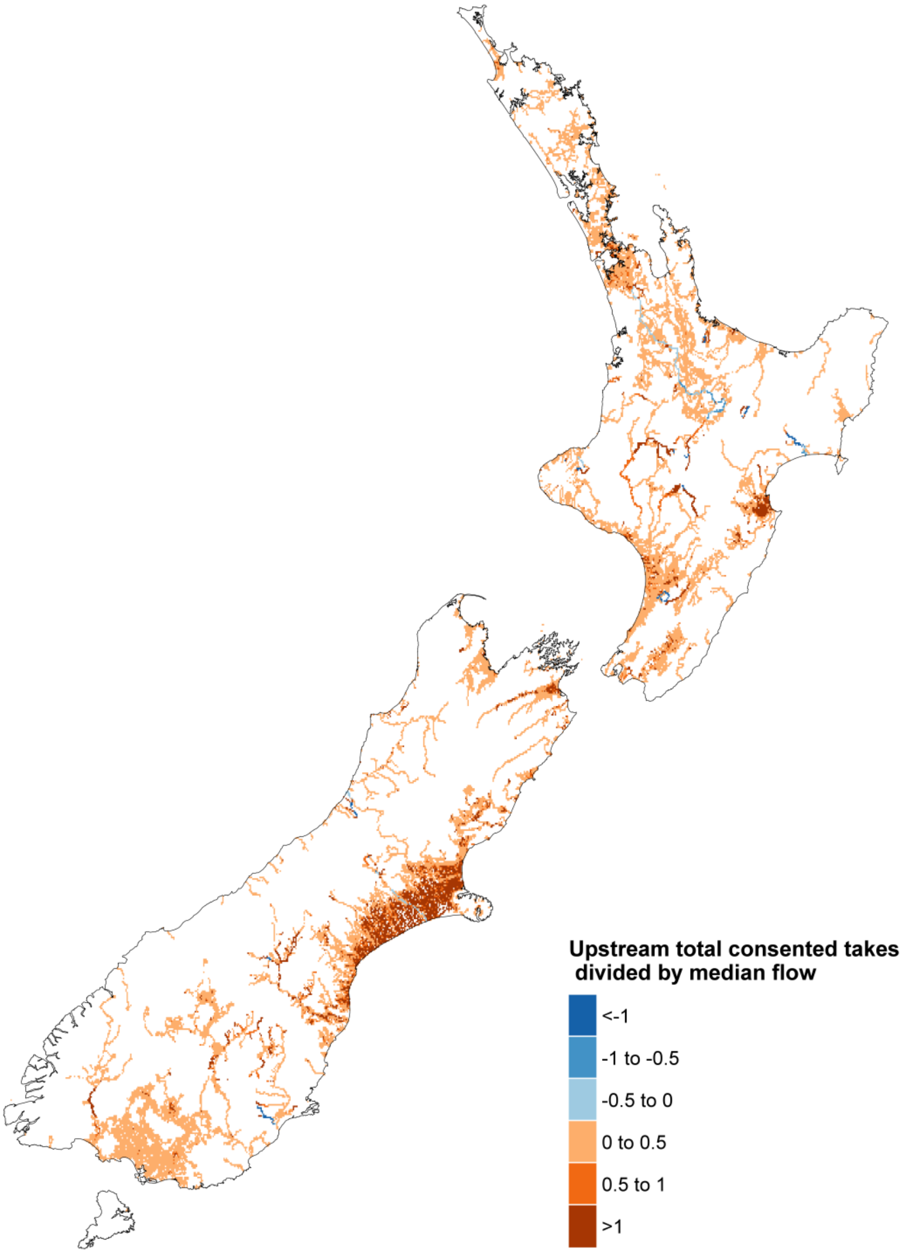
The available data on water use suggested many water-user behaviours. Some records indicated they took consistently far less than their consented values even after restrictions were applied – they complied, but also had ‘headroom’ (ie more water allocated than used) within their consents. Some users had occasional recorded takes that exceeded their consented or restricted takes – they complied on average, occasionally were non-compliant, but still had some ‘headroom’. Other records showed users consistently had recorded takes that met or exceeded their consented or restricted takes – they were consistently non-compliant and had no ‘headroom’ within their current consent conditions (except perhaps in mid-winter). For a few users, recorded values indicated consistently greater takes than their consented or restricted takes – they appeared to be consistently non-compliant and had no ‘headroom’ within their current consents, potentially denying other users of the opportunity to take water.

Source: Booker et al, 2017

For more detail see *Environmental indicators Te taiao Aotearoa*: Consented freshwater takes.

Figure 22

Estimated potential flow reduction as a proportion of the natural median flow as a result of all upstream consented water takes, 2013–14

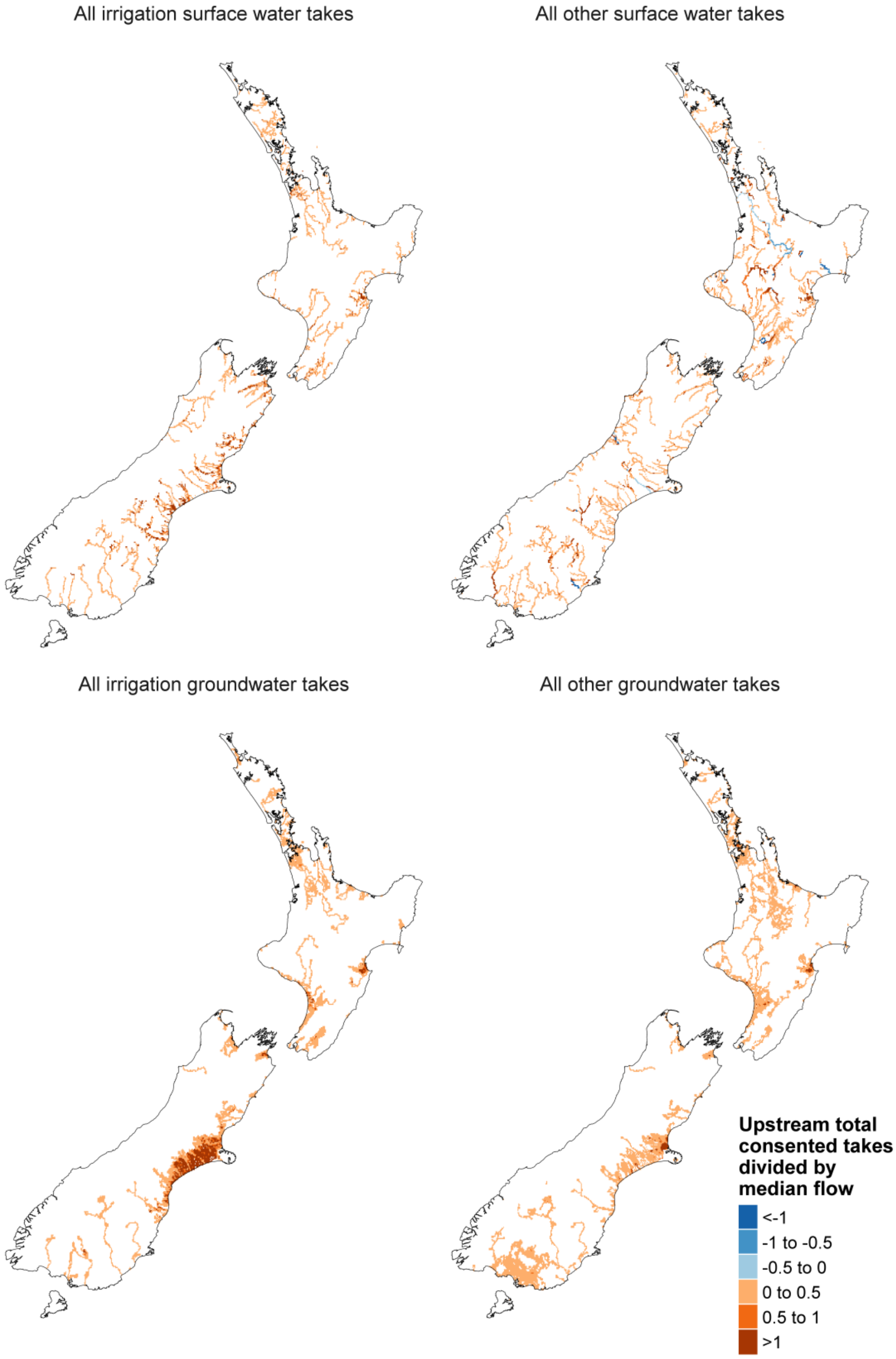


Source: Booker et al, 2016a

Note: Positive values indicate the potential flow depletion resulting from upstream consented takes, while negative values indicate flow augmentation (eg consents for hydroelectricity that return water to a location different from where it was originally taken from). These maps represent a worst-case-scenario of river flow depletion because they do not take into account restrictions on water takes and all groundwater takes were assumed to eventually result in river flow depletion. The median flow refers to modelled naturalised median flows, rather than actual flows. The effects of 53 percent of Otago consents are not included because they had missing values.

Figure 23

Estimated potential flow reduction as a proportion of the natural median flow as a result of all upstream consented water takes, 2013–14



Source: Booker et al, 2016a

Note: Positive values indicate the potential flow depletion resulting from upstream consented takes, while negative values indicate flow augmentation (eg consents for hydroelectricity that return water to a location different from where it was originally taken from). These maps represent a worst-case-scenario of river flow depletion because they do not take into account restrictions on water takes and all groundwater takes were assumed to eventually result in river flow depletion. The median flow refers to modelled naturalised median flows, rather than actual flows. The effects of 53 percent of Otago consents are not included because they had missing values.

Implications of altered river flows

Rainfall and snowmelt replenish our freshwater systems, and help determine natural river and groundwater flows. New Zealand receives a plentiful supply of fresh water but it is not uniform across the country, with rainfall generally much higher on the western side of both the North and South islands. Climate change is predicted to affect rainfall patterns, which may exacerbate pressures on freshwater quantity and flows in some areas of the country. Dams, diversions, and water takes have changed the natural patterns of water flow.

Our reliance on irrigation, especially in drier regions, to support our economy, has the greatest potential of all uses to cause altered flows downstream. Unnatural flow patterns can affect the biodiversity, health, and mauri of freshwater ecosystems and many of the services they provide (Booker et al, 2016b).

Data gaps

We summarise some of many gaps in available data about water quality. We acknowledge that information to fill some of these gaps may already exist, or research is underway. We intend to provide information that will fill these gaps (if available) in our next report on fresh water.

- Long-term water temperature and flow information.
- The effects that pressures are having on flow regimes.
- Information on actual water use and its impact on flow regimes.
- Time series of how consented volumes have changed over time.
- Information on the impact of human-made modifications, such as dams, piped sections of rivers, and other channel modifications, on water flows.
- Information on where and when restrictions on water takes are in place (eg consent conditions may restrict water takes when the river flows fall below a certain flow rate) and the impact of the restrictions on river flows.
- The extent and volume of aquifers.
- Information on how taking water from surface water bodies affects groundwater flows, and vice versa.
- Information on the effects of takes for permitted activities on flow regimes.

Ecosystems, habitats, and species

Top findings

Some water bodies have been physically changed, but we do not know the extent or the impact this is having.

Fine sediment deposited on riverbeds is estimated to have increased, but we don't know the national extent or impact this is having.

Wetland extent has greatly reduced and losses continue.

Cultural health is rated moderate at most tested freshwater sites.

Of the native species we report on, around three-quarters of fish, one-third of invertebrates, and one-third of plants are threatened with, or at risk of, extinction.

What is happening?

The health and mauri (life force) of some of our freshwater ecosystems declined because of human activities that reduced water quality, increased sediment yields, altered water flows, introduced pest species, and modified or lost habitats or the connections to habitats. These changes resulted in a decline in the populations of freshwater species, and many of our native freshwater plant, fish, and invertebrate species are now classified as threatened with or at risk of extinction.

Why does it matter?

Many of these species are endemic (found nowhere else in the world) so our biodiversity is nationally and internationally important. If the condition of freshwater ecosystems and habitats declines, this affects the species within them, and the economic, recreational, and cultural benefits we derive from them. The loss or decline in biodiversity can also have negative impacts on other species and the functions of the wider ecosystem.

The condition of our freshwater habitats and species are influenced by human activities on adjacent land, on river and lake margins, and within water bodies. Changes to flow regime, degraded water quality, pest species, channel modification, presence of barriers to fish migration, and increased sediment can also adversely affect biodiversity in these ecosystems.

This chapter covers:

- Human activities are degrading some ecosystems
- Status of the health and mauri of ecosystems and habitats
- Status of our freshwater species
- Implications of degrading ecosystems
- Data gaps.

Human activities are degrading some ecosystems

New Zealand has a long history of using river controls works, such as stop banks, weirs, channel realignment, and streambank plantings (eg willow trees) to confine rivers to well-defined channels and to protect nearby floodplains from floodwater that could damage infrastructure and houses.

River channelling prevents river migration, makes floodplains available for infrastructure development, increases agricultural efficiency, and improves flood control and security (Catlin et al, 2017). However, river-control works alter the natural character of rivers including their width, slope and depth, number of bends, and bed elevation/depth (Davies & McSaveney, 2011). These changes can erode river banks and increase deposition of sediments downstream (Fuller et al, 2011).

River-control works reduce the ecological connectivity of floodplains (and associated lakes and wetlands) within rivers by altering flood pulses into the floodplain. Flood pulses are an important driver of connectivity within riverine floodplains – flood pulses aid in dispersing seeds, establishing plants, cycling nutrients, scouring, depositing sediment, and maintaining species richness (Catlin et al, 2017). This reduction in ecological connectivity of floodplains is particularly important in rivers with low-gradient floodplains and prolonged floods, and less important in rivers with steep gradients and flashy flows (Young et al, 2004).

Planting trees at the river edge or on banks is also a form of modifying physical habitats in rivers. Riparian planting can be an effective way to quickly restore bank stability, improve stream habitat, and control streambank erosion (Phillips & Daly, 2008). Willow trees are commonly planted in New Zealand as they grow faster than native species. However, willow can invade stream channels, causing stream diversions and blockages and disrupting habitats for freshwater species (Phillips & Daly, 2008).

Deposited fine sediment can degrade freshwater habitats

Deposited sediment occurs naturally in the beds of rivers and streams, but too much fine sediment (particles less than two millimetres in size) can severely degrade streambed habitat (Davies-Colley et al, 2015). Excess fine sediment fills up the spaces between cobbles and gravel used by fish and invertebrates and can alter food resources or make them difficult to consume (Davies-Colley et al, 2015). Excess fine sediment can also affect the aesthetic appeal of rivers and streams for human recreation.

Erosion from the land results in the deposition of sediment in rivers. For example, our fast-eroding Southern Alps produce masses of sediment (eg boulders, rocks, cobbles, sand, silt, and clay), most of which is initially displaced by landslides, large gullies (Fuller & Marden, 2008), and earthflows (Glade, 1998). Sediment is then transported downstream by water and gravity; during this time abrasion contributes to the creation of fine sediment. These processes of transport and abrasion have contributed to the formation of our iconic braided river systems and many of our flat land areas (like the Canterbury Plains) (Gray et al, 2016). Because sediment is naturally transported longitudinally through a river network, its state at any given point will be influenced by climate, geology, topography, and current velocity (Knighton, 1998).

Human activities can have a negative impact on the natural sediment cycle by accelerating the delivery of sediment to streams and increasing the quantity of smaller particle sizes. Changes in land cover are one factor that can alter rates of erosion (Dymond et al, 2010). Native forests covered 85 to 90 percent of New Zealand before humans arrived around 1,000 years ago (Quinn & Phillips, 2016). Polynesian settlers cleared the forests with fire, reducing the original forest by half. Subsequent European colonisers further reduced forest cover to make way for agricultural and urban land use (Quinn & Phillips, 2016). Accelerated erosion is still being caused by human activities like earthworks, forest harvesting, livestock farming, and cultivation practices. Basher (2013) suggested that annual sediment loads (the amount of eroded sediment that makes its way into streams) from agriculture may have been declining over the past 30 years. This is based on changes to land cover (eg an increase in plantation forestry and scrubland), but does not take into account variations in weather or other factors that may also be having an effect on sediment loads.

There are not many sites across the country where fine sediment deposition has been observed over the long-term using consistent methods. This makes it challenging to report on deposited fine sediment at a national level (Hicks et al, 2016; Clapcott et al, 2011).

A spatial model was developed using the sediment observations from the New Zealand Freshwater Fish Database. The model estimated an average fine-sediment cover of 29 percent for stream segments (Clapcott et al, 2011). The same model also estimated an average fine sediment cover of 8 percent in the absence of human land use and land-cover change, suggesting a significant increase in deposited fine sediment cover has occurred in New Zealand rivers since human occupation. In future, collecting robust data is needed to validate such estimations, as fine-sediment levels greater than 20 percent cover are known to have adverse effects on streambed life (Clapcott et al, 2011; Burdon et al, 2013).

For more detail see *Environmental indicators Te taiao Aotearoa*: Streambed sedimentation.

Wetland habitats have been greatly reduced

Wetlands perform many functions. They filter nutrients and sediment from water, absorb floodwaters, and provide habitat for plants, fish, and other animals. The draining of our wetlands due to land-use change and farming practices has led to a loss of biodiversity and natural function (Clarkson et al, 2013).

Although we have no national information on the health of our wetlands, we have information on their extent. Before human habitation, wetlands covered approximately 2.5 million hectares of New Zealand's land area. In 2008, the extent of wetlands reduced to approximately 250,000 hectares – 10 percent of their original extent (Ausseil et al, 2008).

Wetland losses occurred historically through drainage and conversion to farmland (McGlone, 2009). Although we are less clear on contemporary patterns of national wetland extent, we know that losses are still occurring today. For example, in Southland a loss of 1,235 hectares, which equates to 10 percent of wetlands outside the area's public conservation land, occurred between 2007 and 2014–15 (Ewans, 2016).

The West Coast has the greatest extent of wetlands (84,000 hectares), followed by Southland (47,000 hectares), and Waikato (28,000 hectares) (Ausseil et al, 2008).

For more detail see *Environmental indicators Te taiao Aotearoa*: Wetland extent.

Structures in water bodies can obstruct fish migrations

Structures commonly found in our streams and rivers, such as dams, weirs, culverts, and tide gates, affect river flows and can obstruct fish migration (Franklin et al, 2014). A significant proportion of New Zealand native fish species need to migrate to and from the sea to complete their life cycles (McDowall, 2010). In-stream barriers prevent fish from reaching suitable habitats and food sources and completing their life cycles. Ultimately, this restricts the quantity and quality of habitat that is available for these species to colonise, as they can only use areas that retain access to the sea.

Barriers to fish can result in changes to the composition of fish community above and below the barrier. For example, research into dams in New Zealand found sites above dams had fewer fish species, lower proportions of diadromous fish species (fish that spend parts of the life cycle in fresh water and the ocean), and higher proportions of exotic fish species (Jellyman & Harding, 2012).

The combined physical characteristics of the barrier and surrounding environment, and the swimming or climbing ability of a fish species, determine the extent to which a barrier may negatively impact a fish community (Franklin et al, 2014). For example, īnanga (one of the five whitebait species) are weak swimmers and cannot climb, whereas juvenile eels/tuna can move through small spaces both in and out of water, and climb most wetted surfaces (Stevenson & Baker, 2009). However, not all barriers are detrimental to fish communities; in some circumstances, the barrier will prevent invasive species from reaching the fish community, thereby protecting the ecosystem. For example, our native galaxid fishes can persist and thrive in habitats above barriers that keep out exotic trout (Woodford & Mcintosh, 2010; Townsend & Crowl, 1991).

The extent and degree to which human-made structures in our water bodies obstruct fish passage are not known nationally. Several regional councils do collect this information, but in inconsistent ways. In one regional example, data from Hawke’s Bay shows that 80 of 240 (33 percent) culverts, weirs, and stormwater pump stations were identified as barriers to fish passage during some or all flow conditions between 2002 and 2010 (analysed by Ministry for the Environment and Stats NZ).

An example of a barrier to some fish.

Source: NIWA

For more detail see *Environmental indicators Te taiao Aotearoa*: Selected barriers to freshwater fish in Hawke's Bay.

Pest species pose a major threat to fresh water biodiversity

Many algae, plant, and animal species introduced intentionally or accidentally into our environment (pests) have altered freshwater ecosystems and contributed to the decline in native freshwater species (Collier & Grainger, 2015). New Zealand is considered one of six global hotspots for non-native fish introductions, with 21 species of non-native fish in our freshwater ecosystems. The number of non-native freshwater fish species in New Zealand has increased from 12 in the 1930s to 21 in 2010 (Collier & Grainger, 2015).

Pest species can reduce native biodiversity by preying on native species, competing for food and habitat, and damaging freshwater habitats (see *Koi carp in New Zealand*). Freshwater plant pests can cause economic losses by blocking water intakes for hydroelectricity generation, impeding drainage and irrigation, and affecting cultural and recreational values and landscape aesthetics.

Koi carp in New Zealand

Of all our introduced freshwater fish, the Koi carp has the most adverse impact on the key components of freshwater ecosystems (Rowe & Wilding, 2012). Presumed to have arrived in New Zealand in the 1960s, the Koi carp feeds on material in sediment, stirring this material as it feeds. This resuspension of sediment and nutrients reduces water clarity and can lead to algal blooms. The Koi carp also feeds on invertebrates and the eggs of other fish, and competes with our native freshwater species. It is found in the North Island, and is widespread in Auckland and Waikato. Since its eradication from Nelson in 2001–03, it is no longer present in the South Island (Collier & Grainger, 2015).

Source: Bruno David

Introduced species, such as trout, can also have recreational and food-gathering benefits. The brown trout was brought to New Zealand in 1867. Its successful establishment has been a boon for recreational anglers, but has also had negative impacts on New Zealand streams (Townsend, 2003). In many streams, trout have replaced native galaxiid fish and altered how kōura (freshwater crayfish) and other large invertebrates are distributed (Mcintosh et al, 2010; Usio & Townsend, 2000). Because trout prey on invertebrate species that graze algae, algal biomass has been found to be six times higher in some streams with trout compared with neighbouring streams without trout (Townsend, 2003).

Once established, freshwater pest species can be difficult to control or eradicate. For example, didymo (*Didymosphenia geminata)*, an introduced algae first discovered in New Zealand in 2004, is now found in many South Island rivers. A study of 20 South Island rivers found that fish biomass tends to decline to up to 90 percent when there is a heavy infestation of didymo (Jellyman & Harding, 2016). Controls of didymo have been trialled but finding an effective and environmentally acceptable control is challenging, especially considering didymo can regenerate from a single cell (Ministry for Primary Industries, nd).

In 2013, nine fish species, 11 invertebrate species, and 41 algae and plant species were identified as pests of greatest concern to our freshwater environments (see table 6; Champion et al, 2013). This means these species have the potential to form self-sustaining populations in other freshwater ecosystems beyond their present range, indicating that pressures from these pest species could get worse.

Table 6: Number of pest species of greatest concern by major taxonomic group, 2013

Species group	Species	Species thought to no longer be present in New Zealand at time of publication in 2013	'Unwanted' or 'notifiable' species listed in the Biosecurity Act 1993
	Number		
Fish	9	1	3
Invertebrates	11	2	2
Plants (algae)	2	0	1
Plants (freshwater weeds)	39	4	28

Source: Champion et al, 2013

For more detail see *Environmental indicators Te taiao Aotearoa*: Freshwater pests.

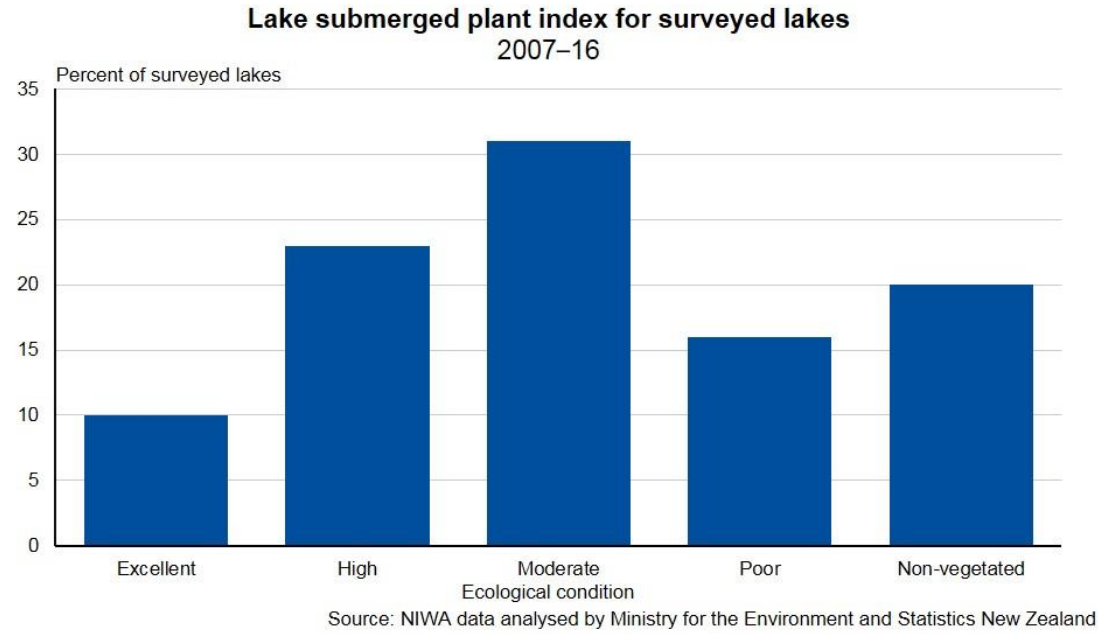
Status of the health and mauri of ecosystems and habitats

When the mauri of freshwater ecosystems is intact, they provide habitats (food, water, cover, and space) so a diversity of plants, animals, insects, and other organisms can thrive. Biodiversity is a key component of ecosystem health, and underpins important ecosystem processes, such as decomposition and nutrient cycling.

Ecological condition of surveyed lakes varies

The lake submerged plant index provides an indication of the ecological condition of lakes, which is informed by the diversity and distribution of native and invasive plant species (de Winton et al, 2012). Of 210 lakes surveyed for lake submerged plant index between 2007 and 2016, 33 percent were in excellent or high ecological condition, 31 percent were in moderate condition, and 36 percent were in poor ecological condition or non-vegetated (see figure 24) (analysed by Ministry for the Environment and Stats NZ). Only 10 percent of surveyed lakes (excluding non-vegetated lakes) had only native vegetation.

Figure 24



For more detail see *Environmental indicators Te taiao Aotearoa*: Lake submerged plant index.

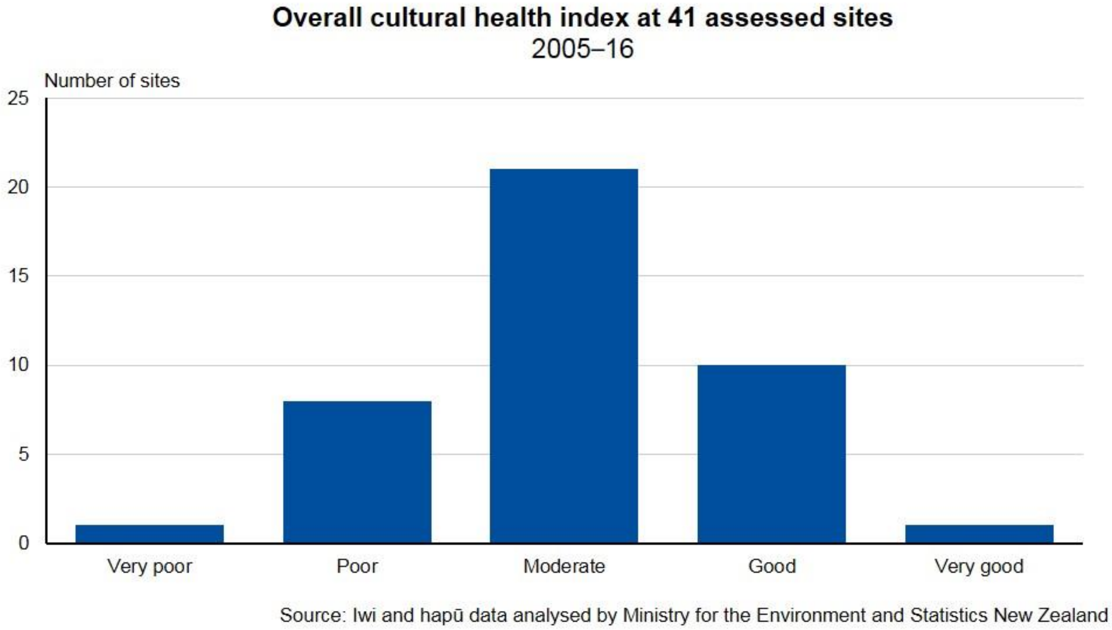
Mauri of tested sites varies

New Zealand's freshwater ecosystems are an important part of the culture and well-being of Māori. These ecosystems provide valuable resources, and support Māori values and practices such as mahinga kai (customary food gathering). The cultural health index (CHI) is one method that can be used to measure factors of cultural importance to Māori, giving an overall indication of the cultural health of a site on a water body. A CHI score cannot be applied without local indigenous knowledge.

A CHI score has three elements: site status (the association tangata whenua have with the site, and whether they would return); mahinga kai status (range of species present and species abundance); and cultural stream health status (water quality and land use).

CHI ratings were assessed at 41 sites between 2005 and 2016 by various iwi and hapū/runanga groups nationally (see figure 25). The majority of sites assessed were located in the South Island. Of the 41 sites assessed, 11 sites had a good or very good overall CHI rating. A further 21 sites had a moderate rating, and nine had a poor or very poor rating.

Figure 25



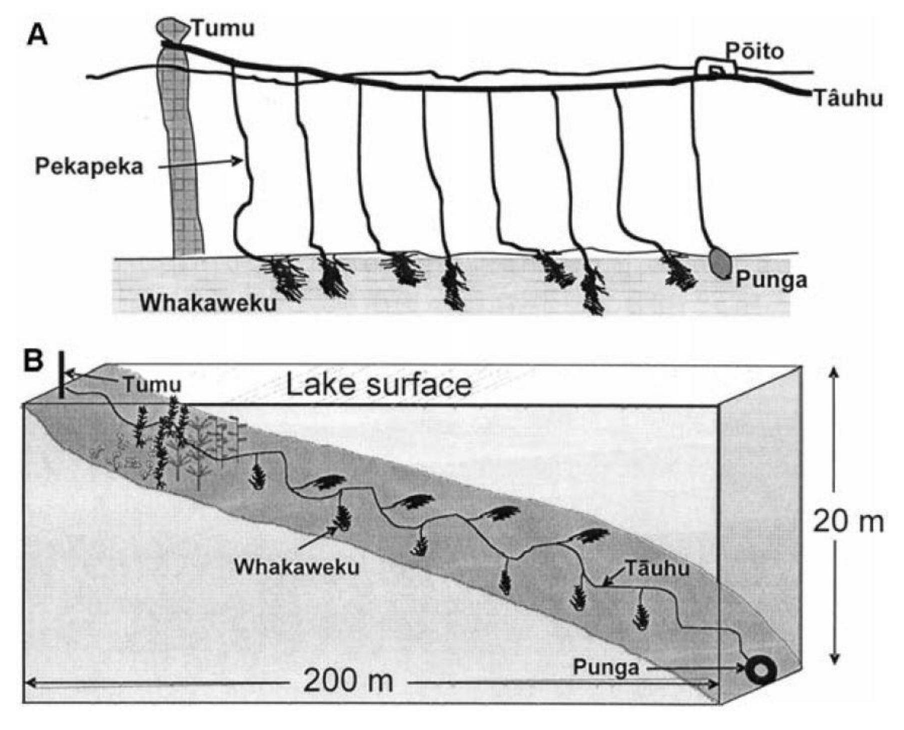
Mahinga kai status is one element that makes up the CHI. Of 39 assessed sites, the mahinga kai status was poor or very poor at 28 sites, moderate at seven sites, and good or very good at four sites. See *Kōura in the Te Arawa lakes* for an example of the impact of degraded mauri and habitats on mahinga kai.

Kōura in the Te Arawa lakes

Kōura (freshwater crayfish) is an important food for Māori. Today, it is considered a taonga species by Te Arawa iwi and hapū, and is important for mahinga kai activities on the Te Arawa lakes.

Iwi cultural histories and anecdotal evidence suggests kōura abundance in the Te Arawa lakes has been declining. This decline is thought to be caused by pressures such as the introduction of exotic plant and fish species, and increased nutrient concentrations causing excessive growth of algae that reduce oxygen levels in the lakes.

Limited information on kōura abundance and ecology has made it difficult for Māori to manage lake-dwelling kōura. Until recently, the main reason for a lack of quantitative information was the absence of suitable sampling methods (Kusabs & Quinn, 2009). Tau kōura (see figure below), a traditional method for harvesting kōura, has been resurrected by the Te Arawa iwi to improve the monitoring of kōura abundance in Te Arawa lakes (Kusabs et al, 2015). Tau kōura was found to be a more effective monitoring technique for kōura in the Te Arawa lakes compared with conventional methods such as baited traps.



Source: Kusabs & Quinn, 2009, based on Hiroa, 1921

Note: Diagram A shows the tau kōura, a traditional Māori method for harvesting kōura (freshwater crayfish) after Hiroa (1921). Pekapeka (drop line), tumu (post), pōito (float), tāuhu (surface line), punga (anchor), whakaweku (fern bundles).

Diagram B shows the modern-day tau kōura. The depth and length of tau are indicative and can be varied depending on lake bathymetry.

For more detail see *Environmental indicators Te taiao Aotearoa*: Cultural health index for freshwater bodies and Tau kōura: freshwater crayfish traditional fishing method.

Some ecosystems are poorly understood

We have incomplete knowledge about the health of our freshwater ecosystems and habitats. A lot of information on freshwater ecosystems and habitats for certain water bodies or catchments are collected by various organisations; however, national-scale data are limited.

There are aspects of freshwater ecosystems we still know little about. For example, we know that wetlands have declined in extent, but we do not know much about the health of the wetlands that still exist. We also have limited information, nationally, on fish and invertebrate communities. We lack information on big (non-wadeable) rivers. We know very little about the biological component of groundwater ecosystems, even though understanding the microbial (bacteria) activity within aquifers is important in understanding how nutrients are processed (Sirisena et al, 2013).

Status of our freshwater species

New Zealand has a diverse range of native freshwater plants, fish, and invertebrates, many of which are endemic (found nowhere else in the world), while some have very localised distributions.

Our freshwater environment supports approximately 53 known resident native freshwater fish species (Goodman et al, 2014), and 630 known native freshwater invertebrate taxa (Grainger et al, 2014), and 559 freshwater-dependant plant and algae taxa (Gerbeaux et al, 2016).

More than half our known fish species migrate between the sea and fresh water to complete their life cycles, meaning they can be severely affected by barriers to migration in rivers and streams (McDowall, 2010). In addition, 21 freshwater fish species, including trout and salmon, have become naturalised after being deliberately or accidently introduced to New Zealand through human activities (Collier & Grainger, 2015).

Many New Zealand bird species live around our wetlands, rivers, and lakes, including threatened iconic and taonga species – kāki (black stilt), whio (blue duck), and the kōtuku (white heron). Other native animals live in, or depend on, our freshwater ecosystems, such as the at-risk Hochstetters frog. Wetland and riparian environments are also home to a range of native plants – these include taonga species which Māori use in rongoa (medicine), raranga/ahatu (weaving), and mahinga kai.

This section focuses on information we have on our freshwater fish, invertebrates, plants, and algae.

Six of the 11 freshwater species for which we have data have declined in abundance over the past 39 years

The presence of a fish species at a site can be affected by changes in catchment land cover, land use, in-stream habitat, fish passage (routes for moving up and down rivers and streams), pests, and contaminants.

National-scale information on the abundance, distribution, and trends in freshwater fish is currently limited. To overcome this limitation, trends in abundance of freshwater fish were analysed using data from the New Zealand Freshwater Fish Database (NZFFD). However, anyone can enter information in the NZFFD (ie there are no set sites or methods used for capturing fish), which means there are sampling differences across sites and time.

To reduce the impact of sampling differences on the trends in the abundance of fish species over time, NZFFD data was standardised using generalised linear models to take into account the different number of samples between years and the differences in sampling (Crow et al, 2016). These models estimate the probability that a species will be present for each year of the 1977–2015 period.

There were enough data to assess trends in abundance for 10 fish species and for kōura (freshwater crayfish). Of the 11 freshwater species, trends for six species were declining and two were improving, over 39 years from 1977 to 2015 (Crow et al, 2016). The six fish species that had declining trends were four native species (longfin eel, kōaro (a whitebait species), Canterbury galaxias, and common bully) and two exotic species (rainbow trout and brown trout). Two species had improving trends over the 39 years (upland bully and shortfin eel). For the other three species (redfin bully, torrentfish, and kōura), the trend was indeterminate, meaning there are insufficient data to determine a trend. For each of the eight species where a trend could be determined, the trends were improving or declining less than 0.5 percent a year.

For more detail see *Environmental indicators Te taiao Aotearoa*: Trends in freshwater fish.

Many freshwater species are under threat

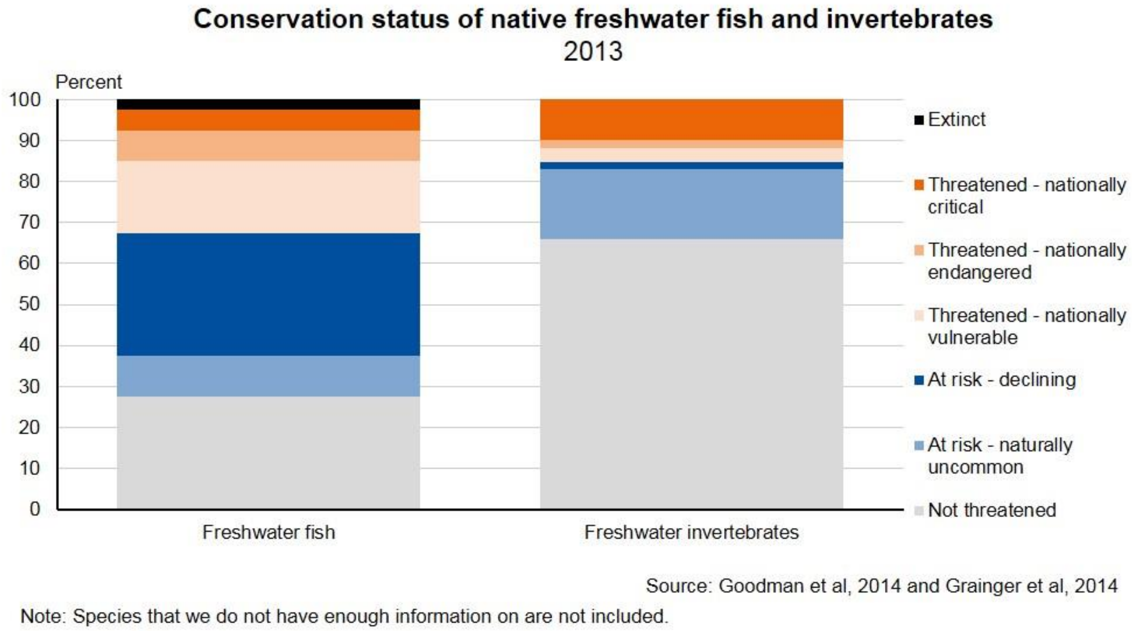
Conservation status refers to the threat classification of resident native freshwater plants, fish, and invertebrate taxa. The Department of Conservation (DOC) developed the New Zealand Threat Classification System to provide a national system similar to the International Union for Conservation of Nature and Natural Resources Red List (see Appendix: New Zealand Threat Classification System for a description of the threat classification categories).

Experts assign a threat of extinction status through a DOC-led process, based on criteria of abundance, distribution, and trends. The criteria are used to monitor the status of individual species and report on the state of native biodiversity (Townsend et al, 2008). We looked at the conservation status of freshwater plants and animals for which we had sufficient information on taxonomy, distribution, and abundance (ie plants and animals that were taxonomically indeterminate and data deficient were excluded from this analysis). This means we only report on 39 of 53 fish species (39 excludes one extinct species), 435 of 630 invertebrate taxa, and 537 of 559 freshwater-dependent plant and algae taxa (537 excludes one extinct plant).

Around three-quarters of our known native freshwater fish are threatened with, or at risk of, extinction

We have one known extinct freshwater fish, the once widespread and common New Zealand grayling. Of New Zealand’s remaining 39 known native freshwater fish species, 72 percent were either threatened with extinction (12 species) or at risk of extinction (16 species) in 2013 (Goodman et al, 2014; see figure 26 and Appendix: New Zealand Threat Classification System). Native freshwater fish species listed as threatened with, or at risk of, extinction include taonga species – such as īnanga, shortjaw kōkopu, giant kōkopu, kōaro (all are whitebait species), kanakana/piharau (lamprey), and tuna (longfin eel). Most at risk or threatened freshwater fish are at risk of a ‘high ongoing decline’ or a ‘predicted decline’ in population size (see Human activities are degrading some ecosystems for more information on the pressures on our freshwater species).

Figure 26



Of the 12 freshwater fish species listed as threatened, two (Otago longjaw galaxias and Canterbury mudfish) are in the highest threat category (nationally critical), meaning they are at a high risk of extinction. Both species are considered likely to become extinct if current conservation management ceases (Goodman et al, 2014).

No improvements in conservation status for native freshwater fish occurred for species that can be directly compared between the two assessment periods (2009 and 2013). Declines in conservation status were observed for four species – Central Otago roundhead galaxias, Canterbury galaxias, black mudfish, and lamprey (kanakana/piharau), an important taonga species (see *The conservation status of lamprey (kanakana/piharau)*; Goodman et al 2014).

The conservation status of lamprey (kanakana/piharau)

The lamprey (kanakana/piharau) is a unique freshwater fish species. Like the tuatara, it is often described as a living fossil that has remained unchanged for hundreds of millions of years. It is a jawless fish, with a distinctive sucking disk mouth. The lamprey migrates into rivers to spawn, and the juvenile lamprey spends four years in rivers and streams before migrating out to sea. The lamprey is a taonga, and is a traditionally important mahinga kai species. It is threatened with extinction (Goodman et al, 2014).

Source: Robert Holdaway

For more detail see *Environmental indicators Te taiao Aotearoa*: Conservation status of freshwater fish and invertebrates.

About one-third of our known native freshwater invertebrates are threatened with, or at risk of, extinction

Freshwater invertebrates include many organisms such as crustaceans, molluscs, worms, and freshwater insects. In 2013, 34 percent of our known native freshwater invertebrates were threatened with extinction (66 species of 435) or at risk of extinction (82 species) (Grainger et al, 2014; see figure 26). The South Island kōura (freshwater crayfish) and all three species of freshwater mussel (kākahi/kāeo) are included in the at risk or threatened categories.

Forty-two invertebrates (10 percent) are in the highest threat category (nationally critical).

Of the invertebrates that can be directly compared between assessment periods (2005–13), three invertebrates had a decline in conservation status.

For more detail see *Environmental indicators Te taiao Aotearoa*: Conservation status of freshwater fish and invertebrates.

Almost one-third of our known native freshwater-dependent plants are threatened with, or at risk of, extinction

Freshwater-dependent plants include vascular plants, mosses, hornworts and liverworts, and green algae that live in and round freshwater. We have one known extinct plant, *Stellaria elatinoides*, thought to have been naturally uncommon and succumbed to over-collection and weed competition in its tussock and lake margin habitats (Norton et al, 1997). Of the remaining 537 plant taxa, 71 plant taxa (13 percent) are threatened with extinction, of which there are 34 plant taxa in the highest category, threatened – nationally critical (Gerbeaux et al, 2016). A further 97 plant taxa (18 percent) are at risk of extinction. None of the common weaving plants (eg kiekie, pingao, raupo) are threatened with, or at risk of, extinction.

Our knowledge of our native freshwater biodiversity is limited

An additional 14 fish, 197 invertebrates, and 22 freshwater-dependant plants do not have generally accepted or formalised taxonomy, or we lack sufficient information on their distribution and abundance to assign a conservation threat classification. This means the current number of species threatened with, or at risk of, extinction may be under-reported.

Biodiversity loss has wider ecosystem impacts

Declining ecosystem health and the resulting degradation and loss of habitat of some freshwater bodies are affecting New Zealand's freshwater biodiversity. Our freshwater algae, plants, fish, and invertebrates interact resulting in complex ecosystems. Invertebrates perform important ecosystem services such as grazing on periphyton (algae) and breaking down leaves and wood (Mcintosh, 2000). They also provide food for our native fish and birds and some provide food to humans (eg kōura (freshwater crayfish) and kākahi (freshwater mussel)). Changes to invertebrate communities through habitat loss (eg when sediment clogs spaces between pebbles) can affect the ability of our native fish to feed, and the availability of freshwater resources for food, and recreational and customary uses.

The loss or decline of a single species can have detrimental effects on other species and the wider ecosystem. For example, a decline in numbers of the at-risk kōaro may also negatively affect the at-risk kākahi (freshwater mussel), which use the kōaro as a host during the parasitic larval stage of their life cycle (Phillips et al, 2007). In turn, a decline in kākahi numbers could potentially result in less nutrients and sediment being filtered from the water, which in turn may alter the water quality and habitat for other freshwater species.

Implications of degrading ecosystems

The health and mauri of some of our freshwater environments, and the habitats and species they support, have declined because of multiple pressures from human activities. The changes to our fresh water are due to increased contaminants and sediment, altered water levels and flows, introduced invasive species, and the building of dams and other in-stream structures.

Habitat degradation and loss are some of the most pervasive threats to freshwater species, both internationally and in New Zealand (Weeks et al, 2016). Habitat degradation has resulted in a decline in freshwater species throughout the world (Dudgeon et al, 2006), and New Zealand is no exception. In addition, New Zealand is vulnerable to biodiversity loss, as many of our native species are endemic (found nowhere else in the world). Our tourism industry leverages on our reputation as a country with relatively unspoiled nature and unique fauna. Freshwater ecosystems also provide opportunities and resources for recreational activities such as fishing, and customary activities such as mahinga kai.

Data gaps

We summarise some of the many gaps in available data about water quality. We acknowledge that information to fill some of these gaps may already exist, or research is underway. We intend to provide information that will fill these gaps (if available) in our next report on fresh water.

- Ecological and cultural health of wetlands.
- The national extent and severity of barriers to fish migration.
- Information on how the freshwater network is connected and the impact of modifications to rivers on the connectivity of the network, including changes in physical habitat.
- Nationally consistent deposited fine sediment data, and the impact of human-induced accelerated erosion on freshwater habitats.
- Freshwater habitat quality and quantity.
- The linkages among biodiversity, ecosystem function, and environmental stress, including stress improved by pest plant and animal species.
- The health of taonga species and the impact this has on te ao Māori, including mahinga kai practices.
- Cultural health information on a larger number and geographic distribution of water bodies.
- The sensitivity and vulnerability of freshwater ecosystems to climate change.
- Increased information on the taxonomy, distribution, and abundance of freshwater plants, wading birds, amphibians, and freshwater fish, invertebrates and microorganisms.
- National distribution and abundance data for freshwater fish, invertebrates, and plants.

Acknowledgements

We would like to thank the following people and organisations for their invaluable contribution to this report.

Data providers

In New Zealand, environmental monitoring is shared across central government agencies, Crown research institutes, and local government. Regional and unitary councils are obliged to monitor our fresh water under the Resource Management Act 1991. Much of the information in this report comes from the data regional councils and other agencies collect.

We would like to thank the following organisations for providing data for this report.

Auckland Council, Bay of Plenty Regional Council, Christchurch City Council, Department of Conservation, Environmental Science and Research (ESR), Environment Canterbury, Environment Southland, Gisborne District Council, GNS Science International, Hawke's Bay Regional Council, Horizons Regional Council, Landcare Research, Marlborough District Council, MetService, Ministry for the Environment, Ministry for Primary Industries, Nelson City Council, National Institute of Water and Atmospheric Research (NIWA), Northland Regional Council, Otago Regional Council, Pukekiteraki Papatipu Runanga, Stats NZ, Taranaki Regional Council, Tasman District Council, Te Arawa Lakes Trust, Waikato Regional Council, Wellington Regional Council, West Coast Regional Council.

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We would like to thank our technical advisors for reviewing drafts of this report. Technical advisors encompass a range of individuals from various organisations who have expertise in technical matters related to the freshwater domain. The role of technical advisers is to support freshwater reporting by providing advice on strategic and technical details of environmental reporting of the Freshwater Domain.

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Glossary

agricultural intensification	An increase in agricultural production per unit of inputs (which may be labour, land, time, fertiliser, seed, feed or cash).
agriculture	The cultivation and breeding of animals, plants and fungi for food, fiber, biofuel, medicinal plants, and other products used to sustain and enhance human life.
aquifer	An underground layer of water-bearing rock or sand from which groundwater can be extracted.
biodiversity	The variability among living organisms, and the ecological systems they are part of. Includes the diversity within species, between species, and of ecosystems.
catchment	Area of land in which rainfall drains toward a common stream, river, lake, or estuary.
climate change	Change in global or regional climate patterns, evident over an extended period (typically decades or longer). May be due to natural factors or human activities.
***E.coli (Escherichia coli*)**	Bacteria normally found in the gut of warm-blooded animals and people. Some types can cause illness, such as *Campylobacter,* which can be transmitted through contaminated water or food, or through contact with infected animals or people.
ecosystem	A community of plants, animals, and microorganisms in a particular place or area, interacting with the non-living components of their environment (like air, water, and mineral soil).
endemic	A plant or animal that occurs naturally only in one place or region.
groundwater	Water located beneath earth's surface in pore spaces (the spaces within a rock body that are not occupied by solid material) and fractures of rock formations.
habitat	A combination of environmental factors that provides food, water, cover, and space that a living thing needs to survive and reproduce.
indeterminate	For river and lake water quality analyses, indeterminate means there is not enough data to determine trend direction (Larned et al, 2015). For groundwater quality, indeterminate means the trend was not significant at a p-value < 0.05.

indigenous	Belonging naturally to a given region or ecosystem, as opposed to an animal or plant that is exotic or introduced. Also referred to as 'native'.
invertebrate	An animal without a backbone or spinal column. Insects, spiders, worms, slaters, and many marine animals such as corals, sponges, and jellyfish are examples of invertebrates.
macroinvertebrate	Small animal that has no backbone and can be seen with the naked eye (eg insects, freshwater crayfish, snails, and worms).
mahinga kai	Customary food gathering. Mahinga kai also refers to the native freshwater species of plants, fish, and animals that have traditionally been used as food, tools, and other resources.
mātauranga Māori	The knowledge, comprehension, or understanding of everything visible and invisible existing in the universe, and often used to mean 'wisdom'. Often includes present-day, historic, local, and traditional knowledge; systems for transferring and storing knowledge; and goals, aspirations, and issues from an indigenous perspective.
mauri	Mauri means life force. It is the spark of life, the active component that indicates life. Mauri is found in all living things on earth, forests, rivers, gardens, lakes, the sea, and the air. For Māori, all parts of the environment – animate and inanimate – are infused with mauri (life force) and are connected to one another.
median	The midpoint of a series when the data are listed in ascending order. Half the numbers or values are above the midpoint, and half are below it.
monitoring site	Site where equipment is deployed to sample and/or measure the quality of water.
native	Belonging naturally to a given region or ecosystem, as opposed to an animal or plant that is exotic or introduced. Also referred to as 'indigenous'.
pastoral	Land use for keeping and grazing livestock.
riparian	Relating to, or situated on, the bank of a river or other water body.
species	A basic unit of biological classification, comprising individual organisms that are very similar in appearance, anatomy, physiology, and genetics, due to having relatively recent common ancestors. Species can interbreed.

stream order	Strahler stream order is used to define stream size based on a hierarchy of streams from the source (or headwaters) downstream. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream, and so on. At a confluence, if the two streams are not of the same order, then the highest numbered order is maintained on the downstream segment.
taxonomy	The description, identification, naming, and classification of organisms.

Appendix: New Zealand Threat Classification System

<table>
<tr><td colspan="2">Extinct</td><td>A species for which there is no reasonable doubt that the last individual has died.</td></tr>
<tr><td rowspan="3">Threatened species</td><td>Nationally critical</td><td>Fewer than 250 mature individuals (natural or unnatural); or
250–1,000 mature individuals and 50–70 percent decline over 10 years or three generations; or
Any population size with a greater than 70 percent population decline over 10 years or three generations, whichever is longer.</td></tr>
<tr><td>Nationally endangered</td><td>250–1,000 mature individuals (natural or unnatural) with a 10–50 percent population decline; or
250–1,000 mature individuals (unnatural) with a stable population; or
1,000–5,000 mature individuals with a 50–70 percent population decline.</td></tr>
<tr><td>Nationally vulnerable</td><td>250–1,000 mature individuals (unnatural) with a population increase of more than 10 percent; or
1,000–5,000 mature individuals (unnatural) with a stable population; or
1,000–5,000 mature individuals with a 10–50 percent population decline; or
5,000–20,000 mature individuals with a 30–70 percent population decline; or
20,000–100,000 mature individuals with a 50–70 percent population decline.</td></tr>
<tr><td rowspan="4">At risk</td><td>Declining</td><td>5,000–20,000 mature individuals with a 10–30 percent population decline; or
20,000–100,000 mature individuals with a 10–50 percent population decline; or
>100,000 mature individuals with a 10–70 percent population decline.</td></tr>
<tr><td>Recovering</td><td>1,000–20,000 mature individuals with a population increase of more than 10 percent.</td></tr>
<tr><td>Relict</td><td>5,000–20,000 mature individuals with a stable population; or
More than 20,000 mature individuals with a stable or increasing population; or
All relict species occupy less than 10 percent of their original range.</td></tr>
<tr><td>Naturally uncommon</td><td>Species or subspecies whose distribution is naturally confined to specific habitats or geographic areas (eg subantarctic islands), or that occur within naturally small and widely scattered populations. This distribution is not the result of past or recent human disturbance. Populations may be stable or increasing.</td></tr>
<tr><td colspan="2">Not threatened</td><td>Species or subspecies that are assessed and do not fit any of the other categories are listed in the ‘not threatened’ category.</td></tr>
</table>

Source: Department of Conservation

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