Our freshwater 2023

New Zealand's Environmental Reporting Series

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Contents

Introduction

Aotearoa New Zealand's freshwater environment

Aotearoa New Zealand's freshwater environment supports all aspects of our lives, and we share an intimate and innate connection with it. It is central to wellbeing, supporting our economy, recreation, and gathering food. For many Māori, the freshwater environment is central to tikanga Māori (customs/protocols), mātauranga Māori (Māori knowledge), and mahinga kai (traditional food gathering practices).

Despite this, our freshwater environment is under pressure from our activities on the land and in the water, and from a changing climate. While some of our freshwater bodies are in a reasonably healthy state, many have been degraded by the effects of excess nutrients, pathogens, and other contaminants from land.

Most of our indigenous freshwater fish and freshwater bird species, including some taonga (treasured) species, are either threatened with extinction or at risk of becoming threatened. The effects of our historic and contemporary activities on our freshwater environment have impacts on many of the things we value as individuals, communities, and as a nation, such as our iconic and taonga species and being able to swim and practice mahinga kai without risk of illness.

This report has been produced at a particularly poignant time, in the immediate aftermath and initial recovery from a number of severe weather events, notably, Cyclone Gabrielle. The effects of these events have made the combined pressures of climate change, land use, and human modifications to waterways more evident than ever before.

While this report covers these pressures and impacts, it does not discuss them in the context of recent severe weather events. Reporting on topics requires an understanding that is grounded in robust data and validated research, and scientific evidence is only beginning to emerge for these events. As new evidence and research about these events is published, it will be available to inform future reports.

Indicators presented in this report alongside the research literature are based on the best available science and highlight the issues facing the freshwater environment. Ongoing monitoring and advancing research have improved our understanding of these issues, but there are still gaps in our knowledge. This is primarily owing to the challenge presented by the scale and diversity of the freshwater environment, and by the complexity of interactions between land-based pressures and their impacts on freshwater. These and other issues are discussed in the Data and research gaps section.

About Our freshwater 2023

Our freshwater 2023 is the latest in a series of environmental reports produced by the Ministry for the Environment and Stats NZ. It is the third report in the series dedicated to the freshwater environment, following the 2017 and 2020 reports, and is part of the third cycle of reports released under the Environmental Reporting Act 2015.

In 2019 the Parliamentary Commissioner for the Environment (PCE) released his report, *Focusing Aotearoa New Zealand's environmental reporting system* (PCE, 2019). The report identified how the environmental reporting system can be improved, and recommended changes to the system and amendments to the Environmental Reporting Act. Implementation of these changes is in progress and will provide a stronger foundation to ensure we better understand te taiao (the environment) and the impacts people are having on it.

Our freshwater 2023 continues the scaled-back format for environmental reports first signalled in *Our air 2021*, making information available while we progress the fundamental changes needed to improve the reporting system to align with recommendations from the PCE (PCE, 2019). This is an information-oriented release, with the primary focus on recent information about the freshwater environment. This report brings current freshwater indicators together with what we know from past reports and insights from the research literature. Interactive graphs and maps can be found on the Stats NZ website (see links to indicator web pages throughout this report).

Our freshwater environment: everything is connected

Our freshwater environment is under pressure. These pressures lead to changes in the state of the environment – and these changes have impacts on ecosystems, our lives, and things that are important to us.

There are many pressures, changes in state, and impacts, and the relationships between them are complex. Here are two simplified examples.

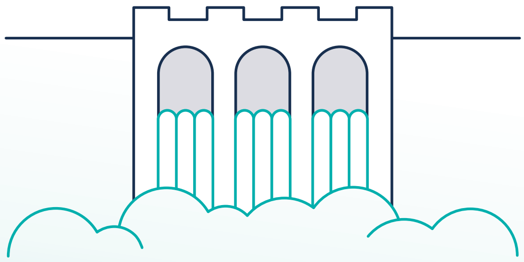
Pressure

LAND USE

Agriculture, forestry, and urban expansion can increase contaminants like harmful amounts of nutrients, such as nitrogen and phosphorus.

STRUCTURES AND MODIFICATIONS

Dams and other structures have changed the natural flow of our waterways and water bodies, and the connections between them.



State

LAND USE

An important way we gauge the health of freshwater ecosystems is the trophic level index (TLI). It gives a score based on nutrient and algae levels.

46% of all our lakes larger than 1 hectare have poor or very poor health, according to computer model estimates of TLI scores between 2016 and 2020. Only 2% of those lakes rated good or very good.

STRUCTURES AND MODIFICATIONS

Native freshwater fish play an essential role in freshwater ecosystems, and many need to migrate to and from different areas and habitats to breed and feed.

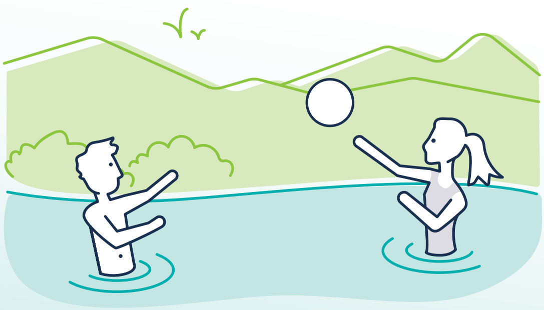
But some migratory species are threatened with extinction or at risk of becoming threatened – including taonga (treasured) species like tuna (longfin eels) and īnanga (whitebait).

Impact

LAND USE

Algal blooms and other effects of excess nutrients can harm freshwater species and ecosystems.

They can also restrict people's use of lakes and rivers for recreational activities like swimming.



STRUCTURES AND MODIFICATIONS

Mātauranga (Māori knowledge), tikanga (customs and protocols), mahinga kai (traditional food gathering practices), and other aspects of te ao Māori are impacted when fish are threatened, and habitats are degraded.

Report structure

As required by the Act, we use pressure, state, and impact to report on the environment and this forms the basis for the report's structure. The logic of the framework is that pressures cause changes to the state of the environment and these changes may have impacts on our values.

The report describes impacts on freshwater species and ecosystems, infrastructure, culture, economy, public health, and recreation. In addition, it explores our connections to the freshwater environment to the extent that is possible with the available information and identifies information gaps. Note that evaluation of specific policy is out of scope for environmental reporting releases under the Environmental Reporting Act 2015, so are not discussed here.

This report also continues discussions of wellbeing that were the focus of the last synthesis report, *Environment Aotearoa 2022*. The concepts of wellbeing that support this report include, among others, the Treasury's Living Standards Framework, the He Ara Waiora framework, and the view that our economic and non-economic wellbeing are inherently connected to te taiao (McMeeking et al, 2019; New Zealand Treasury –Te Tai Ōhanga, 2021; PCE, 2021). For further discussion connecting wellbeing with te taiao, see *Environment Aotearoa 2022*.

The data used in this report came from many sources including Crown research institutes and central and local government. Further supporting information was provided using a 'body of evidence' approach. This body of evidence includes peer reviewed, published literature, as well as mātauranga Māori and observational tools used to identify changes in the freshwater environment.

All data used in this report, including references to scientific literature, were corroborated, and checked for consistency with the original source. The report was produced by a team of analysts and scientists from within and outside of the Ministry for the Environment and Stats NZ, and was reviewed by a panel of independent scientists. The indicators related to the freshwater environment and the date they were last updated are available on the Stats NZ indicators web pages.

Te ao Māori, mauri, and our connection to freshwater

Wai (water) is essential for life. It sustains, cleanses, and refreshes our bodies and provides opportunities for recreation. Wai supports how we live. Freshwater appears in many forms, from tiny alpine streams and puna (springs) to large roto (lakes), repo (wetlands), and the widest awa (rivers). It is also present but unseen in underground rivers and aquifers.

In te ao Māori (Māori world view), the human and non-human worlds are indivisible. Different water bodies have different associated taonga species, and kaitiaki (guardians), that protect the mauri of the wai (Stewart-Harawira, 2020).

Mauri is a te ao Māori concept that describes the spark of life and active component of that life (Mead, 2003), and the binding force that holds together the physical and spiritual components of a being or thing (Durie, 1998; Morgan, 2006).

There is an intrinsic link between the health and wellbeing of wai and the health and wellbeing of communities (Harmsworth & Awatere, 2013; Stewart-Harawira, 2020). When the mauri of the freshwater environment is negatively affected this can affect the cultural, spiritual, and physical wellbeing of communities. Mauri has been used by many scientists to describe state and sustainability of a particular environment and indicators have been created to assist this (Morgan, 2006) (see: *Environment Aotearoa 2022*).

In te ao Māori there are many pūrākau (stories) about the origins of our freshwater systems, each with its own whakapapa (genealogy) to describe their relationships to these important waterways. Wainui-ātea is personified as the mighty waters and through her the other bodies of water are connected (Whaanga & Roa, 2021). After their separation, the soft mists of Papatūānuku (Earth mother) rise to greet Ranginui (sky father), and Ranginui's tears took the visible form of rain and dew that fall from the sky to give life to the land (Salmond et al, 2019; Reed, 2021). This highlights the holistic connection of water in the atmosphere, in groundwater, and on land. Our previous synthesis report, *Environment Aotearoa 2022*, framed the freshwater domain with Waitī. She is the whetū (star) in Te Kāhui o Matariki (the Matariki cluster) who is connected to the freshwater environment (see *Environment Aotearoa 2022*).

Taonga species are endemic to Aotearoa New Zealand (found nowhere else in the world) and significant to Māori, being unquestionably treasured. Taonga species vary among whānau, hapū, and iwi: this can be due to whakapapa connection and identified kaitiaki responsibilities. They are also connected to traditional Māori practices and knowledge (Waitangi Tribunal, 2011). Taonga species names can also vary according to their life-cycle stage, iwi and hapū dialect, and within different regions. Taonga species represent symbols of status, association with death, tohu (signs), predictions of weather, metaphors, and stories (Keane-Tuala, 2015).

Pressures on our freshwater environment

Photo: *Kiwi Droneography – truestock*

Our freshwater environment is an interconnected system and is affected by many pressures from human activities.

Land-based activities in catchments have detrimental effects on freshwater through excess sediment, nutrient, and contaminant pollution, and these pressures have been amplified by the intensification and expansion of agriculture and urbanisation.

Diverting, controlling, and abstracting water from our waterways alters the natural flow and resilience of waterways ki uta ki tai – from mountains to the sea – and places pressure on species.

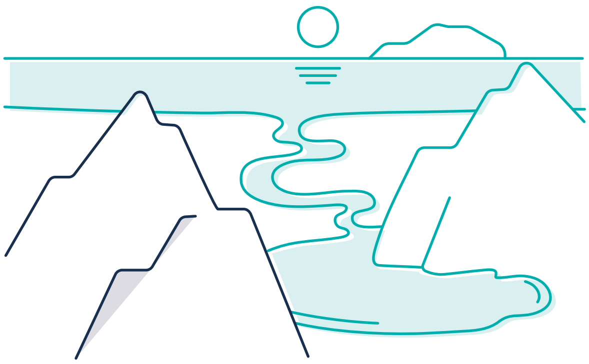
Increases in greenhouse gas emissions are raising sea levels at our coasts and increasing the magnitude and frequency of extreme rainfall and drought, which puts further pressure on the freshwater environment.

Pressures on our freshwater environment

Water is essential for life. But our freshwater environment continues to be affected by a variety of pressures – mostly due to the way we're using land and water, and the changing climate.

KI UTA KI TAI (MOUNTAINS TO THE SEA)

Freshwater comes in many forms, such as lakes, rivers, streams, wetlands, springs, and aquifers. They connect to each other, ki uta ki tai.



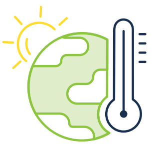
So, if one part of a catchment comes under pressure, there are flow-on effects.

STRUCTURES AND MODIFICATIONS

We've changed the natural flow of waterways and water bodies with dams, channels, stop banks, and culverts. This puts pressure on fish and other freshwater species.

Data suggests 48% of the country's river network is at least partially inaccessible to migratory fish – and the figure may be higher.

CLIMATE CHANGE



Freshwater species and ecosystems are under pressure due to our changing climate.

It is playing a role in:

- increasing droughts and floods
- raising sea levels
- heightening the risk posed by exotic pests.

LAND USE

High intensity agriculture – such as dairy farming – uses more fertiliser and irrigation than other types of farming.

Almost 60,000 hectares of exotic grassland was converted from low to high producing land between 1996 and 2018 – that's 2.5 times the size of Abel Tasman National Park.

Wastewater service suppliers reported more than 4,200 overflows due to wet weather events, or blockages and failures during dry weather in the year ending 30 June 2021.

Agriculture, forestry, and urban expansion can increase contaminants like bacteria, sediment, and harmful amounts of nutrients.

The freshwater environment is a holistic system that connects landscapes, ecosystems, and people.

- The kinship relationship between Māori and the natural world, through whakapapa (genealogy), views all people as part of the natural system including all forms of wai (water), flora, fauna, and natural resources (Harmsworth & Awatere, 2013; Stewart-Harawira, 2020).
- Ki uta ki tai acknowledges the journey that wai makes from the atmosphere to the mountains and across the land. As small and large streams connect and grow bigger, connect with lakes, reach into wetlands and estuaries, and eventually meet with the sea. It highlights how resources and ecosystems throughout catchments and the landscape are interconnected with cumulative pressures and the pressure of human activities affecting the mauri of freshwater (Harmsworth & Awatere, 2013; Hopkins, 2018). (See the Te ao Māori, mauri, and our connection to freshwater section for the definition of mauri used in this report.)
- Ki uta ki tai approaches are intrinsically connected to particular places, wai, whenua (land), and the values of the people that live there (Crow et al, 2018; Rainforth & Harmsworth, 2019) (see *Environment Aotearoa 2022* for more information).

Land-use intensification and other changes to how we use the land have increased pressures on water quality.

- Intensification involves increasing the use of inputs such as fertiliser and irrigation, with the aim of increasing production – for example, having more animals per hectare of land or increasing the number or volume of harvests from crops (see *Our land 2021*). This includes converting land that is used for less intensive agricultural land uses like sheep farming to more intensive uses like dairy farming.
- Analyses of national river water quality monitoring data for 2016 to 2020 show that water quality is more degraded when there is more high-intensity pasture and horticultural land upstream (Whitehead et al, 2022).
- Aotearoa has experienced one of the highest rates of agricultural land intensification over recent decades internationally (OECD/FAO, 2015 within Mouton et al, 2022). Between 1996 and 2018, almost 60,000 hectares of exotic grassland was converted from low producing to high producing, compared with only 3,500 hectares of exotic grassland converted from high to low producing (see indicator: Exotic land cover).
- Urban area increased 14.6 percent (30,264 hectares) between 1996 and 2018, with 24,396 hectares of this increase (81 percent) due to conversion of high producing exotic grassland and 2,602 hectares (9 percent) due to conversion of horticultural land (see indicator: Urban land cover). This loss of highly productive agricultural land means the agricultural land that remains must be farmed more intensely to sustain the same level of production (see *Our land 2021* for more information on urbanisation and highly productive land).
- The intensity of agriculture has increased since the 1980s particularly due to a switch from sheep to dairy farming (Wynyard, 2016). Dairy cattle numbers increased by 61 percent between 1996 and 2014, before falling 5 percent by 2018 (see indicator: Livestock numbers).

- The amount of irrigated land almost doubled between 2002 and 2019 from 384,000 hectares to 735,000 hectares (a 91 percent increase). Over the same period 73 percent of increases in irrigated land area were related to farms with dairy farming as their dominant farm type; 18 percent to grain, fruit and berry, and vegetable growing; and 9 percent to sheep and beef (see indicator: Irrigated land). Modelling indicates that the long-term changes in river water quality measured nationwide between 1990 and 2017 were closely associated with the proportion of upstream land dedicated to pastoral agriculture and plantation forestry, the type and intensity of the pastoral agriculture upstream, and how these changed over time (see Attribution of river water-quality trends to agricultural land use and climate variability in New Zealand, Snelder et al, 2021, for detailed information on this model).
- Models estimate that on-farm mitigations like fertiliser management and protecting waterways from livestock reduced the amount of phosphorus and sediment that reached our rivers between 1995 and 2015, but not nitrogen. While the mitigations were estimated to reduce nitrogen losses from individual farms, this was not enough to offset the effects of the expansion of dairy and intensification of pastoral agriculture, which resulted in an increase in the nitrogen that reached our rivers during this period (see Quantifying contaminant losses to water from pastoral landuses in New Zealand II. The effects of some farm mitigation actions over the past two decades, Monaghan et al, 2021, for detailed information on this model).
- Pressures from existing and intensifying land uses, and a changing climate, are contributing to spatial shifts in biodiversity and ecosystem function in New Zealand rivers (Mouton et al, 2022).

Land-based human activities contribute to excess nutrients and sediment in our fresh waterways.

- Livestock urine is the dominant source of nitrate-nitrogen leaching. Leaching occurs because some of the additional nitrogen that can't be used by plants and microorganisms may leach (drain) from the soil (see indicator: Nitrate leaching from livestock).
- Leached nitrate-nitrogen can enter groundwater and waterways, potentially causing ecological harm. The amount of nutrients leaching from the soil varies around the country because of differing land uses, climates, and soils (see indicator: Nitrate leaching from livestock).
- Fertilisers are added to soil to improve soil fertility. Surplus nutrients that aren't absorbed by plants, such as phosphorus, can run-off into freshwater bodies such as streams, rivers, and lakes (see indicator: Fertilisers – nitrogen and phosphorus).
- Research into soil physical properties suggests pasture irrigation can lead to soil compaction and less readily available water capacity, leading to increased nutrient leaching and run-off to waterways (Drewry et al, 2022).
- Erosion rates in Aotearoa are naturally high by international standards (Basher, 2013).
- Human activities on land such as urban expansion, forestry, and agriculture, can further increase the amount of sediment entering freshwater environments (Larned, 2020; Basher, 2013). When excess sediment exceeds the natural erosion rate it can cause greater ecological, cultural, socio-economic and recreational harm (Larned, 2020; Basher et al, 2011).
- In Aotearoa, most phosphorus enters rivers attached to eroded sediment (Elliot et al, 2005).

- Clear felling (the method used to harvest exotic forests in Aotearoa) exposes and disturbs soil, including from the construction of roads used for vehicle access during harvesting, which can increase erosion and the sediment loads to rivers and lakes (MfE & Stats NZ, 2019; Larned, 2020).
- Agriculture can accelerate soil degradation, erosion, and soil loss rates due to stock grazing on the land and treading on the soil, which can affect our waterways (Donovan, 2022).

Wastewater, stormwater, and livestock waste are sources of freshwater contaminants, such as pathogens and heavy metals.

- Wastewater discharge, including sewage, often from houses, businesses, and industrial processes, must be treated to reduce levels of pathogens and other contaminants before it can be released into freshwater. Wastewater that is discharged is not free of contaminants, and can contain high levels when treatment is incomplete, or the systems fail (see *Our freshwater 2020*).
- Almost half (47 percent) of publicly owned wastewater treatment plants discharge treated wastewater to rivers and lakes, while the remainder discharge it into the sea or onto land (DIA, 2018). Many industrial facilities, like meat and dairy processing plants, also operate wastewater plants that discharge into freshwater.
- In the national performance review by Water New Zealand, participating wastewater service suppliers reported that between 2020 and 2021 there were 4,268 reported overflows of wastewater due to wet weather events, or blockages and mechanical failures that occurred during dry weather. However, it is likely that this number is under reported (Water NZ, 2021).
- Stormwater is rainwater that comes off solid surfaces like roofs, roads, and asphalt and is piped into waterways or the sea. It is almost always collected separately from wastewater and is not generally treated.
- Stormwater can be polluted with pathogens from animal faeces, and from wastewater systems that leak or overflow to stormwater systems (LAWA, 2022; Leonard & Eaton, 2021). It can also be polluted with contaminants like hydrocarbons from leaking vehicles and industrial yards (Kennedy et al, 2016), and heavy metals from vehicles (copper from brake pads and zinc from tyres), metal roofing, and industrial yards (Gluckman et al, 2017; Kennedy & Sutherland, 2008).
- Heavy metals in high concentrations can be toxic to aquatic life. They can accumulate in sediments and living organisms (Boehler et al, 2017).
- Dung from sheep and cows contains pathogenic species of *Campylobacter*, *Cryptosporidium*, *E. coli*, and *Giardia*, which can contaminate waterways where livestock congregate. These pathogens can also be carried from farms into waterways by storm run-off, and contaminated surface water can infiltrate into groundwater (Devane et al, 2018; Leonard & Eaton, 2021).

Plastics and chemicals that have been produced and used for decades contaminate our freshwater environment.

- Plastic waste is a major problem: some plastics take centuries to break down, and large quantities continue to be produced (PMCSA, 2019).

- In 2021 and 2022 there were 807 items counted in Aotearoa freshwater ways in the Litter Intelligence programme, with most items (68 percent) being plastic. More information can be found at Litter Intelligence – Data (Litter Intelligence, nd).
- Microplastics are generally defined as plastic particles that are less than 5 millimetres in diameter (De Bhowmick et al, 2021). Microplastics have been found in urban streams in Aotearoa and are often transported via smaller urban streams (Mora-Teddy & Matthaei, 2020). A survey across 52 urban streams in Aotearoa found microplastics in samples from all sites (Mora-Teddy & Matthaei, 2020).
- Emerging contaminants are non-natural chemicals in the environment that have not been extensively monitored, and whose potential effects on human health and the environment are not well understood. Over 700 different compounds are classified as potential emerging contaminants including pharmaceuticals, pesticides, and personal care product additives (like shampoo preservatives), and industrial compounds such as flame retardants (NORMAN Network, 2016).
- Pesticides have been used in Aotearoa for many decades over large areas of land (Manktelow et al, 2005; Chapman, 2010; Rolando et al, 2016). Many pesticides (which include insecticides, herbicides, and fungicides) stay in the environment for long periods and can enter waterways.
- Emerging organic contaminants, such as biocides and pharmaceuticals, have been internationally shown to interact with microbial communities in freshwater environments and potentially increase the spread and development of antimicrobial resistance. Antimicrobial resistance is the development of resistance to antibiotics, mainly due to significant antibiotic use in humans and animals, threatening human and ecological health worldwide (Alderton et al, 2021).

Introduced freshwater species are widespread, with some degrading freshwater bodies and threatening native species.

- Some freshwater fish, invertebrate, plant, and algal species introduced to Aotearoa by humans, place pressures on our unique native species, ecosystems, and local economy (MPI, nd; DOC, ndm).
- Historically, over 200 species of freshwater animals and plants have been introduced to Aotearoa, mostly deliberately. Illegal and accidental introductions still occur (NIWA, 2020).
- In 2020, 9 fish species, 1 reptile species, 11 invertebrate species, and 35 plant species were identified as non-indigenous species of greatest concern for freshwater environments in Aotearoa (NIWA, 2020).
- Introduced fish account for more than 80 percent of fish species recorded at 925 river sites from 1999 to 2018. These were most prevalent in parts of Otago and the central North Island (MfE, 2020).
- Koi carp is an introduced freshwater fish species that puts pressure on our freshwater ecosystems. With a preference for still and slow-moving water, they destroy native habitat through stirring up mud when they feed, and also eat invertebrates and compete with native species (Tiaki Tāmaki Makaurau – Conservation Auckland, 2023).

- Some introduced species, such as morihana (common goldfish), trout, and brown bull-headed catfish, can be considered culturally important. For example, when īnanga (whitebait) was harder to source, brown bullhead catfish was considered an important food source (Taura et al, 2017; Tadaki et al, 2022).
- Didymo (*Didymosphenia geminata*) is an introduced algae species that can form thick, dense mats – sometimes over entire streambeds. Since its discovery in 2004 didymo has spread to more than 150 waterways in the South Island, but has not yet been detected in the North Island (Jellyman & Harding, 2016; MPI, 2020).

Structures for diverting or controlling water place pressure on freshwater flows and fish and kōura migrations.

- Structures for diverting or controlling water such as dams, weirs, culverts, fords, stop banks, and floodgates can affect the water flow and the connections between waterways in a catchment and put pressure on ecosystems (Franklin et al, 2018; Brierley et al, 2022).
- Blocking waterways and altering flow patterns alters the natural adaptability and resilience of rivers. The mauri of a river is adversely impacted through not being able to flow unobstructed from the mountains to the sea (PCE, 2012; Young et al, 2004). Confining waterways to well-defined channels has consequences for the volume of water in a river, how fast it flows, how the flows vary, and the connections between waterways (MfE & Stats NZ, 2020; Watene-Rawiri, 2022).
- Combined, these barriers and changing flows place pressure on the migration and spawning of taonga species such as īnanga, tuna (eels), kanakana/piharau (lamprey), and kōura (freshwater crayfish) (McDowall, 2000).
- The first national assessment of river barriers in Aotearoa found that we have approximately one barrier per 6.25 kilometres of river length on average. This is high compared to international reporting (eg Belletti et al, 2020), though this may be due to inclusion of smaller barriers other studies often exclude. Data suggests a minimum of 48 percent of Aotearoa New Zealand's river network is at least partially inaccessible to migratory fish, though a further 36 percent have not yet been assessed for barriers and could be potentially inaccessible (Franklin et al, 2022).
- Channelling rivers alters their natural character and can also erode riverbanks and increase the amount of sediment deposited downstream (Maddock, 1999; Fuller et al, 2011).

Hydropower and irrigation are the largest consented uses of freshwater, and place pressure on the timing and volume of freshwater flows.

- Models have predicted that irrigation greatly alters river flows in some parts of Aotearoa (see *National water allocation statistics for environmental reporting: 2018*, Booker & Henderson, 2019 for detailed information on this model). Of all consumptive water uses nationally, except for hydropower, irrigation had the largest consented allocation by total volume (58 percent) in the 2017/18 water reporting year. Hydropower consents are based on rates rather than volume, so this comparison excludes use for hydroelectric generation (Booker & Henderson, 2019) (see indicator: Consented freshwater takes).

- Most hydroelectric generation does not consume water, but some hydro schemes divert flows from one river system to another (like the Tongariro Power Scheme), or to the ocean (like the Manapōuri hydro station), and are considered consumptive (Genesis Energy, 2023; Engineering New Zealand, 2023).
- For the 2017/18 water reporting year, the consented maximum abstraction rates for consumptive hydro schemes were higher than all other water uses in three of the four regions where these schemes operate, meaning they could be the largest consumers of water at any given time (see *Our freshwater 2020*).
- Even where it does not consume water, hydroelectric generation can still affect the timing and volume of flows downstream of dams and diversions. No large hydroelectricity infrastructure has been built in the past two decades, but several schemes have been proposed (see *Our freshwater 2020*).

Our climate is changing, and more frequent and intense rainfall and droughts are putting increasing pressure on our freshwater environment.

- Human-driven increases in global atmospheric carbon dioxide continue to drive climate change, with Aotearoa New Zealand's average annual temperature rising by 1.13 (+/-0.27) degrees Celsius from 1909 to 2019 (see *Our atmosphere and climate 2020* and indicator: Temperature).
- A warmer atmosphere can hold more water vapour, which then comes back to Earth's surface as precipitation. As Earth warms, scientists expect more frequent extreme rainfall. In Aotearoa, extreme rainfall is variable from year to year and from location to location (Bodeker et al, 2022) (see indicator: Extreme rainfall).
- The frequency of extreme weather events due to climate change is expected to increase (see *Our atmosphere and climate 2020*). Droughts are predicted to increase in frequency in northern Aotearoa and heavy rainfall intensity is expected to increase over most regions of Aotearoa (IPCC, 2022). This will change the amount of water in our soils, and the storage, flows, mixing, and temperature of water in lakes, rivers, groundwater, and glaciers (see *Our freshwater 2020*).
- Increasing floods due to climate change may put pressure on freshwater ecosystems and the habitat ranges of species that are culturally important for many Māori (Awatere et al, 2021; IPCC, 2022; Foley and Carbines, 2019).
- Sea levels are rising, with annual average coastal sea levels having risen (relative to land) at all six monitoring sites around Aotearoa based on available data to 2020 (see indicator: Coastal sea-level rise). Sea level rise moves saltwater farther into coastal freshwater environments, which puts pressure on these ecosystems (IPCC, 2022).
- Ecosystem fragmentation and pest species are likely to increase with climate change; however, it is hard to predict exactly how biodiversity will react as Aotearoa New Zealand's climate is highly variable (McGlone et al, 2010 in DOC, 2020a).

State of our freshwater environment

Photo: *Greater Wellington Regional Council*

To understand the health of our freshwater ecosystems we need to understand how they connect to each other and to the land: ki uta ki tai (mountains to the sea). There is an intrinsic link between the health and wellbeing of wai (water) and the health and wellbeing of communities. When wai is healthy and flowing, and ecosystem health is intact, mauri is enhanced and it can better provide for our interaction with freshwater, such as mahinga kai (traditional food gathering practices), swimming, and drinking water.

Mātauranga Māori (Māori knowledge) and the freshwater ecosystem health framework help us understand what different freshwater indicators tell us about the overall health of freshwater bodies and the environment.

These indicators show that the health of our freshwater ecosystems is variable around Aotearoa. High levels of organic pollution and nutrient enrichment in many of our rivers and lakes has degraded habitats and can be harmful to freshwater species. Some of our freshwater is unsuitable for swimming and drinking.

Aotearoa has a lot of freshwater, though we also use a lot for activities such as irrigation and hydroelectricity.

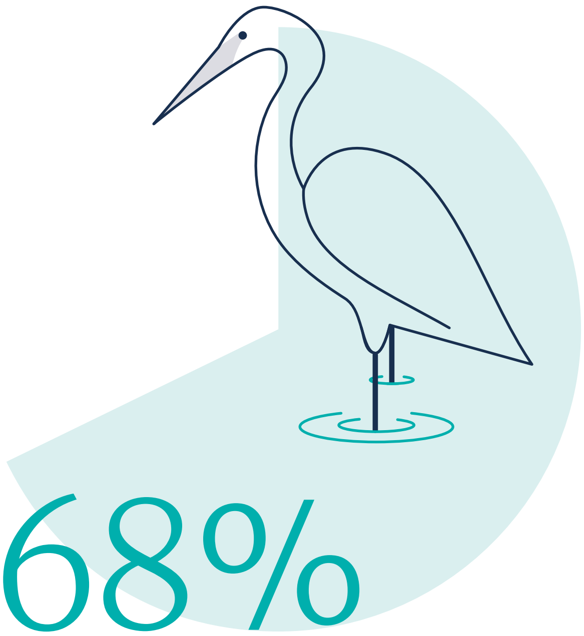
Modifications to our freshwater environment have caused the ongoing loss of wetlands, and this reduces the habitat available for our freshwater-dependent native species. Altering flows diminishes the mauri of our awa (river).

Some of our indigenous taonga (treasured) freshwater species, such as kanakana/piharau (lamprey) and kākahi (freshwater mussel), are threatened with extinction and many others are at risk of becoming threatened.

State of our freshwater environment

Evidence shows the health of freshwater ecosystems around Aotearoa is variable. Some places and measures got better, but others got worse.

INDIGENOUS AND TAONGA (TREASURED) SPECIES



68%

of indigenous freshwater birds were threatened with extinction or at risk of becoming threatened in 2021.

Of these 19 birds, it's estimated that the populations of seven species are increasing, seven are decreasing, and five are stable.

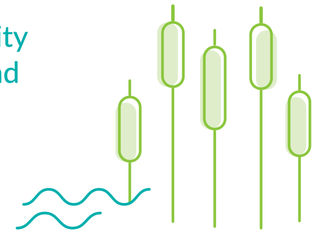
76% of indigenous freshwater fish species were threatened with extinction or at risk of becoming threatened in 2017.

Ten of 18 taonga freshwater fish and invertebrate species were too.

Abundance of food supplies such as īnanga (whitebait) and kōura (freshwater crayfish) is an important sign of mauri (health and vitality of living systems).

REPO (WETLANDS)

We've lost the majority of our historic wetland area, with estimates that only around 10 percent remains.



Wetlands provide a habitat for many of our taonga bird species, including kotuku (white heron), tētē whero (brown teal), and mātātā (New Zealand fernbird).

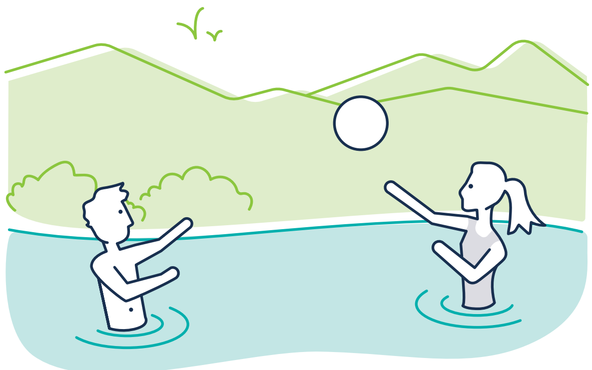
POLLUTION AND EXCESS NUTRIENTS

36% of lake monitoring sites improved and 45% worsened between 2011 and 2020 (according to trophic level index (TLI) scores, a measure of ecosystem health based on nutrient and algae levels).

Models of TLI scores for all lakes larger than 1 hectare suggest 46% had poor or very poor health between 2016 and 2020.

Only 2% rated good or very good.

Models of *Campylobacter* infection risk estimate 45% of our country's total river length was not suitable for activities like swimming between 2016 and 2020.



Indigenous indicators and mātauranga Māori can help us understand the state of the freshwater environment.

- Mauri is an indigenous concept of the state of te taiao (the environment) often characterised/reflected by 'local tribal areas', so it is not possible to understand the state of freshwater without also understanding the core values of the people who engage with it (Crow et al, 2018; Harmsworth et al, 2016; Tipa, 2009). (See the Te ao Māori, mauri, and our connection to freshwater section for the definition of mauri used in this report.)
- Decline in the mauri of wai can also include reduced habitat extent and species population, reduced river/stream flow, and poor condition of ecosystems and resources, such as mahinga kai and taonga species (Harmsworth et al, 2016).
- Mahinga kai is a cultural indicator of a healthy freshwater system (Hikuroa et al, 2018; Tipa, 2009). Sustaining and accessing mahinga kai is closely linked to the state of freshwater and is an important indicator of the mauri of the waters, whenua (land), and people. These are all important for Māori in understanding the health of an ecosystem (Tipa, 2009; Rainforth & Harmsworth, 2019).
- Some iwi and hapū monitor freshwater health using cultural indicators to observe and record changes. The cultural health index (CHI) is a tool for water quality that measures factors of cultural importance to Māori in the freshwater environment. The CHI is made up of three components: site status, mahinga kai status, and cultural stream health status (Tipa & Teirney, 2006; Stewart-Harawira, 2020). Each component is assessed separately by the iwi/hapū and then all three are combined to provide a cultural health measure.
- Following from, and in many cases adapting from, the CHI, other methods and tools used by iwi, hapū, and whānau include the Mauri Model/Mauri-o-meter, the Mauri Compass, Wai Ora Wai Māori, and Cultural Flow Preference Study (Rainforth & Harmsworth, 2019).
- In determining the state of our freshwater, it is important to acknowledge the whole catchment – ki uta ki tai. The whole catchment that is drained by a river must be examined, as an intact mauri depends on the status of all the interrelated components in the catchment. For example, the mauri of the wai diminishes as it moves downstream and increasingly comes into contact with human activities (Tipa, 2009).

The freshwater ecosystem health framework measures multiple components of freshwater to understand the overall health of freshwater ecosystems.

- The freshwater ecosystem health framework is a concept that recognises the holistic nature of freshwater ecosystems. It incorporates factors like biodiversity, the quality of habitats, and how well essential ecosystem processes are working. Understanding the overall health of freshwater ecosystems requires measures of five core components: aquatic life and biodiversity, habitats, water quantity and flows, ecological processes, and water quality (Clapcott et al, 2018).
- Measuring all parts of an ecosystem is challenging, and data are not widely available for some components of ecosystem health like aquatic life and ecological processes. This limits our ability to comprehensively assess the health of most of our ecosystems, and the health of our freshwater environment as a whole (see *Our freshwater 2020*). However, considering individual measures in the context of ecosystem health is useful for understanding the state of the freshwater environment more holistically.

The water quality of some of our rivers and lakes could be harmful to ecosystems and human health.

- Water quality is the most widely measured component of ecosystem health and is assessed by measuring physical and chemical components of water that are important to support life (Clapcott et al, 2018).
- Both measured and modelled data were used to estimate the water quality of our rivers and our lakes. Computer models were used to estimate water quality for all river segments and all 3,813 lakes larger than 1 hectare, including those that do not have monitoring sites. For example, water quality is only monitored in a very small proportion of our lakes (approximately 5 percent of the lakes larger than 1 hectare). Model estimates are informed by measured water quality data, as well as by variables describing aspects of climate, geology, topography, hydrology, and land cover.
- Ecosystem health can be assessed by comparing water quality measures to the National Objectives Framework (NOF) bands, which consider the suitability of a water body to sustain the indigenous aquatic life expected in the absence of human disturbance or alteration (MfE, 2023). Similarly, the ability of a water body to support human connection with the water through a range of activities, including swimming, can be assessed.
- Trends were assessed for monitoring sites, but it would not be appropriate to assess trends for modelled data. For monitoring sites where trends could be determined, trends were classified as improving or worsening if the trend certainty was above 66 percent ('likely') or above 90 percent ('very likely'). We use the term 'indeterminate' when there was either no trend direction or not enough statistical certainty to determine trend direction (less than 66 percent certainty).
- We present 20-year trends for rivers because of the strong influence of natural climate variation on shorter trend periods (Snelder et al, 2021). For lakes and groundwater we present 10-year trends because there was limited data to determine longer trends across the monitoring networks.
- Visual clarity is a water quality measure of underwater visibility in rivers and streams, with low clarity indicating poor visibility. Clarity can be used as an indicator of cultural health, as well as ecosystem health. Seventy-seven percent of Aotearoa New Zealand's river length had modelled visual clarity values indicative of minimal to moderate impact of suspended sediment on instream biota (NOF bands A and B) between 2016 and 2020, whilst 23 percent indicated moderate to high impact (NOF bands C and D). Measured data showed that median visual clarity was greatest at river monitoring sites with lower proportions of human modified land cover in the upstream catchment area.
- For visual clarity, trends at 52 percent of river monitoring sites were improving, and 33 percent were worsening, between 2001 and 2020 (see indicator: River water quality: clarity and turbidity for more information on measured and modelled state and trends).
- Elevated nutrient levels can lead to excessive algal growth, degrading river and lake habitats, including where groundwater enters the surface water environment. Nutrients have flow-on effects for ecosystem health, which we have assessed through high level indicators of river and lake water quality (see following sections). For further discussion of nutrients in water, see indicators: River water quality: nitrogen, River water quality: phosphorus, Lake water quality, and Groundwater quality.

- We have focused on water quality indicators which provide the best high-level understanding of ecosystem health: macroinvertebrate community index for rivers and trophic level index for lakes (see following sections). For further discussion of river and lake water quality, see the Freshwater indicators.

Our freshwater quality is mixed, with some excess nutrient levels that can harm ecosystems.

- Macroinvertebrates play a central role in stream ecosystems by feeding on periphyton (algae), dead leaves, and wood, or on each other. In turn, they are an important food source for fish and birds. The macroinvertebrate community index (MCI) is a measure of the abundance and diversity of macroinvertebrates and is an indicator of overall river health. A high MCI score indicates a high level of river health, with more impacted rivers having low MCI scores.
- Forty-five percent of Aotearoa New Zealand's river length had modelled MCI scores indicative of conditions with almost none or mild organic pollution or nutrient enrichment (NOF bands A and B) between 2016 and 2020, whilst 55 percent indicated moderate or severe impairment (NOF bands C and D). The average proportion of human modified land cover in the upstream catchment area of monitored sites increased with decreasing MCI scores.
- For MCI, trends at 56 percent of river monitoring sites were worsening, and 25 percent were improving, between 2001 and 2020 (see indicator: River water quality: macroinvertebrate community index for more information on measured and modelled state and trends).
- Of 459 river and stream monitoring sites, 79 percent had good or excellent habitat condition based on 10 measured parameters including habitat diversity, streambed sedimentation, bank erosion, bank vegetation, and shade (see indicator: Freshwater physical habitat).
- Trophic level index (TLI) is a lake water quality measure that is an indicator of ecosystem health, and is a combined measure of chlorophyll-a (algae), and the nutrients nitrogen and phosphorus. Forty-six percent of Aotearoa New Zealand's 3,813 lakes larger than 1 hectare had modelled TLI scores indicating poor or very poor health in terms of nutrient enrichment between 2016 and 2020, whilst only 2 percent rated good or very good. Lake monitoring sites with lower trophic levels (linked to better ecosystem health) had significantly lower proportions of human modified land cover in the upstream catchment area compared to sites with higher trophic levels.
- For TLI, trends at 36 percent of lake monitoring sites were improving, and 45 percent were worsening between 2011 and 2020 (see indicator: Lake water quality for more information on measured and modelled state and trends).
- The submerged plant index (SPI) is one measure of a lake's ecological health, that reflects the diversity and extent of native and invasive plant species that provide habitats and support ecosystem processes. Between 1991 and 2019, 34 percent of monitored lakes were in excellent or high ecological condition, 31 percent were in moderate condition, and 36 percent were in poor ecological condition or were entirely without submerged plants. Most monitored lakes (90 percent) with vegetation had some non-indigenous plant species present (see indicator: Lake submerged plant index).

- Aotearoa New Zealand's groundwater ecosystems are poorly understood, though over 100 aquifer-dwelling species have been named, with approximately 700 invertebrate species awaiting analysis (Fenwick et al, 2018).
- Nitrate is present in groundwater across Aotearoa, but the concentration that is harmful to groundwater species is unknown (Fenwick et al, 2018).
- Further research is needed to better understand groundwater ecosystem extent and function, species present, and the cumulative impacts of human activities on these environments.

The quality of some of our freshwater is unsuitable for recreational activities like swimming.

- *E. coli* is used as an indicator for the presence of other pathogens associated with animal or human faeces, especially *Campylobacter*.
- The suitability of rivers and lakes for recreational activities like swimming, paddling, and water sports can be assessed by using measured *E. coli* concentrations to calculate the risk of infection from *Campylobacter* bacteria. Higher *E. coli* concentrations indicate higher infection risk. Suitability for lakes also considers the risk they pose from exposure to cyanobacteria, but we have limited our assessment to *E. coli* (MfE, 2023).
- Models estimate that 45 percent of Aotearoa New Zealand's total river length was not suitable for activities like swimming between 2016 and 2020, based on having an average *Campylobacter* infection risk greater than 3 percent (corresponding to NOF bands D and E for *E. coli*, see MfE, 2023). *E. coli* concentrations tended to be higher at river monitoring sites with higher proportions of human modified land cover in the upstream catchment area.
- For *E. coli*, trends at 37 percent of river monitoring sites were improving (declining concentrations), and 41 percent were worsening (increasing concentrations) between 2001 and 2020 (see indicator: River water quality: Escherichia coli for more information on measured and modelled state and trends).
- For the period 2016 to 2020, 7 of 40 monitored lake sites had an average *Campylobacter* infection risk of greater than 3 percent, corresponding to NOF bands D and E for *E. coli* (see indicator: Lake water quality), making them unsuitable for activities like swimming (MfE, 2023). There were insufficient monitoring data to perform a national assessment of lakes based on *E. coli*, or to assess trends for *E. coli* in lakes (see indicator: Lake water quality).

The quality of some of our groundwater is unsafe for drinking.

- Sixty-eight percent of 364 groundwater monitoring sites failed to meet the Ministry of Health *E. coli* drinking water standard on at least one occasion between 2014 and 2018 (see indicator: Groundwater quality), indicating a risk to people if they consume water from these aquifers that has not been adequately treated. For *E. coli*, trends at 18 percent of groundwater monitoring sites were improving, and 50 percent of trends were worsening between 2009 and 2018 (see indicator: Groundwater quality)[1].

- Nineteen percent of 433 groundwater monitoring sites failed to meet the nitrate-nitrogen drinking water standards on at least one occasion between 2014 and 2018, based on having concentrations above the maximum acceptable value of 11.3 g/m^3 set by the Ministry of Health (Ministry of Health, 2018). Groundwater with concentrations above this standard must undergo specific treatment for nitrate before it is safe to drink (Ministry of Health, 2022). For nitrate-nitrogen, trends at 49 percent of groundwater monitoring sites were improving, and 35 percent of trends were worsening between 2009 and 2018 (see indicator: Groundwater quality).
- In 2018, a national groundwater survey was conducted for pesticides and emerging organic contaminants. For pesticides, none of the 121 surveyed groundwater wells exceeded the maximum acceptable value for drinking water in Aotearoa. Emerging organic contaminants were found in 70 percent of surveyed groundwater wells (85 of 121) but at low levels (Close et al, 2021).

Many of our indigenous taonga freshwater fish and invertebrate species are threatened with extinction or at risk of becoming threatened.

- In 2017, 76 percent of known indigenous freshwater fish species (39 of 51) were threatened with extinction or at risk of becoming threatened. Estimated population trends show 63 percent of freshwater fish species have a decreasing population trend (see indicator: Extinction threat to indigenous species).
- Over half (10 of 18) of taonga freshwater fish assessed in 2017 and invertebrate taonga species assessed in 2018 were threatened with extinction or at risk of becoming threatened, including kākahi, kanakana/piharau, īnanga (whitebait), and tuna (eels) (see indicator: Extinction threat to indigenous species).
- Some freshwater taonga species such as kākahi, īnanga, and tuna are important for mahinga kai (Collier et al, 2017; Williams et al, 2017) and abundance of food supplies such as īnanga, tuna, and kōura (freshwater crayfish) is an indication of mauri ora (health).
- Kākahi include three species. Two are classified as threated with extinction or at risk of becoming threatened and have declining population trends (*Echyridella aucklandica* and *E. menziesii*), and one is data deficient *(E. onekaka*) (Grainger et al, 2018). Kākahi are widespread throughout Aotearoa, with habitats including small, fast-flowing streams, rivers, and lakes (Williams et al, 2017).
- Īnanga are classified as at risk of becoming threatened with extinction and have a declining population trend (Dunn et al, 2018). Īnanga are predominantly observed near the coast. They are often found in gently flowing and still water, such as lowland streams, but also spend part of their life cycle in the marine environment (Williams et al, 2017).

[1] The Groundwater quality indicator is scheduled to be updated pending the outcome of an independent methodological review, which is in progress.

- Kanakana/piharau are classified as threatened with extinction and have a declining population trend (Dunn et al, 2018). They spend different stages of their life in freshwater and marine environments. In freshwater fish surveys, kanakana/piharau are typically underrepresented, with low observations likely due to detection difficulties (Williams et al, 2017).
- The longfin tuna is classified as at risk of becoming threatened with extinction and have a declining population trend (Dunn et al, 2018). Longfin tuna are widespread throughout Aotearoa (Williams et al, 2017). Shortfin tuna are classified as not threatened with extinction and have an increasing population trend (Dunn et al, 2018). Shortfin tuna are not as widespread, but generally outnumber longfin tuna in the most densely populated tuna habitats (Williams et al, 2017).

Many of our indigenous freshwater bird species are threatened with extinction or at risk of becoming threatened.

- Of 28 indigenous freshwater dependent bird species in 2021, 35.7 percent (10 of 28) are threatened with extinction and a further 32.1 percent (9 of 28) are at risk of becoming threatened.
- Of the 19 bird species threatened with extinction or at risk of becoming threatened, the population trend for seven species is increasing, and the population trend for seven species is decreasing. The population trend for the remaining five bird species in these categories is stable (see indicator: Extinction threat to indigenous species).
- Of these 19 bird species, 12 are river, lake, or wetland birds, and seven occupy both freshwater and marine habitats including coastal streams and seashores (DOC, nda – ndk; New Zealand Birds Online, nda – ndh).
- Six of 19 bird species threatened with extinction or at risk of becoming threatened have declining population trends and are also identified as taonga species (see indicator: Extinction threat to indigenous species). These species are koitareke (marsh crake), tarāpuka (black-billed gull), tūturiwhatu (banded dotterel), matuku hūrepo (Australasian bittern), pārera (grey duck), and whio (blue duck) (Keane-Tuala, 2015; Taura et al, 2017; Te Manahuna Aoraki Project, 2022).
- The list of indigenous freshwater birds identified as taonga is not exhaustive. Some of the freshwater bird species included in the Extinction threat to indigenous species indicator are recognised as marine taonga species because of their connection to a marine environment. This indicator uses a definition of taonga species that may differ from that used throughout *Our freshwater 2023*, which is based on taonga species identified in published literature (Keane-Tuala, 2015; Taura et al, 2017; Te Manahuna Aoraki Project, 2022) (see Extinction threat to indigenous species and Extinction threat to indigenous marine species: Approach used to highlight taonga species).

Much of our historic repo extent has been converted to other land uses, and repo loss has continued, reducing habitat for dependent native species.

- Repo (wetlands) cover less than one percent of the land area of Aotearoa, yet they support a disproportionately large number of threatened plants and animals (Clarkson et al, 2013).
- Repo are vital for the survival of many of our taonga bird species, including the matuku hūrepo, tētē whero (brown teal), mātātā (New Zealand fernbird), koitareke (marsh crake), and kotuku (white heron), who rely entirely on remnant wetlands (Clarkson et al, 2013; DOC, ndl; Keane-Tuala, 2015; Taura et al, 2017).
- We have lost the majority of our historic repo area, with estimates that only around 10 percent of this area remains (Dymond et al, 2021).
- Freshwater repo area decreased by 1,498 hectares (0.6 percent) between 2012 and 2018, and saline wetland area decreased by 69 hectares (0.1 percent) in the same period (see indicator: Wetland area).
- Southland has experienced the greatest losses, with a net loss of 2,665 hectares of freshwater repo between 1996 and 2018. Of the area of freshwater repo that were lost, 98 percent were because of conversion to land covers associated with farming and forestry (see indicator: Wetland area).

Aotearoa has a lot of freshwater and we also use a lot of freshwater.

- Rivers have naturally variable flows, but when water flows are also altered by human activities this can affect average flows, alongside the size and frequency of high and low flows. Due to the interconnected nature of the freshwater system, diverted or altered flows in one area can also affect or alter the state of flows in connected water bodies and affect the health of the wider ecosystem (see *Our freshwater 2020*).
- A healthy mauri, or life supporting capacity, is a sign that a river is expressing its mana (power, authority). The re-routing (severing) of the natural water flows has seen the diminishment of the mauri of the Tarawera River (Hikuroa et al, 2018).
- Approximately 440 billion cubic metres flows in our rivers and streams every year (Collins et al, 2015). For the 2017/18 water reporting year, 9.83 billion cubic metres of surface water was allocated for consented consumptive use across Aotearoa. This figure excludes use for consumptive hydroelectric generation, which cannot be calculated because hydropower consents are based on rates rather than volume (see indicator: Consented freshwater takes). Consents (permits) to take water are managed by regional authorities that allocate water for hydroelectric generation, irrigation, drinking water, industrial, and other uses, and set limits on how much can be used, but do not tell us how much water is actually used.
- In 2014, 73.2 percent of our groundwater was located in Canterbury, amounting to 519 billion cubic metres (see indicator: Groundwater physical stocks). For the 2017/18 water reporting year, 3.1 billion cubic metres of groundwater was allocated for consented consumptive use across Aotearoa (see indicator: Consented freshwater takes).

- Glaciers are fed by snow and hold large amounts of freshwater. Glaciers in Aotearoa decreased in volume by 35 percent and the rate of annual loss increased between 1978 and 2020 (see indicator: Annual glacier ice volumes).

Impacts on culture, species, wellbeing, and people

Photo: *Fraser Tebbutt – truestock*

The state of the freshwater environment has impacts on freshwater species, habitats, ecosystems, and people. The health of freshwater environments and ecosystems directly support tikanga (customs/protocols), mahinga kai (traditional food gathering practices), and the transmission of mātauranga Māori (Māori knowledge). Our wellbeing and economy are linked to a healthy freshwater environment.

Excess nutrients can cause algal blooms that reduce visibility and the availability of oxygen, having ecosystem-wide impacts. Excess sediment degrades freshwater habitats, and other contaminants contaminate filter feeding organisms.

The forecasted effects of human-induced climate change, such as changes in water temperature, are likely to change the range and life cycles of some species. Contamination of swimming and water recreation areas and drinking water sources with waterborne diseases and other contaminants can pose a risk to public health.

Our primary production, tourism, and hydroelectricity sectors rely on a plentiful supply of freshwater, but we do not have a complete national picture of how much freshwater we use. This makes it difficult to assess the sustainability of our water use.

Impacts on aquatic life, people, and culture

Pressures on freshwater and changes to it are affecting the environment, our lives, and things that are important to us.

TE AO MĀORI

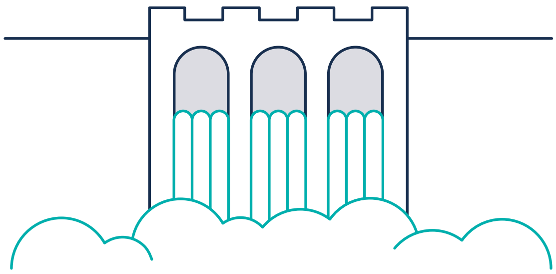
For many Māori, the freshwater environment is central to tikanga (customs and protocols), mātauranga (Māori knowledge), and mahinga kai (traditional food gathering practices).

For example, if rivers and lakes are contaminated, iwi and hapū can't gather kai and offer manaakitanga (helping people and hosting guests).

BIODIVERSITY

Fish and other aquatic life – including endangered species – can be affected by water temperature and weather pattern changes due to climate change.

Algal blooms and other effects of excess nutrient levels can harm freshwater species and ecosystems.



Fish can be affected by structures like dams, weirs, and flood pumps, which hamper their ability to migrate and breed.

LIVES AND LIVELIHOODS

All New Zealanders – and many sectors of the economy – need clean and reliable supplies of water.

Auckland's 2020 drought cost over

$200m

for emergency drinking water supplies.

People's health is put at risk by pollution from wastewater overflows and livestock run-off.

Algal blooms and other effects of excess nutrient levels can restrict people's recreational use of lakes and rivers.

Communities and infrastructure can be dramatically affected by extreme weather events that cause flooding.

Mātauranga Māori of te taiao is connected with the health of freshwater ecosystems and the abundance of taonga species.

- Some freshwaters in Aotearoa have been irreversibly degraded, impacting the connection and interaction with people (Stewart-Harawira, 2020) (see *Our freshwater 2020* for more information on irreversible degradation).
- Degraded ecosystems and the threatened loss of native species impacts the intrinsic connection and wellbeing many Māori have with te taiao (the environment) and associated mātauranga. This impacts mahinga kai practices and physical access to waterways (Mike, 2021; Parsons et al, 2021).
- The state of native taonga (treasured) species such as the longfin tuna (eels) and kōura (freshwater crayfish) impact the maintenance of values like mana (power, authority), mātauranga, and whakaheke korero (passing knowledge to the next generation) (Collier et al, 2017; Harmsworth & Awatere, 2013; Lyver et al, 2017a; Lyver et al 2017b; Lyver et al, 2021).
- The practice of gathering tuna is also connected to the observations of the maramataka, and the loss of our taonga species and mahinga kai areas can impact the ability to transmit mātauranga (Mauri Compass, 2022). Maramataka is the traditional Māori way by which time was marked by observing the phases of the moon.
- Pūrākau (stories) are often associated with taonga species – for example, the matuku hūrepo (Australasian bittern) whose call was thought to help people through grief; pārera is a metaphor for greediness by its way of eating; and the whio (blue duck) named accordingly to the male's call: a whistle sound. The bird calls of koitareke (marsh crake) and tarāpuka (black-billed gull) have been known to signal danger as warning signs of an oncoming attack, and the tūturiwhatu (banded dotterel) are written in songs as the only survivor of a cataclysmic disaster (Keane-Tuala, 2015).
- The deteriorating state of some taonga species can impact the ability of tohu (signs) and mātauranga to be maintained and transmitted (Taura, et al 2021).
- Kāinga (settlements) have existed near waterways for many reasons such as abundance of kai (food) and access. Healthy waterways are important for ahikāroa (connection with place), whanaungatanga (family ties and links), and kaitiakitanga (guardianship) (Morgan, 2006).
- The protection of taonga species that are important to the practice of mahinga kai therefore also contributes to protecting and maintaining te reo Māori (Māori language), tikanga, and mātauranga Māori (Harmsworth & Awatere 2013; Parsons et al, 2021; Rainforth & Harmsworth, 2019).
- The engagement and use of mātauranga Māori benefits the restoration of freshwater systems (Stewart-Harawira, 2020).

The lifegiving and healing properties that are essential for tikanga can be impacted by the health of freshwater systems.

- When wai (water) is healthy and strong it can be used for healing and life giving. But if the wai is depleted or absent it can negatively impact tikanga (Ngata, 2018).

- The pollution, degradation, and diversion of freshwater systems impacts the mauri of each water body (Hikuroa et al, 2018; Stewart-Harawira 2020). (See the Te ao Māori, mauri, and our connection to freshwater section for the definition of mauri used in this report.)
- The threatened status of taonga species and ecosystems, as well as the reduced quality and quantity of rongoā (healing) materials available, impacts important healing practices associated with rongoā (Mark et al, 2022).
- Many freshwater sites such as geothermal environments (eg pools and mud) are known for their healing properties (Hikuroa et al, 2011). Geothermal resources facilitate a spiritual connection between some Māori, their ancestors, and the gods (Taute et al, 2022).
- Wai tapu (sacred waters) are used for ceremonial practices. Traditional uses of wai include rituals, baptisms, drinking, and cleaning (Jefferies et al, 2011).
- Local communities are linked in with specific mahinga kai sites through knowledge and their place-based relationships, and frequently prioritise these areas in iwi and hapū environmental management plans (Awatere et al, 2018).
- Abstractions altering the flow of waterways can adversely impact the mauri of rivers by changing the connections from the mountains to the sea and disrupting the spiritual connection between iwi and the awa (rivers) (Young et al, 2004; Jones & Hickford, 2019).

The ability to practice and access mahinga kai is impacted by the abundance and health of freshwater species and access to mahinga kai sites.

- Mahinga kai can be described as traditional Māori food gathering practices and food gathering sites. Mahinga kai includes the ability to access food resources, food gathering sites, the gathering and use of food, and abundance and health of species (Panelli & Tipa, 2009).
- Mahinga kai is one of the main ways to protect and develop sustainable relationships with freshwater bodies (Awatere et al, 2018).
- Mahinga kai species are gathered from freshwater environments, including tuna, īnanga (whitebait), kākahi (freshwater mussels), kōura and wātakirihi (watercress). These are impacted by habitat loss and destruction which causes a loss of ability to collect kai and fish (Collier et al, 2017) and compromises the cultural use of species (Noble et al, 2016; McDowall, 2011).
- More than simply gathering kai, the ability to collect these resources affects the mana of an iwi or hapū, as they contribute to their capacity for manaakitanga – offering food from their whenua (land) and wai to invited guests, is an important part of hospitality (Rainforth & Harmsworth, 2019).
- When ecosystems and biodiversity have been degraded, there is a corresponding effect on the extent, quality, and access to customary resources. These impacts are felt catchment wide from the mountains to the sea – ki uta ki tai (Tipa, 2009).
- Decreased or altered flows can also affect the availability of traditional and customary resources and access to mahinga kai areas. The cultural health and wellbeing of a site can therefore be deeply affected by changed flows (Tipa, 2009).
- Sewage discharges can contaminate kai harvested from freshwater sources such as awa and roto (lakes). This impacts the health and wellbeing of those who harvest kai (Mika, 2021).

- Altered flows and accumulation of sediment alter the condition of the awa, putting pressure on mahinga kai species availability (Hikuroa et al, 2018).

Wāhi tapu, such as repo, have many benefits, though these benefits have been reduced by reductions in their extent and condition.

- Repo (wetlands) are wāhi tapu (sites of significance). If repo continue to be lost, cultural indicators that have been founded on generations of mātauranga Māori, such as those relating to kōwhitiwhiti (watercress), kuta (giant spike sedge), and harakeke (flax), will also be lost, along with the ability to interact with these places (Taura et al, 2021).
- Repo provide many benefits, such as storing carbon, regulating water flow during storms, and purifying water through filtering out nutrients and sediments (Clarkson et al, 2013; Schallenberg et al, 2013). The extent and condition of repo habitats and ecosystems, therefore, impact these important processes.
- Coastal wetlands are particularly sensitive to climate change, so may be exposed to change in freshwater flow and rising sea levels (Rodríguez et al, 2017).
- Human changes to wetlands and estuaries such as draining, ploughing, and burning impact how well the environment can adapt to flooding events, sedimentation, and pollutants before they reach the ocean (NIWA, 2007; Ausseil et al, 2011; Clarkson et al, 2013).
- Some lakes and waterways used for recreation and cultural practices are affected by high nutrient concentrations, frequent algal blooms, and decreased river flows. This can reduce the water quality for swimming and other activities. Such changes affect the mauri of waterways and how we relate to and use them.
- Many marae and urupā (burial grounds) located near rivers and flood prone areas are increasingly vulnerable to erosion caused by climate change induced extreme weather impacts (Awatere et al, 2021).

Freshwater ecosystems are impacted by the excessive algal growth caused by increased nutrients, which depletes dissolved oxygen levels and reduces clarity. At high concentrations some nutrients become toxic to freshwater species.

- Nutrients, such as nitrogen and phosphorus, occur naturally in the freshwater environment; however, elevated levels due to human activities can drive eutrophication: an overload of nutrients that can cause algal blooms, depleted oxygen levels, and subsequent harmful effects on freshwater ecosystems (Snelder et al, 2020).
- Algal blooms block out light and reduce the amount of native freshwater plants (that provide habitat for native species) (Collier & Grainger, 2015; Schallenberg et al, 2013; Rowe, 2007).
- Kākahi habitat decline has been attributed to river regulation, eutrophication, and other types of pollution (Phillips, 2007).
- High loads of nitrogen input into freshwater ecosystems can cause toxic levels of nitrate and ammonia which impair the survival, growth, and reproduction of some freshwater animals (Camargo & Alonso, 2006 in Snelder, 2020).

- Excess nutrients in waterways can lead to reduced oxygen levels and change the composition of plant and animal communities. This can negatively impact species associated with freshwater, including taonga species such as tuna, kākahi, kōura, and īnanga). These are important food sources in Aotearoa and valued taonga linked to mātauranga and cultural identity (Williams et al, 2017) (see indicator: Fertilisers – nitrogen and phosphorus).
- Some fish, particularly the young of species like īnanga, paraki/pōrohe (common smelt), and toitoi/tīpokopoko (common bullies) are more sensitive to low levels of dissolved oxygen than others (Franklin, 2014; Landman et al, 2005).

Freshwater habitats are degraded by contaminants from human activities on land, which can harm freshwater species.

- Soil washed from the land can degrade freshwaters both when it is suspended in the water and when it settles as sediment on a streambed (MfE & Stats NZ, 2020).
- Excess suspended sediment affects freshwater species by clogging their gills, affecting their oxygen exchange, feeding, and changing the visual clarity of the water which can affect fish feeding and their ability to migrate (Collier et al, 2017). It can also make the water cloudy, block out light, and reduce the amount of native freshwater plants (that provide habitat for native species) (NIWA, 2019; Rowe, 2007; Schallenberg et al, 2013).
- Excess deposited sediment smothers natural habitats on the bottom and banks of rivers and lakes, by filling in the spaces between rock and gravel that small fish and invertebrates use to hide and breed. It can also make their food harder to find (Clapcott et al, 2011; Burdon et al, 2013).
- Altering river channels and flows, increased erosion of riverbanks, and other changes to river habitats affect the range of species that rivers can support and can reduce or prevent the movement of some species (Harding et al, 2009; MfE & Stats NZ, 2020).
- Microplastics have been found to accumulate in freshwater organisms and can cause impacts depending on physical shape and size, age, density, and the chemicals the microplastics are made from (Zimmermann et al, 2020; Ockenden et al, 2022; Ockenden et al, 2021).
- A controlled study by Ockenden et al, 2022 found that dibutyl phthalate (DBP), a common chemical additive in plastic, can leach rapidly from microplastics into water and accumulated in the aquatic larvae of a common New Zealand caddisfly species (*olinga feredayi*) and its food source. DBP was found to have toxic effects on the macroinvertebrate's respiration and feeding rates when it accumulated to high concentrations (Ockenden et al, 2022).
- There is still limited research about the extent to which plastic will impact our freshwater species and ecosystems in Aotearoa (Mora-Teddy & Matthaei, 2020; PMCSA, 2019).

The effects of climate change on water temperatures, flows, and coastal environments are likely to impact our freshwater species and ecosystems.

- Climate change is predicted to have impacts on our freshwater ecosystems, including our taonga species (Egan et al, 2020). However, some of these impacts are not yet fully realised, as long-lived greenhouse gases build up in the atmosphere over decades, affecting long-term climate change outcomes (see *Our atmosphere and climate 2020*).

- Changes in water temperatures are predicted to influence the movement of some fish to higher elevations, impact spawning times, and change their migration timing and success (Awatere et al, 2021; Egan et al, 2020). Species that are already living close to their maximum temperature threshold are particularly sensitive to changes in temperature (Foley and Carbines, 2019).
- Reductions in glacier extent may impact species adapted to glacier-fed environments. As these environments become more similar to rain- and groundwater-fed systems, competition from downstream increases, and species highly adapted to glacier-fed flows are likely to decline. The effects on biofilm and microinvertebrates are less well known than the effects on macroinvertebrates (Fell et al, 2017).
- Due to climate and land-use driven pressures, macroinvertebrates were found to shift their ranges southward by an average of approximately 50 kilometres per decade between 1991 and 2016 (Mouton et al, 2022).
- Floods can wash out and destroy fish eggs that are laid in the vegetation in or beside a waterway (Goodman, 2018; Hayes et al, 2019). Floods also signal for many fish species to migrate so the change in height and variability of floods may also affect species' migration patterns (Goodman, 2018).
- Coastal erosion and rising sea levels can increase the amount of saltwater moving into freshwater environments (MfE, 2017). Even small changes in salinity (saltiness) can affect freshwater species and habitats (Schallenberg et al, 2003; Cañedo-Argüelles et al, 2013; Neubauer et al, 2013). Īnanga, for example, only spawn when the salinity is within a specific range (Goodman, 2018). Sea-level rise could also affect the success of īnanga spawning by forcing the fish into upstream areas that do not have appropriate vegetation for egg laying (Kettles & Bell, 2016).
- Some vulnerable and taonga species may lose parts of their habitats or become extinct due to changes in climate (Hennessy et al, 2007). Local kaitiaki, hapū, and whānau fishers are already noting seasonal shifts that affect their kaitiakitanga practices and harvest times, as well as the tohu that signal them (Deep South National Science Challenge, 2018).

Our native species and their habitats are impacted by introduced freshwater species.

- Climate change is predicted to enable invasive species to establish within higher elevations and move southwards in Aotearoa (IPCC, 2022).
- Impacts from invasions of non-native species can include the destabilisation of aquatic environments and loss of indigenous plant biodiversity (NIWA, 2020).
- Many introduced plants (like hornwort *Ceratophyllum demersum*) form tall, dense weed beds and spread quickly (Wells et al, 1997; de Winton et al, 2009). These plants can take the place of native freshwater species and make the habitat unsuitable for native fish and invertebrates (Champion et al, 2002; Clayton & Champion, 2006).
- Introduced freshwater fish species, such as perch, prey on our indigenous species (DOC, 2020a). Omnivorous species will also feed on aquatic plants, which can degrade water quality and clarity (DOC, 2020a).

- Trout and salmon fishing have recreational and economic benefits for Aotearoa but can have negative effects on rivers and streams (Mcintosh et al, 2010; Usio & Townsend, 2000). In many waterways, trout have replaced native galaxiids as the dominant fish species and affected the distribution of kōura (Mcintosh et al, 2010; Usio & Townsend, 2000).
- Didymo affects the populations of invertebrates in a stream and therefore reduces the number of native fish and trout because they prey on invertebrates (Jellyman & Harding, 2016; MPI, 2020).

Fish migration is impacted by human changes to river flows and habitats.

- Some human-made structures such as dams, weirs, and culverts can obstruct fish migrations, reduce fish populations, affect natural stream processes, and prevent fish reaching habitats critical to their survival (Franklin et al, 2018; Graynoth et al, 2008) (see indicator: Selected barriers to freshwater fish in Hawke's Bay, and *Our freshwater 2020*).
- Research in the Greater Wellington Region has identified that monitoring sites upstream of barriers such as weirs and culverts have reduced diversity of species (Davis, 2021).
- A study of four Canterbury streams found that streams downstream of abstraction points had significantly lower fish abundances per metre of stream length, likely due to low flow rates reducing habitat size, changing interactions with other species, and barriers to movement (Boddy et al, 2020).
- Cumulative effects of warming, drought, floods, and algal blooms are compounded by water abstraction and are predicted to impact the ecosystems and species in rivers (Macinnis-Ng et al, 2021; Puddick et al, 2022). Affected species may include stream invertebrates, native fish, trout, and salmon (Ryan & Ryan, 2006).

Public health has been impacted by contaminants and water-borne diseases in water used for recreation and drinking water.

- Regional councils monitor popular swimming sites, including rivers and lakes, to assess the health risk of swimming at that site (see LAWA website). Faecal contamination from humans and animals is the main reason that exposure to water during swimming can become unhealthy. When counts of faecal contamination are too high it can cause gastroenteritis and infections, such as skin infections (LAWA, 2022).
- In 2017, there were 427 notifiable illness cases of campylobacteriosis, 250 of giardiasis, 219 of cryptosporidiosis, 135 of salmonellosis, and 88 of *E. coli* infection for cases where people reported contact with recreational water (river, lake, or sea). About 100 cases of two other notifiable waterborne diseases were also reported (ESR, 2019).
- Most of the time toxic algae are only present at low levels in Aotearoa freshwater environments. However, during summer months when nutrients and temperatures increase and rainfall decreases, algal blooms are likely to become more frequent (Puddick et al, 2022; LAWA, 2021; BPAC, 2020).
- Ingesting freshwater with high levels of toxic algae can cause illnesses in humans, including nausea, diarrhoea, and in extreme cases, liver damage (LAWA, 2021). Additionally, more than 70 dog deaths have been reported since 2006 across Aotearoa because of consuming cyanobacteria from rivers (MfE & Stats NZ, 2017).

- Rivers, lakes, and groundwater are used for drinking water supplies. When these waters are contaminated and not properly treated, people can become ill. Being able to drink from waterways is an indicator of its mauri (Hikuroa et al, 2011).
- Nitrate-nitrogen contamination of drinking water poses a health risk to formula-fed infants less than six months old through the development of methemoglobinemia (blue-baby syndrome) (WHO, 2016). This is the basis of the maximum acceptable value for nitrate in drinking water set by the Ministry of Health (Ministry of Health, 2018).
- In August 2016, a large campylobacteriosis outbreak occurred in Havelock North due to faecal contamination of the town's drinking water supply. It was estimated that between 6,000 and 8,000 of the town's 14,000 residents became ill with the waterborne disease, leading to 42 hospitalisations and contributing to at least four deaths (Gilpin et al, 2020).
- An assessment of 16 Aotearoa waterways that supply public drinking water between 2009 and 2019 found that sites on rivers draining predominantly agricultural catchments had higher prevalence of *Campylobacter*, *E. coli*, *Cryptosporidium*, and *Giardia* than those predominantly covered by native vegetation (Phiri et al, 2020).
- There are health risks for rural communities and marae who rely on water from unfiltered systems such as tank water and groundwater wells in intensively farmed areas. This may impact the ability of marae to supply sufficient safe drinking water for attendees. The risk can increase with extreme rainfall events and higher temperatures (Awatere et al, 2021).

Our economy relies on our freshwater environment. Changes driven by climate change have impacts on both freshwater and our economy.

- Our primary production, tourism, and hydroelectricity sectors rely on a plentiful supply of freshwater.
- Maintaining water infrastructure has been commonly identified as an issue, due to difficulties with cost and access in isolated communities (Henwood et al, 2019). Many individual household systems need urgent repair or replacement of tanks, roofs, guttering and pipes, or additional water storage (Henwood et al, 2019).
- River flows are projected to change as rainfall increases in the west and south of the South Island and decreases in the east and north of the North Island (see Climate Change 2022: Impacts, Adaptation and Vulnerability, IPCC, 2022, for more information on these projections). Flooding due to extreme rainfall presents direct risks to life, transport, people, access, and property (Awatere et al, 2021).
- Flooding can damage housing and transport, energy, stormwater, and wastewater systems. In 2013 about 675,000 New Zealanders were estimated to live in areas prone to flooding from rainfall and overflowing rivers (Paulik et al, 2019; MfE & Stats NZ, 2020).
- Auckland's 2020 drought cost over $200m for emergency drinking water supply (Orsman, 2020).
- Climate change influences on the frequency and severity of extreme events and long-term weather impact the resilience of many farming practices (Cradock-Henry, 2021).
- Whilst the quantity of water taken from our rivers, lakes, and groundwater are a knowledge gap at a national level, it is hard to assess how sustainable our water use is: whether our freshwater resources are overexploited, and if they can continue to support us in the future (MfE, 2021).

- Our economic and non-economic wellbeing are linked to the environment, now and in the future (PCE, 2021).

A healthy freshwater environment is important for our wellbeing.

- Spending time in or near rivers and lakes can provide important wellbeing benefits, including reduced fatigue and stress, improved immune system function, and increased fitness (Gascon et al, 2017; Pasanen et al, 2019; White et al, 2020).
- Many New Zealanders engage in freshwater and marine recreation. A survey of almost 4,000 New Zealanders found that over 50 percent of adults participate in swimming outdoors at least once a year. Approximately a third of people engage in fishing at least once a year, and around 20 percent of people participate in kayaking or rafting at least once a year (DOC, 2020b). If we are unable to swim, fish, or kayak in our rivers and lakes, this can impair the mental, physical, and psychological benefits of connecting with the freshwater environment.
- Pressures on the freshwater environment, such as fine sedimentation, can increase flooding, causing waterways to be less suitable for recreation and mahinga kai (Collier et al, 2017; Rey, 2021). This impacts the ability for New Zealanders to interact with the freshwater environment.
- The natural beauty of our freshwater environment, including rivers and lakes, is central to our national identity. How we identify as New Zealanders may be affected if we cannot easily access freshwater spaces (see *Environment Aotearoa 2022*).

Data and research gaps

Our freshwater environment is expansive, diverse and part of a highly interconnected system. As a result, the issues facing the freshwater domain are often complex and strongly linked to pressures occurring on the land. The time it takes for pressures, especially those on land, to be felt in the environment adds another layer of complexity. Understanding these dynamics is necessary to ensure the decisions we make now give us the best possible chance for ensuring that future generations benefit from a thriving freshwater environment.

Aotearoa New Zealand's environmental monitoring and reporting system plays a key role in protecting te taiao (the environment), but our ability to report on the state of the environment depends on how well we collect and analyse data about it, and that needs improving.

Many of the issues identified by the Parliamentary Commissioner of the Environment in his 2019 system review still challenge current reporting. These issues are evident in the content of *Our freshwater 2023*: there continues to be gaps in data, inconsistencies in methods and monitoring, lack of accessibility, and a gap in elevating mātauranga Māori (Māori knowledge). Work is underway to establish a fit-for-purpose environmental monitoring and reporting system that is adaptable to future challenges.

The Ministry for the Environment in conjunction with sector partners, are embarking on a significant programme of work to reform the foundations of the system. This will include developing core indicators for monitoring our environment, designing the analytical architecture required to assess and interpret the data, and the blueprint design of a national monitoring network. Alongside this, our work on the Environment and Climate Research Strategy will provide future direction for prioritising investment in science and research as part of Te Ara Paerangi – Future Pathways.

While this report has highlighted new evidence and research into the state of our freshwater environments since *Our freshwater 2020*, there are still critical gaps in our knowledge that need to be filled. These include:

- Building and strengthening our mātauranga Māori evidence base to better understand effects on te ao Māori (Māori worldview). Mātauranga Māori represents a valuable record of our environment that is unique to Aotearoa and that complements our existing science and evidence base. This requires improving the resourcing of Māori research, access to, and integration of ngā tohu o te taiao (environmental indicators) drawing from mātauranga Māori.
- Improving our ability to access and share rohe-based and place-based knowledge and evidence, to enhance our understanding of localised pressures, state, and impacts and elevating the value of this knowledge in reporting.
- Building a more holistic understanding of the health of the freshwater environment and all its component ecosystems, habitats, and species. This requires more integrated analyses of the data we have (like water quality), and investing in wider monitoring of, and research into, lesser understood components of the environment (like groundwater ecosystems and puna (springs)).
- Improving our understanding of how mauri is impacted by pressures from resource use and management and other human activities. (See the Te ao Māori, mauri, and our connection to freshwater section for the definition of mauri used in this report.)

- Improving our understanding of the pressures on freshwater and their causes, including how they interact and intensify in places and over time. This requires more detailed information on spatially complex land-use pressures (particularly those additional to pastoral agriculture) and mitigations in catchments, how these change over time, and how this impacts freshwater.
- Quantifying the benefits of freshwater for multiple values, including social and economic wellbeing, so that trade-offs are better understood. This requires more comprehensive and purposeful measurement of the benefits of freshwater ecosystems, and how these are affected by competing social forces like housing and economic development.
- Understanding how pollutants and other effects of multiple pressures act on the whole freshwater environment over time, from mountains to sea, and where they are having cumulative and cascading impacts on ecosystems. This includes improving our understanding of how human activities from the past several decades (and longer) may continue to impact the freshwater environment, even after these pressures have reduced.
- Understanding how quickly our freshwater ecosystems are changing in response to pressures, and how resilient they are to the ongoing effects of our activities. Central to this is building our knowledge of ecosystem ‘tipping points’, so we know where interventions are most needed to protect the most vulnerable water bodies and freshwater environments. This includes drawing from mātauranga Māori methods for protecting the resilience of te taiao, such as rāhui (temporary restricted access).
- Strengthening our understanding of the long-term risks that freshwater contamination poses to human health in Aotearoa, such as nitrate-nitrogen in drinking water. There is evidence emerging from overseas that suggests long-term exposure to levels of nitrate found in groundwater in some parts of Aotearoa could increase the risk of pre-term births, congenital abnormalities, and bowel cancer, but more research is needed before the level of risk can be fully understood.

Environmental indicators

The data used in *Our freshwater 2023* is drawn from *Our freshwater 2020* and *Environment Aotearoa 2022* and the Stats NZ indicators that have featured in them. Listed below are the indicators that have been incorporated in this report, including one updated indicator in bold:

- Annual glacier ice volumes
- Coastal sea-level rise
- Consented freshwater takes
- Exotic land cover
- **Extinction threat to indigenous species**
- Extreme rainfall
- Fertilisers – nitrogen and phosphorus
- Freshwater physical habitat
- Groundwater physical stocks
- Groundwater quality
- Irrigated land
- Lake submerged plant index
- Lake water quality
- Livestock numbers
- Nitrate leaching from livestock
- River water quality: clarity and turbidity
- River water quality: Escherichia coli
- River water quality: macroinvertebrate community index
- River water quality: nitrogen
- River water quality: phosphorus
- Selected barriers to freshwater fish in Hawke's Bay
- Temperature
- Urban land cover
- Wetland area

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